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Albert Tavidze
Editor

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NOTICE TO THE READER

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CONTENTS

PREFACE

This compilation presents some of the latest advancements in economics research. Chapter One evaluates the impact of public policies, such as those regarding infrastructure and education, on a country's economic performance. Chapter Two deals with the issues of utilization of sludge from wastewater treatment in agriculture as a socio-economic and environmental problem in the European Union and Bulgaria. Chapter Three investigates the impact of cognitive and non-cognitive skills on the quality of a task-specific outcome by conducting an experiment on a popular crowdsourcing platform and finds that the performance of workers depends on cognitive skills, personality traits and work effort. Chapter Four explores how trade show visitors' objectives impact their visual attention to trade show booths and booth visit likelihood. Chapter Five summarizes some trends in R&D expenditures in post-socialist countries in the course of market transformation on the basis of comparative statistical analysis of relative R&D effort. Chapter Six aims to establish the best tourism human resources development practices utilized by Egypt as one of the countries leading the tourism industry in Africa. Chapter Seven outlines the major aspects of the shift in the IMF stance on international capital mobility from the perspective of finding the right balance between freedom, regulation, and control. Chapter Eight focuses on stochastic control of exchange rates via discretionary central bank intervention. Finally, Chapter Nine investigates the quantitative

importance of investment frictions for the propagation of cyclical fluctuations in Bulgaria.

Chapter 1 - In view of all the apprehensions that the private sector has with regard to public policies, the authors considered it necessary to evaluate their impact on a country's economic performance. The method used to do this consisted first of all in carrying out a descriptive analysis of the perception of public policies by the private sector and then in carrying out a Structural VAR Panel (SVRP) on data relating to the growth rate and the perception of the private sector of public policies in 51 countries throughout the world. The method showed that the higher the income level of the population, the more likely entrepreneurs are to believe that public policies are good and that middle-income countries have the highest average GDP growth. The method also showed that entrepreneurs' perception of public policies has various effects on the growth rate of GDP/head, by country and by income level of the countries. Thus, for upper-income countries, the two public policy changes that affect the growth rate the most are: a change in market size improves the growth rate by 41% on average over 10 years, and a deterioration in the quality of infrastructure leads to a slowdown in growth of about -55% on average over 10 years. For middle-income countries, a shock to entrepreneurs' views on infrastructure quality leads to an increase in the growth rate of about 635% for lower-income countries, and an increase of 75% for upper-income countries. For low-income countries, the opinions of the private sector on the quality of health and primary education and the quality of infrastructure affect the growth rate the most and positively at levels of 111% and 42% respectively.

Chapter 2 - The issue of utilization of sludge from wastewater treatment in agriculture is an important socio-economic and environmental problem in the European Union and Bulgaria. It is becoming topical issue along with the growing interests into effective “transformation of wastes into products” and their inclusion in supply chains and circular economy. Despite their relevance, in-depth studies of the diverse effects and critical factors of sludge utilization in Bulgarian agri-food chain are at an early stage. The purpose of this article is to identify and assess the significance

of the various factors influencing the effective utilization of sludge from wastewater treatment in Bulgarian agriculture. Based on a qualitative analysis of regulations and institutional structure, and surveys with managers and experts of urban wastewater treatment plants, and farmers using and not-using sludge, the institutional, political, organizational, personal, educational, informational, social, economic, and environmental factors influencing the utilization of sludge in agriculture in two regions of the country (Sofia and Burgas) are identified. Impact factors are generally divided into two types: factors influencing the behavior of agents, and factors determining the type and extent of the effects of sludge use in agriculture. Research of this type is to continue and deepen to establish the economic, sectoral and regional specificities on the basis of more representative information from all participants and interested parties in the effective utilization of sludge in the country.

Chapter 3 - Crowdsourcing is a new form of labor market activity which incorporates several dynamic and interactive aspects of Web 2.0. Despite the increased popularity of the crowdsourcing activity worldwide, little is known on the quality of output and the associated determinants of a task-specific outcome. In this chapter the authors investigate the impact of cognitive and non-cognitive skills on the quality of a task-specific outcome by conducting an experiment on a popular crowdsourcing platform. Using linear and non-linear regression techniques and controlling for a wide set of individual characteristics and country-specific indicators, the authors found that the performance of workers depends on cognitive skills, personality traits and work effort. The results are expected to gain insights on the effective role of worker attributes on crowdsourcing labor induced projects.

Chapter 4 - This chapter explores how trade show visitors' objectives impact their visual attention to trade show booths and booth visit likelihood. Trade show attendees were recruited at an industry trade show in Florida. Attendees' objectives were noted as they evaluated a series of trade show booth images. The authors used eye-tracking cameras to record participants' visual attention while they viewed the series of booth images and answered visit likelihood questions. A follow-up survey collected

additional demographic and firm demographic information. Results showed that visitor objectives impact their visual attention to and the likelihood of visiting trade show booths. Visitors whose objective was to 'scoping out the competition' visually attended the booth images the most and were more likely to visit the booths. Increased visual attention to the total booth resulted in an increased visit likelihood. Implications and directions for future research are discussed.

Chapter 5 - The market transformation of the former socialist countries of the Central and Eastern Europe and the former USSR posed a serious challenge to integrate in the world economy in various dimensions. The ability to stand the technological competition is one of the most crucial ones, which is important at all levels – in domestic market, within regional economic unions and within the whole world economy. The countries of Eastern and Central Europe and the former USSR followed K-shape in their R&D aggregate national financing paths in the course of development after the end of transformation recession in the years of 2000-2018. The proposed chapter aims to summarize some trends in R&D expenditures in post-socialist countries in the course of market transformation on the basis of comparative statistical analysis of relative R&D effort in this group of countries and to outline some important issues which are to be investigated more closely in future research efforts on the matter. The research methodology of the paper uses the comparative analysis of relative R&D input measured as % of GDP throughout the period of 2000-2018 both inside the group and with some external countries.

Chapter 6 - African countries depend on the tourism industry to boost their infant economies; hence, the industry's human resources development is a critical area requiring attention in recent years. However, tourism human resources development is an under researched subject in the African context. Because Africa is underperforming in global tourism competitiveness, the aim of this research is to establish the best tourism human resources development practices utilised by Egypt as one of the African countries leading in this industry. This is anticipated to shed light on strategies that other African countries can adopt to improve their tourism human resources skills. Literature review research methodology

was used to gather data for this study, and the results indicated that factors such as government funding and lead role in various tourism human resources development initiatives led to Egypt's tourism success story. Short and medium-term policy recommendations emanating from identified practices from Egypt provided guidance and development actions for African less tourism competitive countries.

Chapter 7 - The chapter intends to outline the major aspects of the shift in the IMF stance on international capital mobility from the point of view of search of the right balance between freedom, regulation and control. The sequence of financial crises and other episodes of financial instability in the last three decades most of which included the input of international capital flows made it impossible to follow the linear route to capital account liberalization and made it necessary to broaden the theoretical and methodological foundations of the discussion moving from the first-best to the second-best approach. In practice the Fund is trying to put in place the internally coherent new operational framework which serves as basis for policy advising which goes beyond the conventional macroeconomic policies and relies on heterogeneous mix of instruments. The job is far from being completed and tested while the COVID-19 brought the test of new unprecedented external shock which caused the new level of uncertainty in all social and economic processes.

Chapter 8 - Stochastic control of exchange rates via discretionary central bank intervention is the topic of the authors' chapter. The authors modify the monetary model, allowing the central bank to set exchange rate targets while it practices diffusion monetary policy augmented by sudden, discretionary monetary interventions. Deviations between exchange rates and their targets are costly for central bankers. The monetary interventions affect exchange rates directly, moderating deviations from targets, but are costly to engineer. Central bankers choose interventions to minimize target deviation and intervention costs while preserving credibility by constraining interventions across time. Cost function restrictions ensure intervention never occurs, meaning freely floating exchange rates are optimal. The value function is linked to a PDE involving monetary dynamics.

Chapter 9 - The authors introduce investment adjustment costs into a real-business-cycle setup augmented with a detailed government sector. The authors calibrate the model to Bulgarian data for the period following the introduction of the currency board arrangement (1999-2018). The authors investigate the quantitative importance of investment frictions for the propagation of cyclical fluctuations in Bulgaria. The model with investment frictions performs poorly vis-a-vis data, and is ”rejected” in favor of the standard (frictionless) model. The authors thus declare the transmission mechanism associated with the convex investment adjustment costs to be an unlikely driver of the observed business cycle fluctuations in Bulgaria over the period studied.

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Chapter 1

PRIVATE SECTOR PERCEPTION OF PUBLIC POLICIES AND ECONOMIC PERFORMANCE

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ABSTRACT

In view of all the apprehensions that the private sector has with regard to public policies, we considered it necessary to evaluate their impact on a country's economic performance. The method used to do this consisted first of all in carrying out a descriptive analysis of the perception of public policies by the private sector and then in carrying out a Structural VAR Panel (SVRP) on data relating to the growth rate and the perception of the private sector of public policies in 51 countries throughout the world. The method showed that the higher the income level of the population, the more likely entrepreneurs are to believe that public policies are good and that middle-income countries have the highest average GDP growth. The method also showed that entrepreneurs' perception of public policies has various effects on the growth rate of GDP/head, by country and by income level of the

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countries. Thus, for upper-income countries, the two public policy changes that affect the growth rate the most are: a change in market size improves the growth rate by 41% on average over 10 years, and a deterioration in the quality of infrastructure leads to a slowdown in growth of about -55% on average over 10 years. For middle-income countries, a shock to entrepreneurs' views on infrastructure quality leads to an increase in the growth rate of about 635% for lower-income countries, and an increase of 75% for upper-income countries. For low-income countries, the opinions of the private sector on the quality of health and primary education and the quality of infrastructure affect the growth rate the most and positively at levels of 111% and 42% respectively.

Keywords: public policy, private sector, perception, economic performance

INTRODUCTION

In recent years, the private sector has been placed at the heart of economic development policies in many countries. The main factors in favour of this consideration are, on the one hand, the failure of economic development driven by the public sector, as we observed in the communist countries with the appovrisement of the population, and on the other hand, the rise of globalisation with the attractiveness of direct foreign investments.

Until the 1970s, the engine of economic development was largely the domain of the state, which often took over the production and distribution of goods and services. Thus, many governments did not limit themselves to the choice of the production sector for investment, but were responsible for its administrative and technical operation.

The combination of state control of enterprises and lack of competition in the markets eventually led to widespread malfunctioning. These manifested themselves in the form of poor quality and high prices of products and an increasing need for public subsidy of public and parastatal enterprises. This limited the mobilization of public funds available for

essential public services and facilities, such as social services, education and basic infrastructure.

The period from the 1970s to the mid-1990s witnessed a redefinition of the role of the state, associated with globalization. As a result, the private sector has come to the forefront of economic development in most countries, particularly in the developing world, in the last decade. Indeed, it is generally accepted that business creates wealth, generates jobs and thus contributes to improving the living conditions of the population.

However, the performance of a country's enterprises depends on many external factors that refer to adequate conditions for stimulating wealth-creating productive investments. Generally speaking, these conditions refer to the availability of factors of production, the development of technologies, the quality of regulations and infrastructure, etc. These influence, to a large extent, the economic performance of a country. These influence, to a large extent, the economic performance of a country.

As a result, countries are looking for the best policies to ensure strong and sustainable growth (Easterly, 2001; Aghion and Durlauf, 2004; Hausmann et al., 2004). Private sector participation in public policy-making responds to the need for governments to establish their legitimacy by improving the transparency, quality and effectiveness of their policies (OECD, 2002).

In a context where the problems of private sector development are becoming priorities, the perception of the effectiveness of public policies by the private sector could lead to the implementation of conditions that would really lead to its development. This is therefore the objective of this work: to assess as precisely as possible the impact of the perception of the private sector on the implementation of public policies.

To understand the link between private sector perceptions of public policy and economic performance, first review the general considerations of public policy and private sector involvement in its assessment and formulation. This will allow us to review the different approaches and mechanisms by which public policy influences private sector dynamism. We will then present the empirical approach used and the results obtained

will be discussed. We will conclude this chapter with a presentation of the main lessons learned from this work.

REVIEW OF THE LITERATURE

Some Public Policy Considerations

In a given society, any problem can become political, the question being by what mechanisms. In any case, it is certain that the triggering of public action is not linked to any threshold of problem intensity. For example, the relationship between the emergence of environmental protection policies in the 1970s and the pollution of the industrial revolution era cannot be established. Even if one assumes that the question of problem identification is resolved (everyone agrees today that there are problems of pollution, delinquency or poverty), it remains to be determined at what threshold of intensity public action should be triggered.

What is Public Policy

Public policy, because of the multiplicity of research studies, is defined in various ways. However, these definitions are based on the following elements: actors and activities, and problems and solutions.

Scholars in this actor-activity stream view public policy as activities or lack of activities on the part of actors that are more or less precisely defined. Dye Thomas (1984) presents public policy as everything that governments decide to do or not to do. This definition is similar to that of Sharkansky (1970): public policy is action taken by government. Bellavance (1985), in his book on public policy, describes public policy as what legitimately constituted political and administrative authorities decide to do or not to do, and what they actually do. Helco (1972) states that public policy is a sequence of actions or inactions, rather than specific actions or decisions.

These definitions focus on governmental actors (public, political or administrative authorities). They neglect the impact of other actors, such

as members of political parties, the private sector, and the electorate or the population under administration, in the decision or non-decision to implement public policies. In order to correct this shortcoming, Jenkins (1978) presents a definition that involves all actors. He thus presents public policy as the set of interrelated decisions made by one actor or a group of political actors.

Other definitions complement this by emphasizing the object of public policy. Indeed, when the object of public policy is defined in a precise manner, the authors generally refer to the notions of problems or conflicts. These notions make it possible to clarify the "stimuli" to which public policy seeks to respond. Rakoff and Schaefer (1970) state that public policies are actions or inactions in response to demands. Anderson (1984) refers to actions directed toward solving a problem. Pal (1992) defines public policy as a series of actions or inactions that public authorities choose to take to address a problem or an interrelated set of problems. It is important to note that the stimuli for public policy can be external or internal to the political system, since the political system can be the object of economic policy.

The goals or solutions sought are central to some definitions of public policy. In asking why public policy is made, Lasswell and Kaplan (1950) state that policy is a project and includes desired values and practices. The notion of purpose is also present in Jenkins' (1978) definition, which complements it by saying that public policy refers to the selection of goals and the means to achieve them, and thus to the search for solutions.

In summary, a public policy can be presented as a set of activities (or non-activities) of public authorities (central, regional or local) to provide solutions to societal problems. This response consists of public actions/interventions through legislation, regulation, taxation, transfers and public expenditure to satisfy a demand in a specific area.

Typology of Public Policies

History shows that the fields, actions, means and objectives of public policies have varied over time. The different variations make it possible to draw up a typology of public policies.

The most widely used typologies of policies were drawn up by Lowi (1972), which combines two dimensions: the instruments of public action and the recipients, and is broken down into two parameters: the type of citizen (individual or collective) and the type of constraint (direct or indirect). By pooling the dimensions and parameters, four typologies of public policies can be distinguished:

- Regulatory policies that target individuals through direct coercion. They consist in enacting mandatory rules that apply to any individual in a given situation.
- Allocative policies that target individuals through indirect coercion. They are based on the allocation of specific permits or benefits.
- Redistributive policies that target groups of individuals by means of a direct constraint. They make transfers between groups, often with a view to solidarity.
- Procedural policies that target groups of individuals by means of indirect coercion. They lay down the rules or procedures to be followed by public policy actors.

Table 1: The different types of public policies

		Constraint	
		Direct	**Indirect**
Public	**Individual**	Regulatory Policy	Allocation policy
	Group	Redistributive policy	Constituent Policy

Source: Lowi (1972)

The practice of public policy, today as in the past, remains delicate. In general, economies are stronger today insofar as market mechanisms are more robust and institutions better organized and managed. Having become more complex, they have become more delicate to operate and more vulnerable to economic downturns, through the anticipations of agents who react to changes in their environment.

Mechanisms by Which Policies Affect Private Sector Development

As the holder of the "monopoly of legitimate violence", the State is the cornerstone of regalian activity: it legislates, codifies, regulates, and, as far as companies are concerned, defines the legal environment that frames, in a given territory, the conditions for the exercise of economic activities. It also sanctions and thus guarantees that the rules defined can be implemented. It is also a major economic player through public spending, taxation and industrial policies: its intervention is part of both a Keynesian perspective of stimulating growth and an action intended to remedy "market failures".

Since the conditions in which the private sector operates are evolving and dynamic, they can, to some extent, have a positive or negative effect on performance, leading to prosperity or stagnation. As a result, countries are looking for the best policies to ensure strong and, above all, sustainable growth (Easterly, 2001; Aghion and Durlauf, 2004; Hausmann et al., 2004). Seven groups of factors can be identified as being of key importance to the development of a country's private sector, which will have a significant impact on the country's growth and the productivity of firms. These factors are: political stability, economic stability, regulation, taxation, financial system, infrastructure and labour market.

Economic Stability

Controlled inflation, a balanced government budget and an exchange rate system that reflects reality are all objectives that governments set for themselves in order to improve their macroeconomic framework (Easterly, 2001). Macroeconomic instability leads to a loss of investor confidence, making future returns more uncertain. It can also deteriorate asset values (Hnatkovska and Loayza, 2004). While large investors have the tools to deal with such constraints, small investors are very vulnerable. The costs of macroeconomic instability can be very high for companies (Caballero, Engel and Micco, 2004). One example is the situation in the economies of

Latin American countries, which experienced chronic instability in the 1980s, a decade that has been called the “lost decade”.

Political Stability

Political stability is fundamental to private sector development, as it can create uncertainty for investors and therefore risk associated with that uncertainty. This has the effect of obscuring the credibility of the host country's laws and policies. The issues at stake here are essentially the protection of property rights, contract enforcement and security.

As regards the protection of property rights, many studies establish a strong link between it and the growth of a country (World Bank, 2004; Erb and al., 2000). Moreover, the security of these rights at the level of land is positively correlated with investment (Feder et al., 1988). The key question for governments is how to improve the land titling process. This is an important issue in many developing countries. A large amount of land, especially in rural areas, is not registered at the government office level, with significant wastage effects and a negative impact on productivity due to lost revenue. The costs associated with registration are generally blamed. The establishment of effective national registration programs using the most advanced technological tools is one way to improve the protection of private property.

Another type of property has evolved exponentially in recent decades: intellectual property (patents, copyrights, etc.). Unlike other types of property (land), intellectual property is intangible. It can therefore be easily transported across borders. This raises the problem of the protection of intellectual property rights. International agreements to strengthen these rights are therefore critical to improve protection. This will have a positive impact on confidence and therefore on investment.

In general, property rights are more secure when contractual risks (costs and risks associated with business transactions) are minimized. Uncertainty in the execution of contracts deteriorates the value of traded goods and has a negative impact on investment opportunities. To limit the impact of this uncertainty, governments can use two levers:

- **Facilitate information flows based on the reputation of firms.** Indeed, the reputation of a firm plays a fundamental role in the existence and execution of contracts in any society (Greif, 1989; Fafchamps, 2004). In this sense, a firm that wishes to enter into a contractual relationship with another will do so on the basis of the information it has about the potential contractor. This information is crucial and relates to the economic and financial performance of the firm (credit status, etc.). Governments therefore have an obligation to remove the obstacles to the circulation of information that makes it possible to assess the reputation of firms and to facilitate access to this information, for example via dedicated public agencies that build their databases on the basis of information collected from central banks in particular (Jappelli and Pagano, 1999).
- **Improving the functioning of justice in dispute resolution**. Indeed, improving the functioning of commercial justice is imperative in the case of dispute resolution as the number and complexity of commercial transactions are constantly evolving. The positive impact of the functioning of a judicial system on the commercial activity of firms is not only measured by the number of cases resolved, but rather by the impartiality of the courts and the time taken to resolve each case. In general, a significant number of studies establish a strong link between the efficient functioning of a country's justice system and its investment environment. A well-functioning system will significantly reduce the risk faced by firms and increase firms' willingness to invest (Laevan and Woodruff, 2003).

Fight Against Insecurity

In general, human and property rights abuses, fraud and theft are all factors that undermine the investment environment and that governments must combat effectively. Investment decisions by the private sector, whether domestic or foreign, are strongly influenced by the security situation in a country insofar as an unsafe environment will generate an

additional cost for the investor who, if he cannot compensate for it by a higher return (risk premium), will invest elsewhere. Fighting crime and ensuring a stable environment where everyone's rights are respected is the responsibility of every government. The social stability of the country is at stake. In order to do so, the government has the choice between three approaches: a reinforcement and strict application of the law without complacency, a dissuasive approach and the implementation of crime prevention programs (World Bank, 2005).

The Regulation

Many studies have shown the positive relationship between regulation and investment (Alesina et al., 2003; Nicoletti and Scarpetta, 2003). In general, governments regulate business activity for several reasons. On the one hand, to restrict market access in certain sectors of activity, to define where investors will operate, the production processes used, the quality of the goods and services produced and marketed, the distribution process used, etc. On the other hand, to ensure that the market is fair and equitable, to ensure that the market is not used to justify investment. However, fairness is never achieved in regulation because governments cannot satisfy everyone. Thus, governments must seek a compromise between market imperfections and government imperfections, while taking into account the institutional context of the country, and not seeking to import ready-made regulations from outside.

The Tax System

Taxation is the main tool that allows states to raise these revenues. This taxation is partly made up of taxes paid by companies and is therefore one of the strongest constraints that the private sector repeatedly complains about. The dilemma for the State is to find a balance between a level of taxation that is both bearable for investors and that takes into account its own fiscal needs in order to meet its obligations. Indeed, the share of the tax burden imposed on firms depends on considerations of equity and efficiency, but also on more pragmatic considerations of national need (Tanzi and Zee, 2001).

Taxation is therefore a tool that affects competition between companies through the integration of their economy into the global economy and the differential treatment given to firms operating in a similar market. The challenge for any government is to ensure that public taxation generates sufficient resources to sustain the budget over several time frames. This must be done in such a way as to broaden the tax base by putting in place a support system to facilitate the migration from the informal to the formal sector.

The Financial System

Financial markets, when functioning efficiently, connect investors with lenders who are willing to share some risk with them. Thus, poorly functioning financial markets create biases that lead to market imperfections, increasing the costs to firms. Barriers to entry are erected, preventing new entrants from entering the market; this erodes the perception of the investment environment.

The development of financial markets also contributes to poverty reduction, by reducing income inequalities, in particular by facilitating access to financing for the poorest populations (Li, Squire and Zou, 1998). For the private sector, this development should lead to rapid changes in the production and productivity of enterprises (King and Levine, 2003; Levine et al., 2000; Beck et al., 2000; Bandiera et al., 2000).

Numerous measures are taken by governments to strengthen the functioning of financial markets, including stability of the macroeconomic framework, promotion of competition, securing capital and facilitating information flows.

The Infrastructure

Overall, good infrastructure helps to connect customers and suppliers and to lower production costs by allowing them to benefit from modern production techniques. Indeed, firms with access to modern telecommunications infrastructure, access to electricity and a reliable transport network are generally more productive and invest more than those without (World Bank, 2005).

However, the construction and maintenance of infrastructure (roads, ports, electrical installations and telecommunication networks) are very costly, especially for poor countries. It is no coincidence that these countries have the worst infrastructure. Contrary to popular belief, however, this is not just a problem of funding (Devajaran et al., 1996; Tanzi and Davoodi, 1997, 1998). Since the government budget is usually more limited than the country's infrastructure needs, governments have to make technical and political trade-offs. It should therefore be ensured that these are based on a certain rationality and economic logic (cost/benefit analyses, etc.).

The Labour Market

Improving the number and quality of jobs created is one of the central objectives of governments of all political stripes. Unemployment, particularly among young people, is the scourge facing all governments. Thus, creating an environment that stimulates investment is crucial to meeting the challenges of youth unemployment in particular. To do so, governments must act on the labour market by putting in place effective labour policies that are incentive-based, dynamic and flexible for investors.

Therefore, governments must make every effort to improve the training and qualification of the workforce through ambitious and proactive educational and vocational training policies. Indeed, improving the conditions for private sector development necessarily involves strengthening human capital. It is only under these conditions that the demand by companies for qualified and competent workers will be able to meet an adequate supply.

The role of the public authorities in improving the conditions for private sector development is explained by the existence of market imperfections that hamper business activity. As such, the latter have the responsibility, among others, to intervene at the level of the markets by regulating the activity of firms in order to reduce asymmetric information, externalities and monopolistic situations as much as possible; to ensure the application of the law and order in order to protect the rights of investors;

and to provide the infrastructures necessary for the good conduct of their activities.

Private Sector and Public Policy

Does the private sector still have an interest in lobbying the state? A literature, referred to as "business-as-capital" (Lindblom, 1984), challenges this vision of the relationship between the private sector and the State. According to this literature, since the end of the 1970s, the deterritorialization of economic phenomena has called into question the autonomy of the State in terms of political policies, and even their capacity and legitimacy to formulate strategies in this area. Governments would no longer have the leeway to regulate and legislate in areas such as the control of capital flows, corporate taxation, the labour market or foreign direct investment. In other words, the state would be forced endogenously to create conditions favourable to the private sector.

The private sector can put pressure on the state not only to improve and reform itself, but also to strengthen and clarify the conditions for the development of its business and to intervene in areas of significant market failure. The need for the private sector to influence legislative and regulatory processes, and thus to put pressure on the state, is clear. The acceleration of the so-called "globalization" phenomena over the past three decades has not, contrary to what the so-called "convergence" analyses argue, radically challenged this need.

The private sector's perception of public policy can encourage governments to adopt good policies. It also provides an opportunity to redefine the very place of the state in the economy. In particular, the private sector can use it to demand greater transparency and integrity from the state. Doner and Schneider (2000) highlight the active role that business associations can play in reducing corruption in the political-administrative system. In the case of Nigeria, Kraus (2002) shows the active role of leading business associations in the liberalization of foreign exchange and credit policies in the 1990s under the authoritarian regime of General Abacha.

Indeed, Borner, Brunetti and Weder (1995) point out that government credibility with the business community is, more than other policy variables, a statistically robust determinant of economic performance (as measured by growth) in developing countries. Establishing credibility and building trust with the private sector, which is by nature a sceptical public, is a challenge for governments. The government must therefore send strong signals if it wants to convince the private sector of its "sincerity". Indeed, the private sector generally seeks to obtain from public authorities an environment, regulations and public policies favourable to the development of its activities (transparency, security, predictability, development of infrastructures, etc.) and that it is able to apply them.

METHOD

Data Source

The data used in this work come from two main sources: data from the World Economic Forum (WEF) World Competitiveness Report and data on the growth rate of GDP and GDP/head.

With regard to the WEF data, it should be noted that each year this organization conducts an opinion poll among business leaders to gather their views on a set of factors that determine the competitiveness of a territory. And to be taken into account in the ranking, each country must return at least 80 questionnaires whose responding companies reflect the structure of the GDP. The answers to these questions, which are evaluated on a linkert scale ranging from 1 to 7, are summarised in the report for each country in the form of sub-pillars and pillars. Thus, the perception of public policies is seen through the following 12 pillars: quality of institutions, infrastructure, ability to manage technology, macroeconomic stability, health, education and skills, goods market, labour market, financial system, market size, business dynamism and innovation.

For performance data, we will use percentage growth rates of GDP and GDP per capita. These data will be extracted from the World Bank's World

Development Indicators database. The data set will be mobilized for the period 2006 to 2017.

Sample Construction

The set of countries in our sample was determined by the availability of data. The number of countries (the statistical unit of our work) in our study is 51. These countries are divided into four categories: lower income countries; lower middle income countries; upper middle income countries and finally upper income countries according to the world bank group (2016). The structure of our base is 25% lower income countries, 27% lower middle income countries; 18% upper middle income countries and 29% upper income countries.

Data Analysis Method

In the framework of our work, we will use two methods of analysis: the descriptive statistical analysis method and the explanatory analysis method.

Descriptive Statistical Analysis

The descriptive statistical method will be done through univariate analysis to describe each variable and their modalities. And the multivariate analysis with an Analysis of correlations between variables.

Explanatory Analysis

The relationship between public policy and growth is complex. The two can be deeply intertwined, in the sense that the achievement of policy objectives is generally conditioned by the level of growth of the economy, which in turn is conditioned by the policies implemented. The nature of these dynamic relationships is not necessarily the same in the different countries in the sample. Moreover, changes in economic activity as well as

changes in other factors that determine the implementation and perception of public policies at the national or international level affect public policies and economic growth at the country level. This creates potential additional complexity in the form of cross-sectional, and/or spatial, dependence of public policy and economic activity across countries.

To overcome these difficulties, our explanatory approach takes into account potentially complex dynamic endogeneities that differ across countries and the heterogeneity between public policies and other economic activities. The methodology we will use is based on the structural panel VAR approach developed by Pédroni (2013). This approach then exploits the static relationship of structural shocks to effectively decompose them into shocks common to panel members and idiosyncratic shocks to individual panel members.

Panel structural VARs can be based on a number of identification restrictions, including short-run or long-run restrictions. In our study, this identification is based on long-run restrictions. Thus, we consider shocks as structural forcing processes of the underlying economic model. As a result, they are considered conceptually distinct and therefore orthogonal to each other. Furthermore, since they are conceptual and unobserved, their units are arbitrary, so we are free to scale them as we wish.

Since in our case we have 12 years of data and adopting the same approach as Blanchard and Quah (1989), considering that long-run shocks are supply shocks while short-run shocks are demand shocks, we will use a structural vector autoregression panel (SVAR).

Presentation of the Model

As mentioned above, we will use the recent panel method proposed by Pedroni (2013) in structural vector autoregression (PSVAR). The PSVAR has the particularity of capturing heterogeneity among panel members and individual dynamics as well as decomposing structural shocks into common and idiosyncratic shocks. This allows the estimation of impulse response quantiles and variance decompositions for each type of shock.

In order to evaluate the effect of the perception of public policies on growth, measured by GDP/head, we propose a series of bivariate models (12 models). Indeed, according to Catherine Bruneau and Olivier De Bandt (1998) bivariate systems give more significant results than large systems. The variables used are the following: GDP/head in year t+1 and public policy i in year t and consider respectively Y2,t+1 and Pi,t (i goes from 1 to 12) with Zt= (Y2t+1,Pi,t)'. The determination of policy effects can be understood using the following VMA model $\Delta Zt = A(L)\varepsilon t$, where A(L) is a polynomial matrix described by the lag operator L, εt is a two dimensional white noise vector of structural shocks. In this model, we will use two endogenous variables and twelve exogenous variables shown in the table below.

Table 2. Presentation of variables

N°	Variables	Description
Endogenous		
1.	Y1	GDP growth rate in percent
2.	Y2	GDP per capita growth rate in percent
Exogenous		
3.	P1	Quality measurement institutions
4.	P2	Infrastructure quality measurement
5.	P3	Measuring the quality of the macroeconomic environment
6.	P4	Measuring the quality of health and primary education
7.	P5	Quality measurement in higher education and vocational training
8.	P6	Measuring the quality and efficiency of the product market
9.	P7	Measuring the quality and efficiency of the labour market
10.	P8	Measuring the quality of financial market development
11.	P9	Measurement of the quality of technological development (or agility)
12.	P10	Market size measurement
13.	P11	Measuring the sophistication of business activities
14.	P12	Measuring innovation

Source: Authors

The approach to identifying shocks to each of the explanatory variables on GDP per capita is based on the literature presented in the table below. Indeed, one strategy to effectively identify shocks is to consider the variables of interest in relation to the shocks they determine. In our case, we are mainly interested in the effects of a policy shock on economic growth, represented by GDP/head. Thus, for each of the variables measuring a policy component, we study the responses to the main structural shocks that can have an impact on growth. In the macroeconomic literature, shocks are often referred to as aggregate supply (AS) and aggregate demand (AD). They are distinguished from each other according to whether they correspond to shocks that permanently increase or decrease total economic activity (AS) or shocks that have only a transitory effect on total economic activity (AD).

Table 3. Shock identification strategy

Explanatory variables	**Type of shocks (sign of shock on GDP/head)**	**Literature**
P1	Offer (+)	Barro (1996), Clague, Keefer and Olson (1996), Alesina and Perotti (1994)
P2	Offer (+)	Barro (1990), Zakane (2004)
P3	Offer (+)	
P4	Offer (+)	Aghion, P., Howitt, P., & Murtin, F. (2010).
P5	Offer (+)	David Bloom, David Canning, and Kevin Chan HARVARD UNIVERSITY, 2006
P6	Offer (+)	Sutherland and Hoeller, 2013
P7	Offer (+)	Sutherland and Hoeller, 2013
P8	Offer (+)	R. King and R. Levine (1993);
P9	Offer (+)	
P10	Offer (+)	Sutherland and Hoeller, 2013
P11	Offer (+)	
P12	Offer (+)	

Source: Authors

To make the identification of shocks easier, it is usual to assume that the different structural shocks of the same date are uncorrelated and have unit variance. To do this, we must impose some minimal restrictions, known in the literature as identification restrictions. To distinguish AS shocks from AD shocks, we use the restriction that AD shocks do not lead to a permanent movement in GDP/head, unlike AS shocks. This is in line with the literature and consistent with their definitions. In the present case, and based on the economic literature in Table 2, the only identification constraint per equation is a long-run constraint, which translates here into the nullity of one of the coefficients of the matrix A(L).

We assume, as is common practice, that the supply shock is the only shock that contributes to the trend in GDP, which translates into the nullity of the long-run dynamic multiplier in the trend in GDP. Since each of the variables is related to each of the two shocks, schematically our configuration can be characterized as follows: when we use a 0, it is to indicate a restriction for the input, a * to indicate a completely free value for the particular input, and finally we used a + to indicate a sign restriction, so that the value of the response is not constrained.

$$\begin{bmatrix} PIB_{t+1} \\ Pi_{,t} \end{bmatrix} = \begin{bmatrix} + & 0 \\ * & + \end{bmatrix} \begin{bmatrix} \varepsilon^{AS} \\ \varepsilon^{AD} \end{bmatrix}$$ i and t ranges from 1 to 12.

Software Used

The estimates in this work are made on the RATS software, which provided the impulse responses of each country following a supply and demand shock on the variables considered.

RESULTS AND DISCUSSION

Descriptive Statistics

This section presents the results of univariate and multivariate descriptive statistical analysis to describe the study data.

Univariate Analysis

Preliminary analysis of the study variables reveals that there is a high variability in the rate of economic growth across countries, whether measured by the GDP/head growth rate or by the GDP growth rate.

The purpose here is to present the results from univariate and multivariate descriptive statistical analysis to describe the study data.

Table 4. Characteristics of the dependent variables

Income group	Indicateur statistique	Y1	Y2	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
High income	min	-8.1	-15.2	3.4	3.7	3.3	5.4	4.1	3.8	3.3	3.1	3.2	2.7	3.6	2.9
	max	14.5	12.5	6.2	6.7	6.6	6.9	6.3	5.8	5.9	6.4	6.3	6.9	6.0	5.8
	moyenne	1.9	0.7	5.1	5.6	5.0	6.3	5.3	5.0	4.9	4.9	5.4	4.9	5.1	4.7
	ecartype	2.9	2.1	0.8	0.7	0.7	0.3	0.5	0.4	0.6	0.7	0.6	1.1	0.5	0.8
Upper middle income	min	-6.8	-7.0	2.7	2.7	2.3	3.6	3.2	3.0	2.8	2.4	2.3	2.3	2.5	2.1
	max	14.2	13.6	5.2	5.5	6.6	6.3	5.1	5.4	5.0	5.8	4.9	7.0	5.3	4.8
	moyenne	3.4	2.7	4.0	3.9	4.9	5.5	4.2	4.3	4.3	4.2	3.7	4.3	4.1	3.4
	ecartype	3.5	3.3	0.6	0.7	0.9	0.6	0.4	0.4	0.5	0.8	0.6	1.1	0.5	0.5
Lower middle income	min	-11.3	-12.2	2.6	1.8	2.2	2.8	1.9	3.0	3.0	2.1	2.2	1.1	2.6	2.2
	max	18.3	15.0	4.5	4.5	5.8	6.1	4.5	5.1	4.8	5.1	4.5	6.4	4.9	4.1
	moyenne	5.0	2.9	3.7	3.1	4.3	4.7	3.4	4.1	4.0	3.9	3.1	3.7	3.8	3.1
	ecartype	3.5	3.3	0.4	0.7	0.7	0.8	0.6	0.3	0.4	0.6	0.4	1.2	0.4	0.4
Low income	min	-17.7	-18.5	2.5	1.5	1.0	2.6	1.9	2.2	3.1	2.2	1.9	1.2	1.6	2.2
	max	19.7	18.1	5.6	4.0	5.1	5.5	4.3	4.7	5.4	4.6	3.8	3.9	4.2	3.6
	moyenne	4.7	2.1	3.6	2.6	4.0	4.1	2.8	3.7	4.2	3.4	2.7	2.6	3.3	2.9
	ecartype	7.4	4.3	0.7	0.5	0.8	0.7	0.4	0.5	0.5	0.5	0.4	0.6	0.4	0.3
All	min	-17.7	-18.5	2.5	1.5	1.0	2.6	1.9	2.2	2.8	2.1	1.9	1.1	1.6	2.1
	max	19.7	18.1	6.2	6.7	6.6	6.9	6.3	5.8	5.9	6.4	6.3	7.0	6.0	5.8
	moyenne	3.7	2.0	4.1	3.9	4.6	5.2	4.0	4.3	4.4	4.2	3.8	3.9	4.2	3.6
	ecartype	3.8	3.7	0.9	1.4	0.9	1.1	1.1	0.6	0.6	0.9	1.2	1.4	0.8	1.0

Source: Our work on Stata 16, from WDI.

The extreme values of GDP growth rate and GDP per capita are found in the group of low-income countries. This group of countries has the

greatest dispersion of growth. The lower middle-income countries have the highest average economic growth, with the smallest gap between growth levels. While the group of countries with the highest dispersion and lowest average growth rate is the high-income group.

In terms of the private sector's perception of public policies. Entrepreneurs in high-income countries consider, on average over the period, that they tend to agree with the quality of the macroeconomic environment, the quality of product market efficiency, the quality of labour market efficiency, the quality of financial market development and market size. These entrepreneurs agree with the quality of institutions, the quality of infrastructure, the quality of higher education and vocational training, the quality of technological development (or agility), the sophistication of business activities. And they are very much in agreement with health and primary education.

Entrepreneurs residing in upper-middle-income countries are indifferent to the quality of institutions, the quality of infrastructure, the quality of technological development (or agility), innovation.and they rather agree with the quality of macroeconomic environment, the quality of higher education and vocational training, the quality of product market efficiency, the quality of labor market efficiency, the quality of financial market development, the size of the market and the sophistication of business activities. And they agree with the quality of higher education and vocational training.

Business leaders in lower-middle-income countries are indifferent to policies related to the quality of institutions, the quality of infrastructure, the quality of higher education and vocational training, the quality of labor market efficiency, the quality of financial market development, the quality of technology development (or agility), the size of the market, the sophistication of business activities, and innovation. They tend to agree with the quality of the macroeconomic environment, the quality of health and primary education, the quality of product market efficiency.

As far as entrepreneurs from low-income countries are concerned, they tend to disagree with the quality of infrastructure, quality of higher education and vocational training, market size and innovation. They are

indifferent to the quality of the macroeconomic environment, the quality of the product market efficiency, the quality of the product market efficiency, the sophistication of business activities. And they tend to agree with the quality of health and primary education and the quality and efficiency of the labour market. This last finding does not give an idea of how these perceptions are changing

High-income countries show an increase in entrepreneurs' perception of the efforts made by their governments to improve the quality of institutions, infrastructure, health and primary education, higher education and vocational training, innovation, labour market efficiency, and technological development (or agility). This last policy has by far the highest growth rate, while the quality of financial market development has the lowest growth rate, which is also negative.

Table 5. Evolution of opinions on public policies

Income group	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
High income	0.11%	0.39%	-0.09%	0.14%	0.51%	-0.05%	0.27%	-0.72%	1.82%	-0.10%	-0.16%	0.45%
Upper middle inc	0.18%	1.67%	-0.33%	-0.05%	1.21%	0.17%	-0.32%	0.21%	3.04%	0.24%	0.40%	0.54%
Lower middle inc	-0.42%	1.23%	0.03%	-0.28%	0.26%	-0.04%	-0.74%	-0.68%	1.52%	0.34%	-0.29%	0.26%
Low income	-0.45%	1.50%	3.05%	0.43%	0.80%	0.63%	-0.44%	-0.79%	1.02%	-0.40%	0.70%	0.16%
ALL	-0.14%	1.12%	0.61%	0.05%	0.65%	0.15%	-0.28%	-0.53%	1.81%	0.02%	0.11%	0.35%

Source: Our work on Stata 16, from the WDI

The perception of entrepreneurs in upper-middle-income countries evolves positively regarding the majority of public policies. However, on average, their perceptions of the quality of the macroeconomic environment, the quality of health and primary education and the quality of labour market efficiency have changed. The policies with the greatest (over 1%) average changes in entrepreneurs' perception are the quality of infrastructure and the quality of technological development (or agility).

For the lower middle-income countries, 6 public policies could not convince entrepreneurs of their effectiveness, i.e., they show a negative evolution. These are quality institutions, quality health and primary education, quality product market efficiency, quality financial market development, sophistication of business activities and quality labour

market efficiency. The latter has the lowest average rate of change. Like the upper-middle-income countries, the policies with the highest (above 1%) average change are infrastructure quality and technology development quality (or agility).

For low-income countries, the policies that did not have a positive evolution in the perception of entrepreneurs are: the quality of institutions, the quality of the efficiency of the labor market, the quality of the development of financial markets, and the size of the market. In contrast to the other groups, 3 public policies record the highest opinions of entrepreneurs in this group: the quality of infrastructure, the quality of technological development (or agility) and the quality of the macroeconomic environment. The latter has the highest average annual growth rate of all groups..

Multivariate Analysis

The analysis of the correlations shows that public policies are more strongly linked to each other than to the growth rate of GDP and GDP per capita. The GDP growth rate is most closely related to the quality of infrastructure, the quality of higher education and vocational training, and the quality of technological development (or agility).

Table 6. Correlation table

Variables	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Y1	Y2
P1	1.00	0.70	0.19	0.49	0.69	0.78	0.47	0.67	0.67	0.19	0.67	0.69	0.02	0.00
P2	0.70	1.00	0.19	0.65	0.85	0.71	0.30	0.58	0.86	0.42	0.79	0.72	0.07	0.02
P3	0.19	0.19	1.00	0.18	0.20	0.23	0.11	0.12	0.16	0.20	0.17	0.17	0.00	0.00
P4	0.49	0.65	0.18	1.00	0.72	0.49	0.17	0.34	0.61	0.30	0.53	0.48	0.04	0.00
P5	0.69	0.85	0.20	0.72	1.00	0.72	0.34	0.63	0.88	0.40	0.80	0.77	0.07	0.01
P6	0.78	0.71	0.23	0.49	0.72	1.00	0.51	0.70	0.68	0.32	0.81	0.68	0.02	0.00
P7	0.47	0.30	0.11	0.17	0.34	0.51	1.00	0.44	0.37	0.09	0.38	0.45	0.00	0.00
P8	0.67	0.58	0.12	0.34	0.63	0.70	0.44	1.00	0.57	0.27	0.66	0.62	0.01	0.00
P9	0.67	0.86	0.16	0.61	0.88	0.68	0.37	0.57	1.00	0.33	0.77	0.78	0.09	0.03
P10	0.19	0.42	0.20	0.30	0.40	0.32	0.09	0.27	0.33	1.00	0.50	0.42	0.00	0.01
P11	0.67	0.79	0.17	0.53	0.80	0.81	0.38	0.66	0.77	0.50	1.00	0.84	0.05	0.01
P12	0.69	0.72	0.17	0.48	0.77	0.68	0.45	0.62	0.78	0.42	0.84	1.00	0.04	0.01
Y1	0.02	0.07	0.00	0.04	0.07	0.02	0.00	0.01	0.09	0.00	0.05	0.04	1.00	0.80
Y2	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.01	0.01	0.01	0.80	1.00

Source: Stata 16, from WEF and WDI.

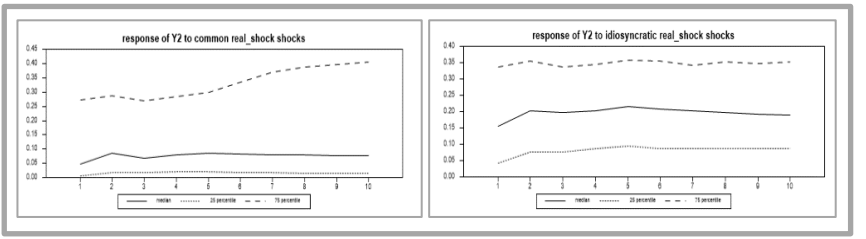
Similarly, the growth rate of GDP per capita is related to the quality of infrastructure and the quality of technological development (or agility). It is worth noting that these links are weak.

First Level Econometric Analysis

The estimates are made using the RATS software, which provided the impulse responses of each country following a supply and demand shock on the variables considered. These results are thus reported in the various graphs in this section. The upper solid lines show the third quartile response to a given shock. The lower dotted lines show the response of the first quartile to a given shock. The middle solid line shows both the difference in impulse responses and the heterogeneity across countries. It ultimately reflects a median response, i.e., the level of response that 50% of the panel members would have.

A Policy Shock to the Macroeconomic Environment

The median percentage change in a country's GDP/head growth rate due to a policy shock related to the improvement of the macroeconomic environment is about 15% in the first year, and by the second year it stabilizes at 20%. While the shock due to a global shock is relatively stable over 10 years, and is about 5%, although we note a peak in the second year of 8%. The main shock causing the variation in the GDP/head growth rate is an idiosyncratic shock based on the median percentage. For at least a quarter of the countries, the variation in the GDP/head growth rate of 30% is due to a global variation in macroeconomic policy for the first year, this variation goes up to 49% after 4 years before stabilizing at 30%. For this quarter of countries, the variation in the inclusive growth rate due to country-specific macroeconomic policy shocks ranges from 35% to 40% over the period.



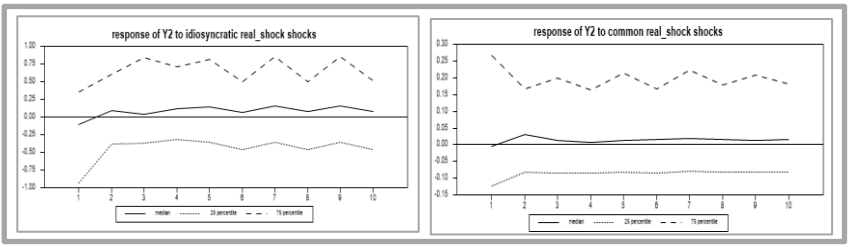
Source: Our work on Rats, based on WEF and WDI

Figure 1. Variance decomposition due to a supply shock of a policy relative to the macroeconomic environment.

The 25% quartile shows that for three quarters of the countries studied, the observed variations in the growth rate attributable to a macroeconomic policy shock are at least 05% in the first year, and from the second year onwards stabilise around 08%. For the common shock, the last percentile indicates that for 25% of the countries, the variation of the growth rate is not positively affected by a global macroeconomic shock.

The response of the median country's GDP/head growth rate to a common or individual shock to entrepreneurs' perception of the quality of policies relating to the macroeconomic environment is initially about -0.12 or -0.25 respectively, and then from the second year onwards, it becomes positive.

The evolution of the responses is sawtooth-shaped, oscillating between 0.05 and 0.25. The 75 per cent quartile certainly evolves in a sawtooth fashion, but remains above 0.25 for almost ten years. This translates into economic terms as follows: for at least a quarter of the countries in our study, a *ceteris paribus* shock to a policy relating to the macroeconomic environment increases the growth rate by at least 25% per year over 10 years. The median response to such a policy shock in the countries in our study has an initially negative effect on the growth rate of GDP per capita, but remains positive from the second year. It should be noted that for more than 25% of the countries in the study, such a shock has a catastrophic effect on the growth rate, with reductions ranging from about 95% of its value in the first year to 25% on average over the period.

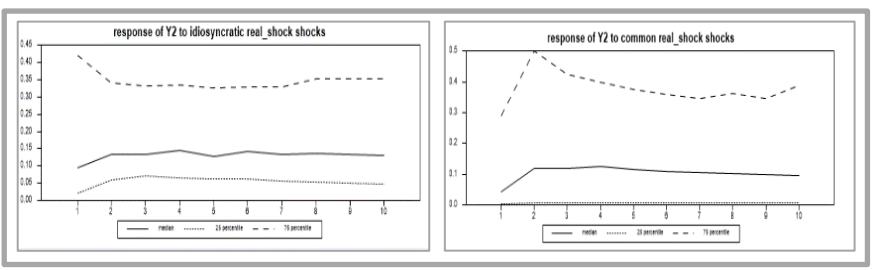


Source: Our work on Rats, based on WEF and WDI.

Figure 2. Impulse response function of GDP/head due to a shock to the perceived quality of the macroeconomic environment.

The Impact of Public Policy on the Quality of Infrastructure

The variation in the growth rate of GDP/head due to a *ceteris paribus* shock to the private sector's perception of [2]infrastructure quality is sensitive to the variation in an idiosyncratic shock. A variation of 1% in the variance of this shock only contributes to a variation in median responses of 10% in the first year, then it stabilizes around 13% for the rest of the years.



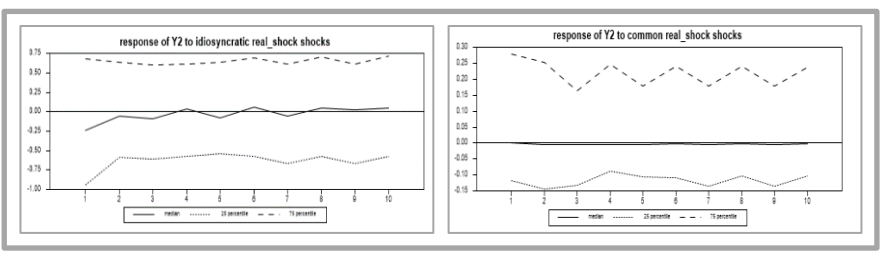
Source: Our work on Rats, based on WEF and WDI.

Figure 3. Variance decomposition due to a supply shock of an infrastructure quality policy.

A variation of 1% of a shock on the perception of the private sector of the countries of the study on the quality of the infrastructures induces a median variation of the order of 0.05% the first year, then from the second year it stabilizes at 10%. As for the median variability of the GDP/head growth rate due to a variation of 1% of the common shock relative to the perception of entrepreneurs on this policy, it is 8% in the first year and

stabilizes at 13% in the second year. The observation that we can make is that there is a strong heterogeneity between countries as regards the variability of the GDP/head due to a variation of 1% of the shock on the perception of the quality of the infrastructures. Indeed, the interquartile range of variations due to the different types of shocks mentioned above tends to increase over time.

As regards the response of GDP/head to a ceteris paribus shock on the perception of resident entrepreneurs on the quality of infrastructure, we see that the first and second quartile have an upward trend. The response of countries in the first quartile remains below -0.50 over the study period. The estimate of the median response is negative for the first three years, then it oscillates around 0 until the eighth year before taking positive values.



Source: Our work on Rats, based on WEF and WDI.

Figure 4. Impulse response function of GDP/head due to a shock to perceived infrastructure quality

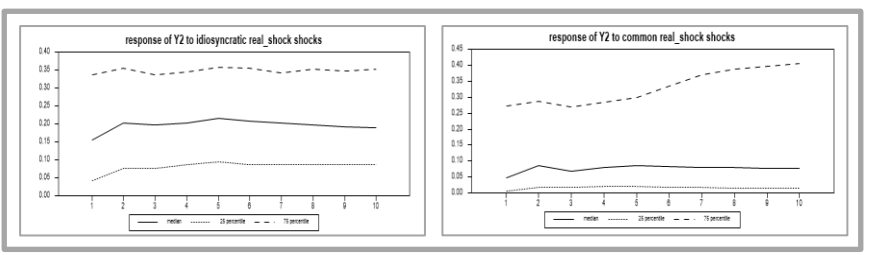
This would mean that a quarter of the countries studied have a fall in the GDP/head growth rate of at least 50% over 10 years, and for half of the countries, this shock induces a fall in the GDP/head growth rate over 5 years. However, the last quartile allows us to observe that there is a quarter of countries that have an increase of at least 50% of the GDP/head growth rate due to this national shock of the private sector's perception of public policies related to infrastructure.

A common ceteris paribus shock to the private sector's perception of a country's GDP/head growth rate induces a median response of almost zero. The last quartile shows that three quarters of the countries have an increase

in the GDP/head growth rate below 28% in the first year. Then this value decreases to 16% in the third year, and then it oscillates around 21%.

A Public Policy Shock on the Quality of Institutions

A variation of 1% of a shock *ceteris paribus* in the perception of the quality of institutions by the private sector induces a median variation of the growth rate of GDP/head increasing from the first to the second year, then a slight fall from the third year. This observation can be observed both at the country level and even at the level of all countries.



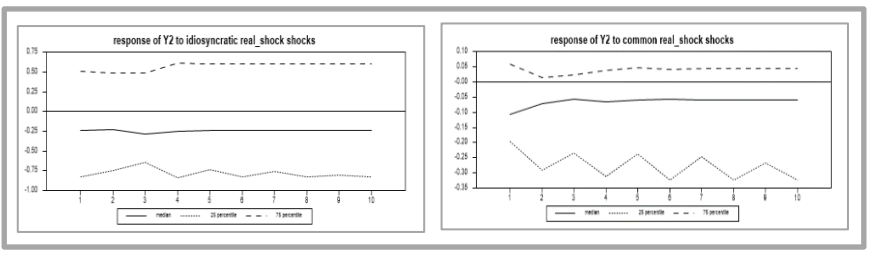
Source: Our work on Rats, based on WEF and WDI.

Figure 5. Variance decomposition due to a supply shock of an institutional quality policy.

The median variation affecting the variation of GDP/head the most is a variation of 1% of the idiosyncratic shock of a public policy related to the quality of institutions. Indeed, a 1% variation in resident entrepreneurs' perception of institutional quality is responsible for an 18% variation in GDP/head. In the median country of the study, a variation of 1% in the perception of the private sector on this policy affects inclusive growth by 6% on average. At the global level, the variation of 1% in the perception of the private sector affects the growth rate of the GDP/head by 07% from the third year. Heterogeneity in the responses is observed by the extent of the interquartile range, which increases over time.

The median response of the countries studied is negative and its point estimate is -0.25 over the period, except in the third year when a dip of -0.3 is observed. The first quartile shows that for a quarter of the countries studied, a *ceteris paribus* shock to the perception of resident entrepreneurs

on the quality of institutions induces a sustained decline in GDP/head of at least 55% over the 10 years. And the last quartile allows us to observe that a quarter of the countries have a positive reaction of inclusive growth to a shock on the perception of resident entrepreneurs on their perception of institutional quality, i.e., the growth rate of GDP/head increases by 50% the first 3 years, then by 60% over 7 years.



Source: Our work on Rats, based on WEF and WDI.

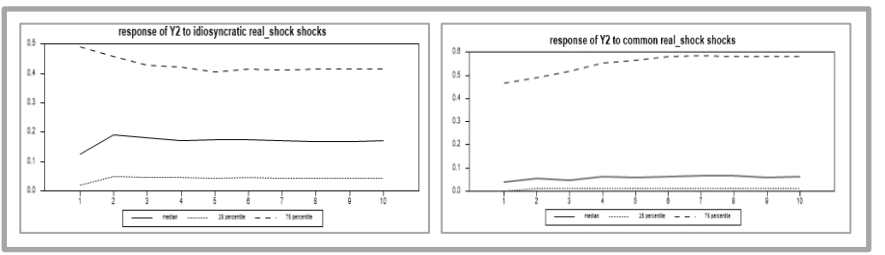
Figure 6. Impulse response function of GDP/head due to a shock to the perception of institutional quality.

Regarding the response of the GDP/head growth rate to a common shock on the perception of entrepreneurs on this policy, the median response of the countries remains negative although its initial estimate is -0.10 and improves over time to stabilize at the fifth year at -0.06. This would mean that, for more than half of the countries studied, the GDP/head growth rate decreases as a result of this common shock. The last quartile allows us to say that 25% of the countries studied have a GDP/head that reacts positively to this common shock on the perception of the private sector on the quality of institutions, with an increase of at least 5% in the first year and then stabilizing from the fourth year at 4%.

A Shock to Public Policy on Quality of Health and Primary Education

The variance of the growth rate of GDP/head is sensitive to the variation of an idiosyncratic shock *ceteris paribus* on the perception of the private sector on the quality of the health system and the quality of primary education.

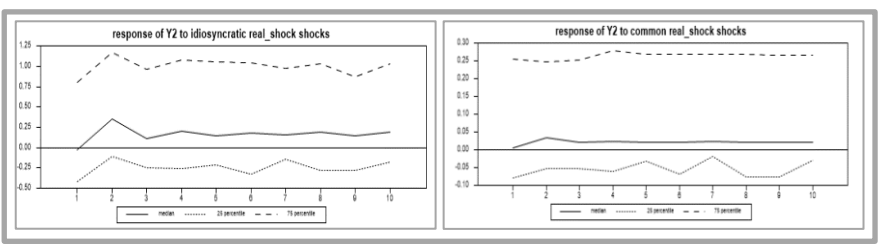
In fact, this shock is responsible for 12% of the variation in the GDP/head growth rate in the first year, then 19% in the second year and finally it stabilizes in the fourth year at 17%. As for the common shock, it is responsible for a variation of 05% of the inclusive growth on average over the period. This variation is relatively stable over time. The composite shock affects the variation of the GDP/head growth rate by 18%.



Source: Our work on Rats, based on WEF and WDI.

Figure 7. Variance decomposition due to a supply shock of a policy related to the quality of health and primary education.

The median response of the GDP/head growth rate to a common and individual *ceteris* paribus shock to entrepreneurs' perceptions of the quality of health and primary education is zero in the first year, but it maintains positive values over 10 years.



Source: Our work on Rats, based on WEF and WDI.

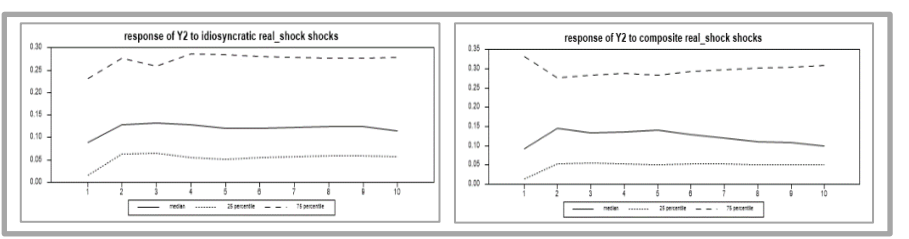
Figure 8. Impulse response function of GDP/head due to a shock on the perception of health quality and primary education.

We observe a peak in the second year of 0.35 for the individual country shock and 0.5 for the common shock. This reflects the fact that such a

shock induces an increase in the GDP/head growth rate for more than half of the countries in the study. The third quartile shows that the common shock is responsible for an increase of more than 75% of the GDP/head growth rate for a quarter of the countries, while an increase of 25% of the GDP/head growth rate is due to the common shock.

A Shock to Public Policy on the Quality of Higher Education and Vocational Training

The variation of GDP/head is sensitive to a variation of a *ceteris paribus* shock of perception of the resident private sector on the quality of higher education and vocational training. Indeed, a variation of 1% in a shock to the perception of national entrepreneurs leads to a median variation in inclusive growth of 8% in the first year, then 14% in the second year, and finally it gradually decreases to stabilise at 12%.



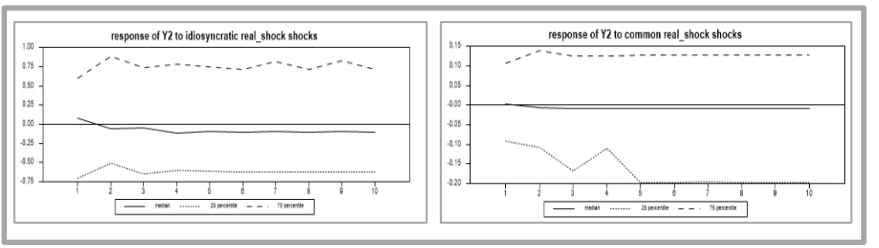
Source: Our work on Rats, based on WEF and WDI.

Figure 9. Variance decomposition due to a supply shock of a policy on the quality of higher education and vocational training.

As for the common shock *ceteris paribus* on this perception, we observe a positive median variation of 5% in the first year of the growth rate, then it increases to 9% in the third year. Then it gradually decreases to 6%. Whereas, the composite shock induces an increasing variation the second year to reach 15%, then it decreases to stabilize around 10%.

As for the heterogeneity between countries' responses, we find that only the interquartile range of responses due to the idiosyncratic shock is stable over time. We observe a strong heterogeneity in the responses of the GDP/head growth rate of countries due to a *ceteris paribus* shock on the

perception of the private sector on the quality of higher education and vocational training.



Source: Our work on Rats, based on WEF and WDI.

Figure 10. Impulse response function of GDP/head due to a shock on the perception of the quality of higher education and vocational training.

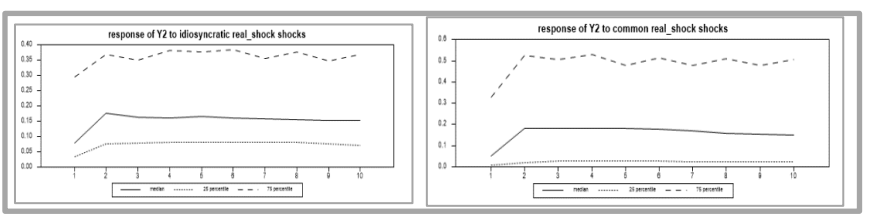
The median response of the growth rate of GDP/head due to a ceteris paribus shock, individual and common, to an initial estimate is positive, i.e., about 0.10 for the individual country shock and 0.01 for the common shock. From the second year onwards, these median estimates take on negative values. The first quartile of impulse responses due to an idiosyncratic shock shows that the point value of a quarter of the countries in the study is less than -0.75, from the third year onwards this value stabilizes below -0.60. While the third quartile shows that for another quarter of the countries, due to this individual shock, the estimated response of the growth rate of GDP/head is initially above 0.55, then from the third year it stabilizes around 0.75. For the common shock, the trend of the curve representing the response of the growth rate of GDP/head to such a shock on the perception of the private sector for the quarter of the countries in the study is decreasing over five years, then it stabilizes. The initial estimate of this response is -0.9, then from the fifth year it stabilizes at -0.20. And for the third quartile, the response of the growth rate of the GDP/head of a quarter of the countries is initially higher than 0.10 and then from the third year this value is at least higher than 0.13.

These results show that, for a common shock on the perception of the private sector on the quality of higher education and vocational training, half of the countries have a 10% increase in their GDP/head, and a quarter

of the countries have a decrease in the rate of growth of the GDP/head lower than 75%, and then from the third year onwards it is lower than 60%. While for another quarter of the countries, we observe an increase in the GDP/head growth rate of at least 55% in the first year, then from the third year it is at least equal to 75%. The analysis of the common shock induces for half of the countries studied a decrease in their inclusive growth.

A Public Policy Shock to the Quality of Product Market Efficiency

A variation of the shock of 1% on the perception of the private sector on the quality of the product market efficiency induces a median variation of the growth rate of 18% on average and 16% on average respectively to a variation of a common and idiosyncratic shock. We note that after a peak in the second year, the median variation of the growth rate induced by each of these shocks slowly decreases and reaches an equilibrium path around 15%, for each of these shocks.

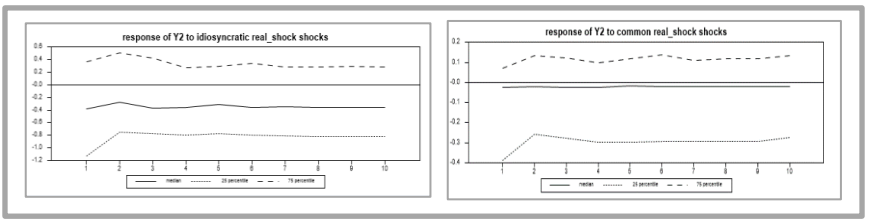


Source: Our work on Rats, based on WEF and WDI.

Figure 11. Variance decomposition due to a supply shock of a product quality efficiency policy.

As for the first quartile, the variations in the growth rate of GDP/head induced by a 1% variation in the perception of entrepreneurs with respect to this public policy have a low growth rate over time. The initial value of this variation is 3% and 1% respectively for an idiosyncratic shock and for a global shock, and the final value is 5% and 3% respectively. Thus, more than three quarters of the countries studied have an increase in their per capita growth rate of more than 3% each year due to a national shock, and an increase of more than 1% for a common shock. The third quartile shows that from the second year onwards, for a quarter of the countries studied,

the growth rate of GDP per capita undergoes a variation of 38% on average for a national shock on the policy considered and a variation of 53% on average for a global shock.



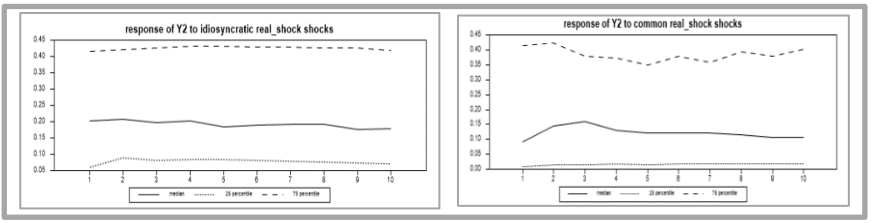
Source: Our work on Rats, based on WEF and WDI.

Figure 12. Impulse response function of GDP/head due to a shock to the perceived quality of product market efficiency.

An idiosyncratic shock to the private sector's perception of the quality of product market efficiency induces a *ceteris paribus* estimate of the median response of the GDP/head growth rate that is relatively stable around -0.35. This means that more than half of the countries in our study experience a decrease in the inclusive growth rate. And half of the countries have a 35% decrease in GDP/head. A study of the third quartile shows that a quarter of the countries studied have a growth of more than 37% in the first 4 years, and then this growth remains higher than 25% over the remaining 6 years. As for the response of the GDP/head growth rate induced by a common shock on this policy, the median response shows that more than half of the countries undergo a decrease in GDP per head. For a quarter of the countries in the first year, these countries have a GDP/head growth rate higher than 7%, then over the rest of the nine years they have a growth rate higher than 10%.

A Public Policy Shock to Labour Market Efficiency

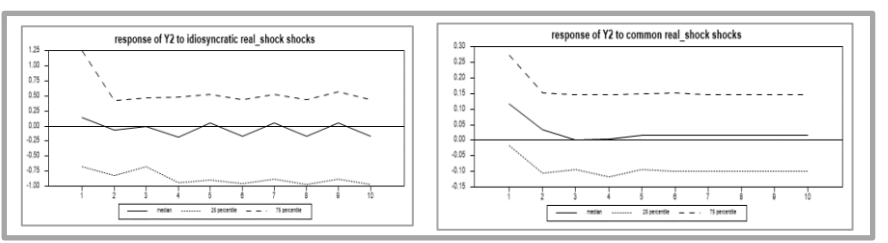
The variation of the growth rate of GDP/head is sensitive to a *ceteris paribus* variation of the perception of the national private sector on the efficiency of the labour market. Indeed, a median variation of 1% in the perception of national entrepreneurs on this policy induces an average variation of 20% of the growth rate of GDP/head.



Source: Our work on Rats, based on WEF and WDI.

Figure 13. Variance decomposition due to a supply shock of a labour efficiency policy.

As for the median variation induced on inclusive growth by a variation of 1% of the world shock of the perception of entrepreneurs relating to this policy, it is 9% in the first year, it increases until the third year to reach 16%, then it decreases progressively to stabilise at 10%. A variation of 1% of a composite shock *ceteris paribus* of the perception of entrepreneurs on the quality of the efficiency of the labour market induces a variation of 17% in the first year, then 21% in the second year and it stabilizes around 16%.



Source: Our work on Rats, based on WEF and WDI.

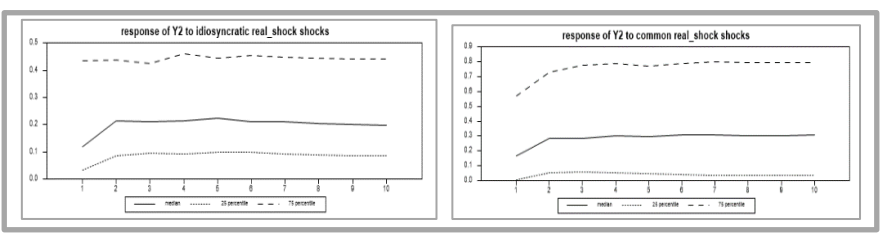
Figure 14. Impulse response function of GDP/head due to a shock to the perceived quality of labour market efficiency.

An idiosyncratic shock, ceteris paribus, to the perception of entrepreneurs on the quality of the efficiency of the labour market induces an increase of at least 125% in the growth rate of the GDP/head of a quarter of the countries in the first year, and then this minimum growth stabilises at 50%. The median response shows that for half of the countries, the evolution of the GDP/head growth rate oscillates around 0, and it is

between 10% and -25%. And for another quarter of countries, this shock induces a negative growth of -70% in the first year, then in the fourth year this value stabilizes around -95%. Regarding the impact of a common shock on this perception of GDP/head, we find that more than half of the countries experience an increase in GDP/head. A quarter of the countries have an initial growth of more than 25%, then from the second year this minimal growth stabilizes at 15% over 9 years.

A Public Policy Shock to the Quality of Financial Market Development

The variation in the growth rate of GDP/head is sensitive to a ceteris paribusvariation in the perception of entrepreneurs on the quality of financial market development.



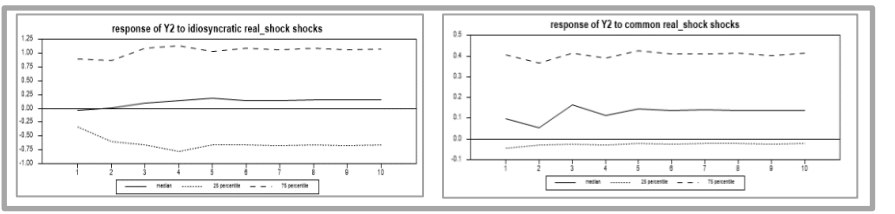
Source: Our work on Rats, based on WEF and WDI.

Figure 15. Variance decomposition due to a supply shock of a policy on the quality of financial market development.

Indeed, a variation of 1% of such a shock induces a variation of the growth rate per capita of 19% the first year, then from the second year it stabilizes at 30%. As for the common shock, a variation of 1% of this shock induces a median variation of the GDP/head growth rate of 11% the first year, then from the second year it reaches its equilibrium path around 20%. Finally, a variation of 1% of a composite shock on the perception of entrepreneurs on the quality of the development of financial markets, leads to a median variation of the growth rate of GDP/head oscillating between 15% and 24% over 10 years.

The median response of the GDP/head growth rate due to an idiosyncratic shock ceteris paribus on the perception of entrepreneurs on the quality of the development of financial markets induces an initially

negative growth, it becomes positive only by the third year and it continues to grow up to 20%.



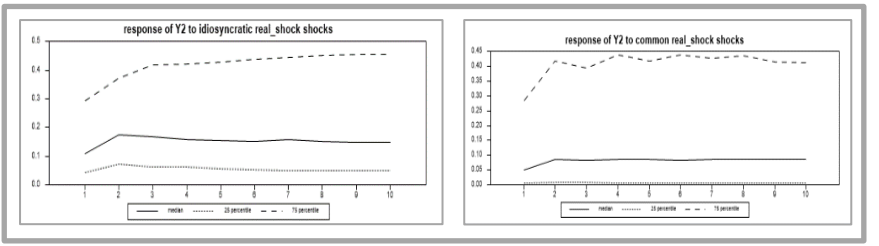
Source: Our work on Rats, based on WEF and WDI.

Figure 16. Impulse response function of GDP/head due to a shock to the perceived quality of financial market development.

A quarter of the countries studied have an inclusive growth rate that follows an upward trend over 10 years. It has an average minimum value of over 100%. For another quarter of countries, we observed a loss of the growth rate of about 27% in the first year, then this increase stabilizes around -70% from the fifth year. As for the impact of a common shock on GDP/head, we observe that a common shock of this policy induces an increase in the initial median growth rate of 10%, then 4 years it stabilizes at 15%. A quarter of countries have an increase of more than 40% and another quarter have a maximum growth value not spending -2%, over 10 years.

A Policy Shock on the Quality of Technological Development (Or Agility)

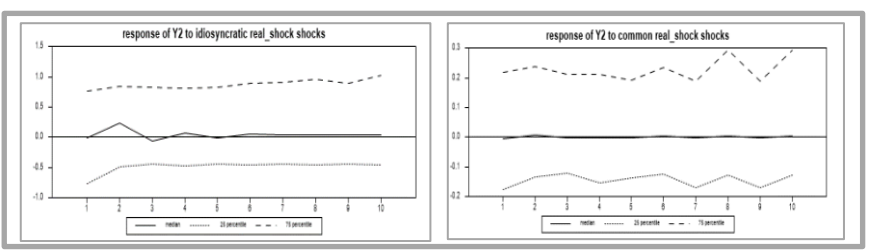
The variation of the GDP/head growth rate is sensitive to a ceteris paribus variation of an idiosyncratic shock of the entrepreneurs' perception of the quality of technological development (or agility). Indeed, the variation of 1% of this shock induces a variation of 11% of the growth of the GDP/head, then we observe a peak at the second year 18%, finally this variation decreases slowly towards 15%.



Source: Our work on Rats, based on WEF and WDI.

Figure 17. Variance decomposition due to a supply shock of a policy on the quality of technological development (or agility).

As for the variation of 1% of a common shock, it leads to a variation of 5% the first year and from the second year it stabilizes at 7%, of the inclusive growth. Finally, the variation of 1% of a composite shock of the perception of entrepreneurs on the quality of technological development (or agility) leads to a variation of 12% in the first year, then from the second year it increases to 18%, to finally decrease over time to 15%.



Source: Our work on Rats, based on WEF and WDI.

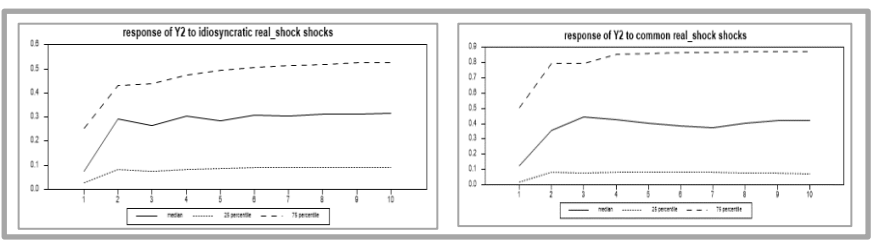
Figure 18. Impulse response function of GDP/head due to a shock to the perception of the quality of technological development (or agility).

The consequences on the growth rate, ceteris paribus, of an idiosyncratic and common shock are described as follows. As far as the median growth rate is concerned, we note that the median country initially has a zero growth rate, then this growth rate reaches its peak at 3% before being gradually cancelled out. As for the growth rate induced by a common shock, it is zero for the median country. As regards the first quartiles, they show us that the increase in the growth rate of a quarter of the countries has a maximum increasing value although negative. While the third

quartile shows us that the increase of the minimal growth rate of a quarter of countries has a positive evolution, higher than 7% for the individual shock and 20% for a common shock.

A Policy Shock on Market Size Measurement

The variation of the growth rate of GDP/head is sensitive to a variation of a common shock of the perception of the entrepreneurs on the measure of the market size. Indeed, a variation of 1% of this shock leads to a variation of 13% of the growth rate of GDP/head in the first year, it increases to reach its maximum value in the third year of 45%, and throughout the rest of the period it oscillates around 40%.



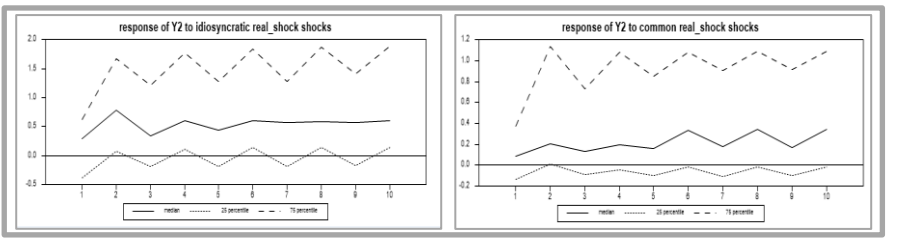
Source: Our work on Rats, based on WEF and WDI.

Figure 19. Variance decomposition due to a supply shock of a market size measurement policy.

A variation of 1% of an idiosyncratic shock induces a median variation of 6% in the first year, it increases over the following four years in a sawtooth fashion to smooth out and have a final value of 34%. Finally, a variation of 1% in a composite shock leads to a median variation in the GDP/head growth rate of 8% in the first year, then from the second year onwards it oscillates around 30%.

An idiosyncratic shock on the perception of the entrepreneurs on the size of the market, induces ceteris paribus a median growth of 3% of the inclusive growth rate, which oscillates around 5% while remaining positive. A quarter of the countries have a minimum value of an increase in the growth of the GDP/head of 6%, then this value oscillates around 15%, while remaining higher than 10%. Another quarter of countries have

a maximum increase in the GDP/head growth rate of around 0, while remaining below 1%.



Source: Our work on Rats, based on WEF and WDI.

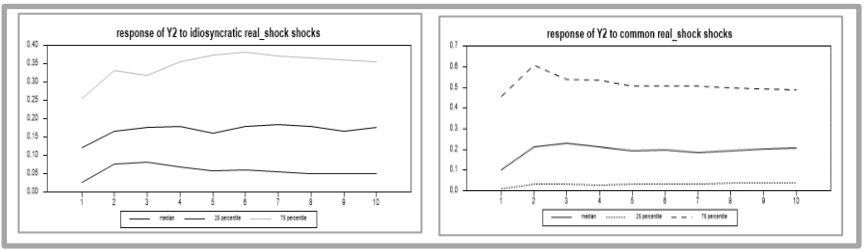
Figure 20. Impulse response function of GDP/head due to a shock to the perceived quality of market size.

A common shock to entrepreneurs' perception of the size of the market creates a median growth rate of GDP/head, which has an upward trend over 10 years with an initial value of 1% and a final value of 3.8%. A quarter of the countries have a minimum contribution of 4% to the growth rate of GDP/head, and then this contribution oscillates around 9.2%. Another quarter has a maximum increase in the GDP/head growth rate of between -1.8% and 0%, fluctuating around -1%.

A Policy Shock on Measuring the Sophistication of Business Activities

The variation of the growth rate of GDP/head is sensitive to a variation of a common shock of the perception of the entrepreneurs on the measure of the sophistication of commercial activities. Indeed, a variation of 1% of this shock induces a median variation of 10% of the GDP/head the first year, then from the second year this variation oscillates around 20%.

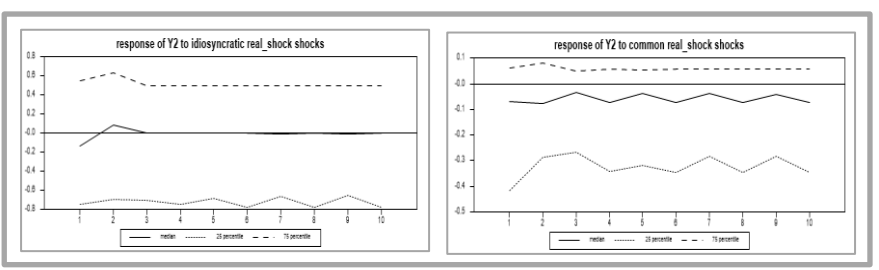
A variation of 1% of an idiosyncratic shock leads to a variation of 12% in the first year, then from the second year it oscillates around 20%. A variation of 1% of a composite shock leads to a median variation of the growth rate of the GDP/head of 13% the first year, from the second year this value oscillates around 17%.



Source: Our work on Rats, based on WEF and WDI.

Figure 21. Variance decomposition due to a supply shock of a policy on the measurement of business sophistication.

The median growth rate of the countries studied induced by an idiosyncratic shock on the perception of entrepreneurs on the measure of business sophistication has an initial negative contribution for a value of -1.6%, then it reaches its maximum value in the second year which is 1.4% before cancelling. A quarter of the countries have a minimum contribution of 5.5% in the first year, this growth peaks in the second year at 6.2% before stabilizing at 5%. Another quarter of countries have a maximum growth of no more than -7%.



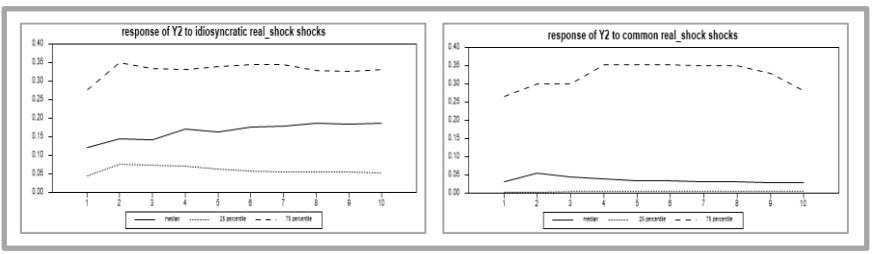
Source: Our work on Rats, based on WEF and WDI.

Figure 22. Impulse response function of GDP/head due to a shock to the perceived quality of business sophistication.

A common shock on this perception induces a decrease in the growth rate for more than half of the countries. More than a quarter of the countries have a decrease in growth rate of less than -3%. While another quarter have a growth rate increase of more than 0.5% on average over 10 years.

A Policy Shock on Innovation Measurement

The change in the growth rate of GDP/head is sensitive to a change in an idiosyncratic shock to entrepreneurs' perceptions of the innovation measure.

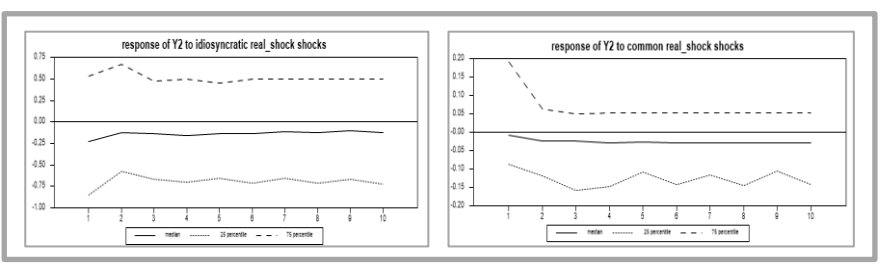


Source: Our work on Rats, based on WEF and WDI.

Figure 23. Variance decomposition due to a supply shock of a policy on the measurement of innovation.

The variation of the GDP/head growth rate is sensitive to a variation of an idiosyncratic shock of the entrepreneurs' perception on the innovation measure. A variation of 1% of an idiosyncratic shock induces a median variation of 12% the first year, then it follows an upward trend to reach a value of 18%.

A variation of 1% of a common shock induces a median variation of 3%, then during the second year it reaches its peak for a value of 5%, finally from the third year it decreases to reach a final value of 3%.



Source: Our work on Rats, based on WEF and WDI.

Figure 24. Impulse response function of GDP/head due to a shock on the perception of innovation quality.

A variation of 1% of a composite shock leads to a median variation of the GDP/head growth rate of 9% in the first year, then from the second year onwards this value oscillates around 13.5%.

An idiosyncratic shock on the perception of entrepreneurs on the measure of innovation induces a decrease in the median inclusive growth rate of -2.5% in the first year before stabilizing around -2%. Nevertheless, for a quarter of the countries, growth increases by 5% in the first year, then reaches a peak in the second year of 7%, to stabilise in the third year at around 5%.

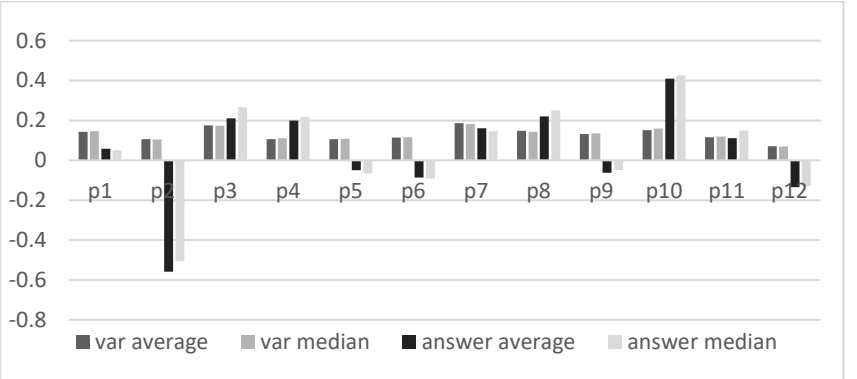
A common shock on this perception shows that more than half of the countries have a decrease in their growth, while for a quarter of the countries the minimum value of the growth rate of the GDP/head is 2% in the first year, then this value stabilizes from the second year at 0.5%.

Second-Level Econometric Analysis

The results of the econometric analysis presented here focus on domestic shocks that can be directly controlled by governments. They are presented by country group. The specific results for each pillar are reported in the annexes.

Specific Cases of Higher Income Countries

The variation that most affects the variability of the inclusive growth rate for higher income countries, all other things being equal, is that of the private sector's perception of public policies relating to the efficiency of the labour market. Indeed, we observe a variation of 17.51% of the growth rate on average. While the variation that affects the variability of the GDP/head growth rate the least in these countries is that of public policy on innovation, with 0.7%.



Source: Our work based on WEF and WDI.

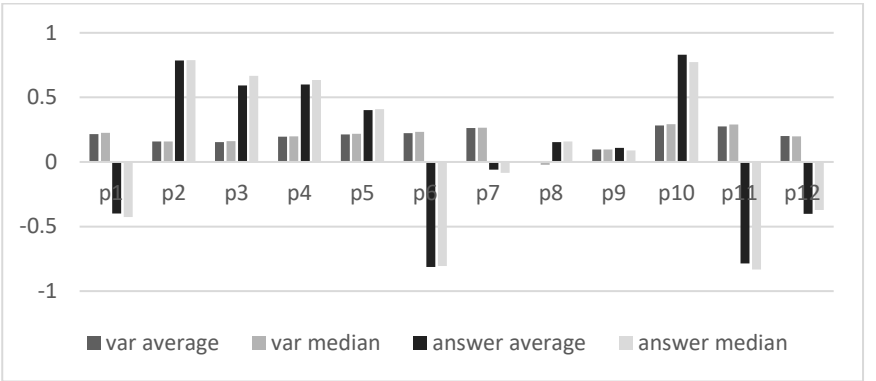
Figure 25. Variation and average response of the growth rate by public policies of upper income countries.

As regards shocks, we observe for this group of countries that a shock on public policies relating to the size of the market affects very positively the growth rate by 41% on average over 10 years. On the other hand, a shock on public policy measures related to the quality of infrastructures affects very negatively the growth rate of the GDP/head on average by -55% over 10 years.

Specific Case of Upper-Middle Income Countries

For upper-middle-income countries, the variation in growth is most affected by variation in private sector perceptions of government policies on labour market efficiency, market size and business sophistication. These variations each induce, *ceteris paribus,* a variation in the growth rate of at least 25% on average over 10 years.

The variations in the perceptions of public policies by the private sector that least affect the growth rate are those relating to the development of financial markets and technological development. Indeed, we observe respective values of -0.6% and 9%.



Source: Our work based on WEF and WDI.

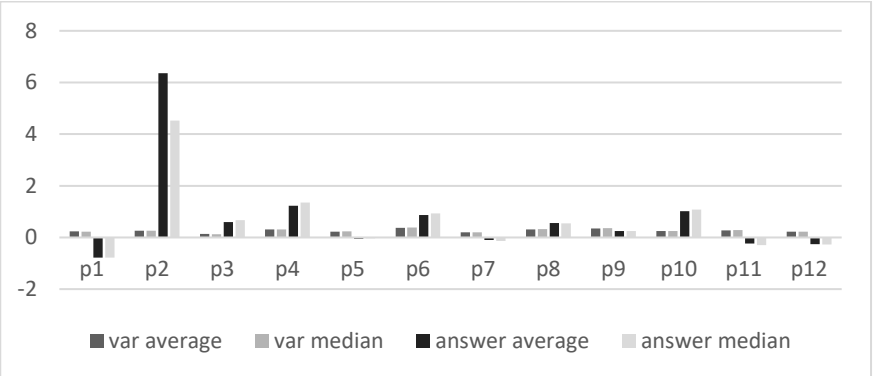
Figure 26. Average variation and response of the growth rate by policy in upper-middle income countries.

The shocks that induce strong growth gains are those related to the private sector's perception of infrastructure quality and market size. Indeed, the increase in the average growth rate on these policies is higher than 75%. Moreover, for this group of countries, the shocks of perception of the private sector negatively affecting the growth rate are related to the efficiency of the product market and the sophistication of commercial activities. The magnitude of these shocks reduces, *ceteris paribus*, the growth rate by 80% on average in these countries.

Specific case of lower-middle income countries

For lower middle-income countries, we note that the variation in the growth rate is sensitive to a change, *ceteris paribus, in the* private sector's perception of public policies relating to product market efficiency. Indeed, we observe a variation of 36% on average of this quantity, over 10 years.

On the other hand, the variation in the private sector's perception of public policies relating to the improvement of the macroeconomic environment affects the variation in the growth rate the least. The average variation observed is less than 15%.



Source: Our work based on WEF and WDI.

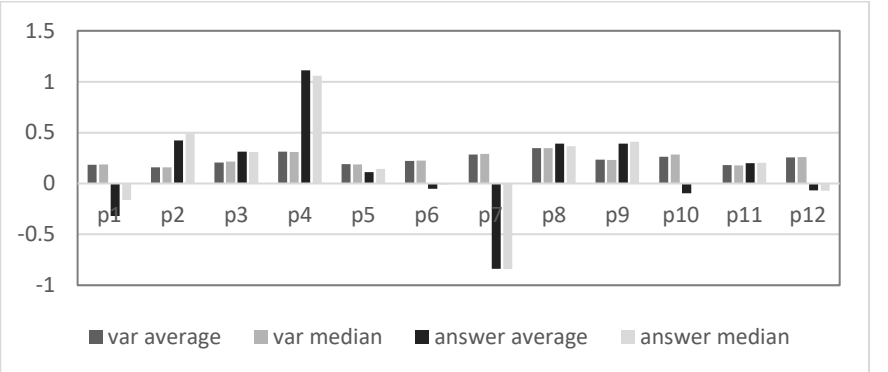
Figure 27: Average change and response in the growth rate by policy in lower-middle income countries.

Looking at the shocks, we find that those that positively affect the growth rate are related to the opinion of business leaders on the quality of infrastructure, health and primary education, and market size. The good opinion of the private sector on these different public policy results in an average increase per year of the growth rate of 100%. In fact, the growth rate responses to these shocks induce economic increases in the order of 635% on average, 122% and 102% respectively.

On the other hand, of the shocks to the perception of the private sector in this group of countries that negatively affect the growth rate, the one relating to the quality of institutions affects it very negatively. Indeed, the results give us a depreciation of the growth rate of about -77.5%.

Specific Case of Low-Income Countries

For low-income countries, the variation in growth is very sensitive to a change in the private sector's perception of public policies relating to the financial market and to health and education. Indeed, they induce respective variations in the growth rate of 35% and 34%. On the other hand, the private sector's perception of public policies relating to infrastructure and higher education - vocational training has a very low impact on the growth rate.



Source: Our work based on WEF and WDI.

Figure 28: Variation and average response of growth rate by public policies in low-income countries.

In examining the shocks, we note that the opinions of the private sector on the quality of health-primary education and the quality of infrastructure affect the growth rate the most and positively at levels of 111% and 42% respectively. On the other hand, the opinions of the private sector on the efficiency of the labour market and the quality of institutions affect the growth rate very negatively with magnitudes of -84% and -32% respectively.

CONCLUSION

In light of the above analysis, it is clear that the private sector's perception of public policies that can lead to improvements in both the design and implementation of public policies to boost economic performance is far from self-evident.

The results obtained through statistical analysis lead us to say that there is an evolution in the average opinion of the private sector regarding the quality of technological development (or agility). In addition, except for the group of middle-income countries, policies in favour of infrastructure quality have a favourable opinion, which is growing and at a rate exceeding 1%. The results obtained in the econometric part allow us to say that the

perception of entrepreneurs on public policies has diverse effects on the growth rate of GDP/head by category of countries.

For upper-income countries, the policy shocks that affect the growth rate the most are related to market size, which affects it positively, and infrastructure quality, which affects it negatively. For upper-middle-income countries, the policy shocks that affect the growth rate the most are related to infrastructure quality, which affects it positively, and product market efficiency, which affects it negatively. Lower middle-income countries have their growth rates affected mainly and positively by a shock to infrastructure quality. While a shock to institutional quality affects the growth rate most negatively. Finally, the growth of low-income countries is mainly affected by a shock on the quality of health and primary education which improve the growth rate and a shock on the efficiency of the labour market which induces a decrease.

The disparities observed in the shocks to the private sector's perception of public policies reflect the public policy levers on which the emphasis should be placed to ensure economic performance. For each group of countries, actions should focus on shocks that induce a deterioration of the growth rate. This is because it reflects the ineffectiveness of the public policy implemented and could explain why global growth has been declining in intensity for some decades.

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Chapter 2

AGRICULTURAL SLUDGE UTILIZATION IN BULGARIAN CIRCULAR ECONOMY

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ABSTRACT

The issue of utilization of sludge from wastewater treatment in agriculture is an important socio-economic and environmental problem in the European Union and Bulgaria. It is becoming topical issue along with the growing interests into effective "transformation of wastes into products" and their inclusion in supply chains and circular economy. Despite their relevance, in-depth studies of the diverse effects and critical factors of sludge utilization in Bulgarian agri-food chain are at an early stage. The purpose of this article is to identify and assess the significance of the various factors influencing the effective utilization of sludge from wastewater treatment in Bulgarian agriculture. Based on a qualitative analysis of regulations and institutional structure, and surveys with managers and experts of urban wastewater treatment plants, and farmers using and not-using sludge, the institutional, political, organizational, personal, educational, informational, social, economic, and environmental factors influencing the utilization of sludge in agriculture

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in two regions of the country (Sofia and Burgas) are identified. Impact factors are generally divided into two types: factors influencing the behavior of agents, and factors determining the type and extent of the effects of sludge use in agriculture. Research of this type is to continue and deepen to establish the economic, sectoral and regional specificities on the basis of more representative information from all participants and interested parties in the effective utilization of sludge in the country.

Keywords: sludge, use, agriculture, factors, efficiency, Bulgaria

INTRODUCTION

The issue of utilization of sludge from wastewater treatment is an important socio-economic and environmental problem in Bulgaria and the European Union (EC, 2021). The total amount of the European production of sludge is 8.7 Million tonnes DS/y (EurEau, 2021). Its significance of the issue in Bulgaria is determined by the fact that the amount of sludge formed in the country is constantly growing, and reaches 53 thousand tons of dry matter in 2018 (ИАОС, 2019). At the same time, according to the national goals by the end of 2020 as much as 65% of the sludge from Municipal Wastewater Treatment Plants is be recycled and materially utilized, and the remaining 35% of them is to be energetically utilized (НСПУУ, 2014).

One of the main ways to utilize sludge from wastewater treatment in its use as fertilizer in agriculture (Маринова, 2008; Usman et al., 2012). Sludge use in general, and in agriculture in particular, is not an automatic but a complex process that depends on many institutional, production, economic, psychological, social, environmental, etc. factors. As a result of the specific combination of the critical factors in the individual countries of the European Union, there is a great diversity in the degree of sludge ute in agriculture - from almost zero in Malta, Slovenia and Slovakia to 80% in Ireland (EU, 2016). Currently, agricultural destination or use of sludge in Europe accounts for 47% of the total or 4.1 Mt DS/y (EurEau, 2021). Our study found that a small proportion of Bulgarian farms utilize sludge on their farms (Башев et al., 2021; Bachev, 2007, 2012).

Arround the globe, there are numerous studies on the factors and efficiency of sludge use in agriculture (Barbu, 2012; Daniels, 2011; Iticescu et al., 2021; EC, 2008; 2021; Ekane et al., 2021; Hudcová et al., 2019; Rosiek, 2020; Rosemarin et al., 2020; Scozzari and Mansouri, 2011; Taşeli, 2020; Tesfamariam et al., 2020; Usman et al., 2012). Interest in this area is growing even more in connection with the new challenges related to environmental pollution, climate change, protection of human and animal health, the current COVID pandemic and others. Strict regulation and standards for sludge use have been introduced in most countries and the European Union, including in agricultural sector. Many countries (such as Germany, the Czech Republic, Hungary, France, etc.) have introduced greater restrictions than the EU minimum, and some countries (such as Switzerland, certain US states, etc.) have even banned the use in agriculture (Hudcová et al., 2019). Recent concerns about coronavirus have led some countries (such as France) to introduce mandatory disinfection of sludge before use in agriculture (ANSES, 2020).

In Bulgaria, regardless of their relevance, in-depth studies of the diverse effects and critical factors of sludge utilization in agriculture are a new phenomenon, single, unilateral (mainly bio-chemical and agronomic use) and at an early stage (Иванов et al., 2021; ИАИ, 2021; Маринова, 2008; Сяров, 2020; Ivanov and Bachev, 2021). The goal of this article is to fill the existing gap, and to identify and assess the significance of the various factors affecting the effective utilization of sludge from wastewater treatment in Bulgarian agriculture.

Impact factors can generally be divided into two types: factors influencing (motivating and demotivating) the behavior of agents, and factors determining the type and size (formation technology) of the effects of sludge use in agriculture. If the system of incentives of the various agents involved in the process is not properly formed ("managed"), the potential positive socio-economic effect of the use of sludge in agriculture will not be realized (Bachev, 2009, 2013, 2015, 2018). Therefore, the specific interests and incentives of the main participants in the process (striving for maximum positive and minimum negative economic effects) should be analyzed and the extent to which the existing governance system

contributes to the public interest (maximum positive and minimum negative public effects) should be assessed. In the specific conditions of each region, farm, etc. impact factors have different significance, and in many cases are interconnected or subordinate (Bachev and Terziev. 2018). The later requires the use of multifactorial and comparative structural analysis to correctly identify the factors and establish their significance, relationships, subordination, dynamics over time, etc.

This study is based on a qualitative analysis of the specific regulations and institutional structure related to the utilization of sludge in agriculture. It also uses the results of surveys conducted during 2020-21 with managers and experts of Municipal Wastewater Treatment Plants (WTPs) in Sofia and Burgas region, and with agricultural producers recovering and not using sludge from the two regions of the country[1].

Nearly half of the total amount of sludge in the country is produced in the studied two regions (Table 1). According to the 2018 official information in agriculture about 56% of the total sludge formed in Bulgaria are utilized (*И*АОС, 2019). In recent years, the sludge of "Sofiyska Voda" AD[2] has been mainly applied in agriculture, where all of the sludge formed by this treatment plant for 2018 is utilized. The Sofia region also utilizes the largest share of sludge used in the country's agriculture - 43.4% of the total. The sludge in this area has been utilized on 2169,7 ha of arable land as in 2018. A total of 38,440 tDS have been distributed, including quantities of temporarily stored sludge from 2017 (*И*АОС, 2019).

Table 1. Ammount and share of the produced sludge on the territories of Regional Environment and Waters Inspections (REWI) in Sofia and Burgas, 2018

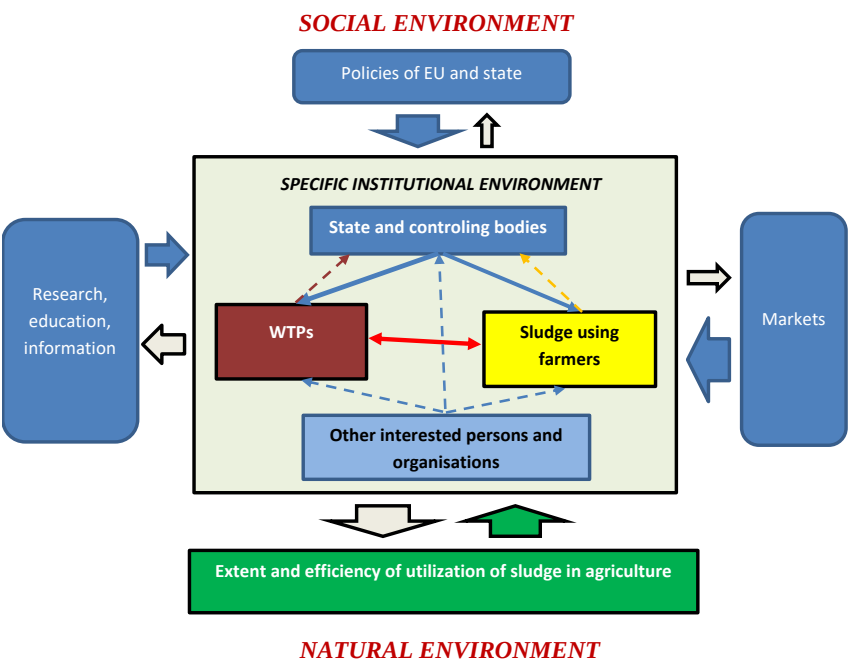
REWI	Ammount, tors of dry sludge	Share in total, %
Sofia	23101	43,52
Burgas	3319,94	6,25
Bulgaria	53082,62	100

Source: *И*АОС.

[1] The authors are grateful to all participants for their cooperation and provided information.
[2] It is a part of French company VEOLIA.

POLITICAL, INSTITUTIONAL AND MARKET FACTORS

In order to identify and assess institutional factors, the specific institutional environment ("rules of the game") and structures (agents and relationships between them) related to sludge utilization in agriculture are to be analyzed (Figure 1). Account should also be taken of the development of important factors of the external social, market and natural environment that influence the management of the process of agricultural use of sludge - EU and state policies, the development of the research system, education, and information, evolution of markets and demand, etc. Depending on the efficiency of the management system (institutions, market, private, public and hybrid forms) there will be different degree and efficiency of sludge utilization in agriculture (Bachev, 2007, 2018).



Source: Authors.

Figure 1. Institutional environment and structure of sludge utilization in Bulgarian agriculture.

Table 2. Institutional, personal and educational factors for sludge utilization in Bulgarian agriculture

Type	Positive	Negative
Politically and institutional	Long - term policy on safe sludge use in the EU Modern legislation with clear procedures and standards Long-term state and regional strategies Restrictions on utilization on agricultural land Mandatory standards for the protection of soil, water, air, biodiversity, and human and animal health	Need for a special management system Long and complicated licensing procedures Possibility for impunity for violation of procedures and standards Possibility for development of dependancy and corruption Imperfect contracting (additional coordination costs, little possibility for enforcment) Restriction of users (sole traders and legal entities) Restrictive goals and uncertainty related to the EU Green Deal
Personal and organizational	Vision and proactive strategy of WTP Logistical and material support from WTP Innovation Entrepreneurship of the farmer Qualification and experience of the farmer Size of the holding Good and long-term relations between WTP and using farmers	Passive strategy of WTP Tendency not to take risks High costs for proper treatment, storage and delivery Need for precise organization and management of production Difficulty to introduce in non-innovative and risk-averse farmers Difficulty to introduce in cooperative farms with numerous members Practice of one-year rent contract for supply of agricultural lands

Table 2. (Continued)

Type	Positive	Negative
	High efficiency of self-learning and learning by doing of good managers High bilateral dependency between WTP and sludge using farms	Standard contracts for supply of sludge from WTP
Information and educational	Up-to-date, comprehensive, reliable and accessible information Independent evaluations and information "Fast" training by doing of good managers Provision of information and advice by the WTP Close distance between user farms and WTP	Lack of sufficient scientific literature on the technology of growing crops with sludge Lack of special training Lack of a system for special consultation and advice Need for additional information, training, consulting and exchange of experience of farmers Reluctance to share positive experiences High asymmetry between WTP and farmers, and with control bodies

Source: interview with WTP managers and farmers.

The specific institutional environment includes the various legislative and regulatory provisions and the system for their enforcements, which regulate the rights, methods, processes, and control of sludge utilization in agriculture. This analysis should also include the informal rules of the game, predetermined by the ideology of conservation farmers, interest groups and consumers, which occupy a growing place in the system of governance of society and agriculture.

One of the most important factors for the effective utilization of sludge in agriculture is the existence of modern legislation and regulations (Table 2). It is to define the rights and obligations of the various agents involved in the process (regulatory and control bodies, WTPs, farmers, etc.), standards for sludge quality and safety, soil fertility and human and animal

health, norms and restrictions of application, etc. The institutional set-up also includes various state policies, programs, plans, and incentive instruments for achieving certain social goals regarding the utilization of sludge in agriculture and other sectors of production.

Well-defined "rules of the game" and adequate government intervention will create conditions for inducing effective behavior of key agents and effective (and not only) use of sludge in agriculture (maximizing the positive effects and minimizing the negative effects). Conversely, in the case of inefficient regulation (for example, complex procedures and high costs of obtaining permits for use from farms), there will be no sufficient interest in participating in the process.

In the European Union there are strict regulations for the utilization of sludge in agriculture established by the European Union Directive of 1986 (Директива 86/278/ЕИО) and other documents on the protection of the environment and human health. The EU directive encourages the use of sludge in agriculture only if it is used in areas where it does not have a negative impact on soil and agricultural products. The main requirements in the Directive are limited to compliance with limits related to the content of heavy metals and nutrients in sludge and soil, as well as limits on the annual load of agricultural land with sludge. It is also mandatory to treat the sludge before using it for fertilization.

The requirements of the European Directive are also introduced in the national legislation in the Ordinance on the procedure and manner of utilization of sludges from wastewater treatment through their use in agriculture (adopted by с ПМС № 201 of 04.08.2016). It determines the order and the manner of utilization of the sludge from treatment plants and wastewater treatment facilities through their use in agriculture; the requirements that sludge must meet in order to ensure that it does not have a detrimental effect on human health and the environment, including the soil; and the procedure for reporting the used sludge. According to the regulation, "sludge users" can only be sole traders and legal entities. The ordinance does not allow the utilization of sludge on: meadows, pastures or areas sown with fodder crops, when used for grazing or the fodder is harvested in a period shorter than 45 days after the use of the sludge; soils

on which fruits and vegetables are grown, with the exception of fruit trees and vineyards; soils intended for the cultivation of fruit, vegetables and other crops which are in direct contact with the soil and are consumed in the raw state, for a period of 10 months before and during the harvest; coastal floodplains, riverbeds and protective dikes; zone I and zone II of sanitary protection zones of water sources and facilities for drinking and domestic water supply and around water sources of mineral waters used for medical, prophylactic, drinking and hygienic needs; and in agricultural land in protected areas.

The utilization of sludge in agriculture is allowed on the basis of a permit. For the issuance of a permit, sludge users provide to the Bulgarian Food Safety Agency (BFSA) information and results of analyzes of the soil from the places where the sludge will be used, of the soil characteristics: soil type, bulk density, soil particle size distribution, and total soil porosity. The sampling and their subsequent testing is performed by accredited laboratories according to certain indicators. Soil testing is mandatory before the initial use of sludge, and after their use - every 5 years. The permit contains: the quantities of sludge meeting the MDK for heavy metals in the sludge, expressed in tonnes of dry matter, which may be imported annually into the soil per unit area; the location and size of the landplots on which the sludge will be used. The permit is issued for a single application of a certain amount of sludge for a specific plot.

The bodies related to the implementation of an ordinance and control of its implementation are a key element of the institutional structure. The control over the application of the ordinance is assigned to the Minister of Agriculture, Food and Forestry, to the Minister of Environment and Water and to the Minister of Health in accordance with their competencies. In fact, these functions are performed by the specialized agencies of these ministries, whose functions are described in detail in the regulatory documents.

Regulatory requirements for the management of sewage sludge are also contained in other official documents, most of which are related to the legislation on waste and water management. It can be concluded that in Bulgaria there is a modern legislative and regulatory framework for safe

use of sludge in agriculture, which is based on modern European standards. The ordinance regulates and restricts the use (permits for doses and plots) and users (sole traders and legal entities) of sludges from wastewater treatment in agriculture.

It is to be taken into account that the institutional requirements and restrictions, and the standards for quality and safety of food and feed, protection of the natural environment and biodiversity, animal welfare, etc. in the EU and Bulgaria are constantly evolving and "tightened." This modernization also affects the monitoring and control system and is closely linked to the support of farmers with CAP instruments (cross compliance, eco-payments, eco-contracts, overall "greening," etc.). For example, the newly adopted by the European Union in 2019 Green Deal sets ambitious goals in terms of reducing greenhouse gases, using mineral fertilizers and pesticides, and increasing the area with organic production by 2030 (The European Green Deal, 2019). Discussions are still ongoing in the EU countries and in the Union's governing bodies, and procedures are being developed to achieve these goals through the CAP instruments, the Strategic Development Plans until 2030, and other policies and mechanisms. In this regard, there is considerable lack of precision and "institutional uncertainty" on many issues related to the achievement of European goals, and in particular how the reduction will be distributed among the individual EU member states, production sub-sectors, agricultural and agri-environmental regions and types of farmers, whether the total reduction will include and how the use of manure and sludge, etc. The degree of use of sludge in agriculture in the coming years will largely depend on the solution of all these issues.

Another factor is the possibility and the degree of implementation and control of the procedures, standards and restrictions for the use of sludge in agriculture by the competent state authorities. In the years of the country's membership in the EU, there are many examples of incomplete and "Bulgarian way" implementation of the common policies of the union. Moreover, there is no long-term and widespread experience in the use of sludge in agriculture in the country and almost all agents are outside or at the beginning of the "knowledge curve." The later leads to unintentional

errors in the implementation and/or search for "effective" practical solutions outside the regulatory framework, etc. Finally, many of the eco-activities and eco-standards in agriculture are difficult to effectively control by enforcing authorities due to high cost or practical impossibility (Bachev, 2011, 2014, 2017). This is related to the well-known "mass" non-compliance with certain official eco-standards and norms, etc.

Agents involved in the management of sludge ruse in agriculture are regulatory and controlling (state, regional, etc.) authorities, WTPs, sludge using farmers, other farmers and agents (landowners, traders, processors, etc.), population and business in the area, end users, interest groups, etc. An important component of the analysis of institutional factors is the interests and incentives of the participating agents and the nature of their relationship.

The state regulatory and controlling bodies are the main agent in the system. They apply the provisions of the legislator and the policies pursued by the government. One can only assume that (like other state structures) mistakes are likely to be made due to lack of experience in this "new" area, poor governance, and incompetence of employees. In addition, corruption is possible, as is the practice in all cases of licensing, control of certain practices and standards, etc. The same applies to some of the accredited laboratories, whose activity is not always in accordance with the regulations (imprecise tests, purchase and falsification of results, etc.).

In addition to the regulatory and controlling bodies, the main agents of the system are WTPs and sludge using farmers. The relations of WTPs and sludge utilization farms with the state authorities are of "unilateral" dependency. Applying for permits is voluntary, but permits are given, and this involves procedures, time, labpr costs, payments for tests, etc. In addition to permits, other parameters of the process are determined (restricted) – technology of application, mandatory standards, time periods, etc. However, the control over the implementation of the regulations is divided between many structures, which complicates the coordination between them and creates difficulties for the other participants. At the same time, there is a situation of few players, and the agents "know" each other well, which should facilitate the relationship in

the interest of "overall" efficiency. This situation often contributes to the easy development of "personal ties" and "coalitions" that are detrimental to the effective implementation of the legislation. A major problem identified by the present study is the slow issuance of new permits by public authorities.

The high asymmetry of the information between the interested agents (the state, WTP, farmers, consumers, etc.) provides a great opportunity and creates incentives for non-compliance (violation) of the requirements of the regulations, both by WTPs and by farmers using sludge. For example, it is practically possible that there are cases when incompletely treated sludge is provided to farmers by WTPs and imported into agricultural lands, that sludge per unit area is applied higher than the allowed norms, that sludge is also applied to unauthorized agricultural plots, and that sludge is applied in the not indicated manner (with simultaneous burying), etc. All this is associated with a number of risks and actual negative effects in terms of cleanliness of roads, soil, water and air, the health of farm workers, consumers of products, etc.

The contradictions and conflicts of the interested agents (and the individual, economic and social effects) in the process require the development of a special system for management and control of sludge utilization in general and in agriculture in particular. This is associated with additional costs for individual agents and society as a whole (taxpayers) - for maintaining government agencies, for studying and complying with regulations, for soil testing, for obtaining permits, for relationships with government institutions, etc.

The introduction of a system of permits and control is also associated with the development of "dependency relationships," as well as the possibility of unregulated payments (and corruption) for fast and/or illegal obtaining of permits, for reduced or inefficient control of the implementation of legal norms and restrictions, and as a result of insufficient or inefficient utilization of sludge in agriculture. The degree of actual non-compliance with regulatory constraints is difficult to assess, as the agents involved are not interested in sharing this type of information

and it is impossible to accurately "measure" this type of effect from third parties (researchers, etc.).

The relationship between the WTP and the beneficiary farmers is contractual, based on one-year or multi-annual agreements. Like all contracts, the parties are free to specify the terms of the exchange and terminate their relationship in the absence of benefit. Moreover, in most cases the relations between the WTP and the utilizing farmers are of "bilateral" (symmetrical) dependency - capacity, location, time of supply, etc. It is determined by the fact that the agricultural utilization of sludge in the country is in the initial stages, and with a consistent strategy in this regard the assets of the WTP for treatment and the obtained "product" are in partial or complete high bilateral dependency with the assets (agricultural land with permits obtained) of the sludge using holdings. The degree of this dependency is determined by the amount of sludge for "agricultural" use, and the (limited) number of permits for sludge use in the plots of certain farmers. Long-term relationships between the same partners with symmetrical asset dependencies help to get to know each other well, develop trust, seek cooperation, limit opportunism, share information, and develop mechanisms for coordinating and resolving conflicts, and minimizing transaction costs. This further facilitates the relationship, reduces the associated costs, and increases the efficiency of sludge utilization in agriculture. In this regard, it is important to establish how the WTP selects the particular farmers with whom the sludge is experimented with or widely-utilized, especially when there is a "deficit" of valuable sludge resources in a given area.

Other interested parties (landowners, neighboring farms and businesses, the population in the area, interest groups, consumers, etc.) are also involved in a "relationship" with the WTP, sludge-using farmers and public authorities. However, individual agents do not have the "power" to change dominant practices due to the small size of the (negative) effect on them, the high individual costs and opportunities for "free riding" (one invests costs and everyone benefits if successful), the difficulty of common "collective actions" of agents with divergent interests, power positions and "dependency" by large (sludge-using) producers in the region, etc. Only

when the effect is highly negative and direct (for example, a strong odor when delivering and spreading sludge) the strong collective actions of the population in the area are possible and often lead to the cessation of sludge supply for short periods of time.

The efficiency and incentives for the application of sludge instead of mineral fertilizers will depend strongly (in direct proportion) on the price dynamics of mineral fertilizers of different types (mainly N and P, whose substitute is sludge). In addition, interest in the use of sludge may increase with mandatory or voluntary (for getting public subsidies) restrictions on the use of mineral fertilizers in certain areas, sub-sectors or types of farms in the EU.

There is a psychological barrier, due to the "special nature" of this fertilizer, both in the farmers themselves and in the landowners and the residents of the area, for the negative effects of the use of sludge in agricultural land. These informal "rules of the game" and how they affect each of the stakeholders are to be analyzed. In other EU countries, for example, in areas with highly developed livestock and mass application of manure, there is a higher tolerance for the application of sludge in agriculture, both by farmers and the general population.

The market and buyers are also not yet "open" to the widespread use of sludge in agriculture. Many wholesale buyers and end users question the safety of products procuced with sludge use. This is often associated with lower sales prices of farm products and high marketing costs. Last but not least, farmers and other stakeholders themselves are concerned about the long-term effects of sludge use on the environment - cleanliness and quality of soils and waters, trampling of agricultural land, protection of natural biodiversity, maintaining the ecological sustainability of farms, etc.

The specific institutional structure and the participating agents, in turn, can and do participate in the modernization of national and European policies. However, the repercussions of these elements are severely limited because the "political process" is slow, with different priorities, and not always in the interests of overall efficiency. The same applies to the direct impact of these agents on the development of product and resource markets (fertilizers, agricultural land, etc.) and the natural environment due to lack

of complete information, complexity, high uncertainty, and the need for expensive and long-term collective actions on a huge scale and scope.

The main agents involved in the management of the process of sludge use in agriculture are WTPs and farmers. In principle, all WTPs should have an interest and developed strategies for effective management, and at the present stage for effective utilization of sludge. It can be assumed that to achieve economies of scale and scale (for both WTPs and farmers), certain optimal amounts of sludge produced will be needed to invest in modern equipment for effective treatment, as well as certain minimum sizes of land plots and farms in order to make efficient transportation and import of fertilizers with specialized equipment.

The individual WTPs in the country to varying degrees implement effective strategies for sludge utilization in general, and in agriculture in particular. For example, the Management of "Sofiyska Voda" AD has a clear vision and takes comprehensive measures for the utilization of sludge in agriculture. The quantities of sludge are significant, which makes technologically modern and economically advantageous treatment possible. For years, good relations have been maintained with large farmers in areas where sludge is provided free of charge. The company's experts are also involved in aquiring permits for sludge utilization for the respective land plots in the area. In addition, the company provides transportation and spreading of sludge. In this way, the company creates favorable conditions for the utilization of sludge produced in WTP and strong incentives for farmers to use sludge on farms. In order to minimize the transaction and other costs for relations with state bodies and farmers, it works with a limited number of large agricultural producers in the region.

This company also works closely with research institutes to explore ways to increase the efficiency of the sludge process. Media appearances are also made to inform the public and promote the utilization of sludge among the agricultural producers. The company's long-term strategy is to commercialize the "produced" sludge and sell it on the fertilizer market to offset the significant costs of treatment and storage. Therefore, the experience so far is a kind of experimentation and demonstration of the socio-economic efficiency of agricultural sludge use in the long-term profit

strategy for the company. However, it is not known how the "increase in the price" of sludge will change the incentives of farmers for their economic utilization. In the absence of additional incentives (e.g., public subsidies, personal comviction, etc.), any increase in costs (prices) for farms will lead to a reduction in economic effects and incentives for agricultural use of sludge.

After the study of WTPs in the region of Burgas, it was found that the utilization of sludge is still a challenge for most of them. In some places, a much broader information campaign is needed among farmers. At this stage, there are reservations of some managers of treatment plants and farmers to use the disposed sludge in agriculture, mainly related to the proximity of the area to the sea-coast and developed tourism. Some WTPs do not yet have complete equipment for effective sludge treatment, while others do not have sufficient quantities for possible treatment and extensive use. In the past, a large agricultural producer in the region applied sewage sludge (102 ha with coriander, rapeseed, etc.), but gave up due to the complicated monitoring for soil and sludge testing. Currently, there is also interest from a farmer, who is pay for drilling and testing soil samples, transporting the sludge, and spraying and mixing the sludge with the soil.

Our study found out that for different WTPs there is a different comparative efficiency of agricultural sludge utilization depending on the volume of sludge, available landfills, existing treatment facilities and equipment, and the level of costs for effective treatment, state and public pressure and tolerance, the possibilities for alternative use, etc. With relatively low economic efficiency for agricultural use, WTPs do not have strong incentives and strategies for the development of this process, and state intervention will be required - support, financing, information, etc.

Farmers, on the other hand, have an economic interest in using innovations like sludge to fertilize the soil in order to increase production efficiency. The use of sludge can also have positive agronomic, production, ecological and other effects (improvement of the structure, aeration and moisture retention of the soil, reduction of erosion, faster germination and vegetation development of the plant, higher quality of

production, etc.) which further stimulate economic use. Therefore, the attitudes and capabilities of different types of farmers regarding the application of the innovation "fertilizer sludge" is to be be studied.

In addition, it can be assumed that a certain minimum size of land plots and farms is necessary not only to achieve economies of scale and scale in the transportation and application of fertilizers with specialized equipment, but also to justify the additional costs of training, information, experimenting, taking on possible losses, relationships with organizations, etc. Some specialization is also likely to be required for the efficient use of sludge to produce one or two of the permitted crops.

PERSONAL, EDUCATIONAL AND INFORMATIONAL FACTORS

A very important factor for the efficient utilization of sludge in agriculture are the personal characteristicts of farm managers (Table 2). All of the long-term sludge using farmers are good entrepreneurs and managers, with a high innovative spirit and qualification, and a tendency to seek solutions, experiment and take risks to increase profits. They have "discovered" great economic potential in the use of sludge as fertilizers, assume a certain production and financial risk and losses, invest in new knowledge, adapt technology and organization of production, develop relations with WTP, etc. for its realization. Like any innovation, "fertilizer sludge utilization" is associated with a certain economic risk and the need for non-standard management decisions, and entrepreneurial (risk-taking) farmers are not many in this regard.

Another important factor for increasing the utilization of sludge in agriculture is the availability of comprehensive, up-to-date and reliable information on the opportunities, ways, conditions, effects, challenges and risks associated with sludge utilization in agriculture. Adequate regulatory, scientific, experimental and practical information is important not only for farmers, but also for all other participants in this process - government

agencies and employees, WTPs, farmers, stakeholders, end users and the general public.

Our study found that such information in Bulgarian (only accesible to most agents) and the specific conditions of the country and its individual regions is very scarce and often contradictory. Very few publications are widely available, mostly in academic publications little read by farmers, businesses, the general public, etc., which are mainly based on experimental and laboratory experiments, most often presented in a foreign language. For example, a Google search can find a small number of publications in recent years by a limited number of authors. Occasional information may appear in the media, mainly about regulatory documents or publications induced by interested parties.

Moreover, there are virtually no comprehensive assessments of the actual socio-economic and complementary effects of sludge use on farms of different types, specializations and locations. In addition, the results of published scientific, experimental and laboratory tests and trials are based on ideal conditions (optimal farming techniques, correct fertilization rates, good management, etc.), which differs significantly from the actual practice of farms. For example, experiments are made with perfectly treated sludge, while in practice the sludge is often delivered and imported in a different state from the regulatory requirements - not treated or partially treated, with high humidity, etc.

The study found that many farmers are partially aware of the possibility of sludge urilization, but there is a strong lack of information on the necessary conditions, potential effects, risks, costs, etc. The lack of adequate information on these issues also has a negative impact on the attitudes of the population, producers in the area, and intermediates and end buyers of the product. The information deficit is most often “filled” with false information about the possible effects of agricultural use, and resistance from both farmers and other stakeholders.

In some scientific institutes of Agricultural Academy and other institutions there have been a long-term research on the chemical, biological and agronomic effects of the use of sludge in agriculture. However, the volume and nature of these studies do not correspond to the

modern needs of farmers and society. There are no interdisciplinary studies on this important issue. There is a lack of independent tests and demonstrations, and promotion of practical utilization of sludge in experimental or economic conditions, and specific guidelines for optimal application in farms with different specialization, size, ecological and geographical location, etc.

The utilization of sludge in agriculture is a complex and dynamic process that requires long-term specialized training and consultation of farmers. Our research found that there is no specialized training and consulting in the country dedicated to the utilization of sludge in agriculture. For example, in the Agrarian and related universities, Agricultural Academy and National Agicultural Adviroy Service there are no highly qualified experts for long-term training and consulting of interested farmers. Some farmers also state that they "do not trust the local institutes" and therefore do not seek their services. All this makes it very difficult to make an effective transition to sludge utilization in agriculture.

Some farmers who use sludge in agriculture conduct their own experiments, find their own solutions and/or seek and find the necessary information and training, including from abroad. Some of them consult each other, exchanging experience and useful information, or seek external advice from private consultants, WTP experts, researchers, etc. At the same time, depending on personal characteristics (managerial experience, qualifications, innovation, etc.), self-training or "learning by doing experience" requires different time and gives different results for individual farmers, and in some cases can lead to incorrect or inefficient use of sludge, and not infrequently to the cessation of sludge use on farms.

However, our study found that most sludge using farmers are reluctant to share their experiences for a variety of reasons - lack of time, reluctance to publicize, firm secrets about yields and profits from competitors, etc. An important reason for this is that they do not want to increase the interest of new farmers in the use of sludge, as this will increase demand in the area, increase the "price" and reduce "profitable" access to the limited resource

"sludge." This further slows down the spread of this new practice in the country.

PRODUCTION, SOCIO-ECONOMIC AND ENVIRONMENTAL FACTORS

The main incentives for the use of sludge by farmers are the production and economic benefits (Table 3). Our study found that all users of sludge are large producers who have a strong interest in minimizing the cost of fertilization and have the capacity to bear the additional costs of "external" relations with WTPs and government agencies, experimentation, training, reorganization of the production process and management, risk-taking and possible losses, etc.

All sludge users report that the effect of replacing mineral fertilizers with sludge occurs over a long period of time. In the first years after the application of sludge, the yield usually decreases, and subsequently recovers and even increases without the need for annual fertilization with mineral fertilizers. One-time fertilization with sludge allows to replace the mineral fertilization for the entire regulatory period of 5 years, before re-application of sludge on the same plots. Therefore, the one-off costs associated with obtaining permits, supplying and depositing sludge is to be compared with the current savings from the reduced (removed) mineral fertilization during the period of effect realisation.

"Sofiyska Voda" AD provides (personnel, covers costs, etc.) for obtaining permits for sludge utilization, and provides free of charge sludge and transportation to the farm, additionally providing a machine and operator for sludge covering (only the fuel is paid by the using farmer). The costs for mineral fertilizers represent the main part of the production costs of the farms in the region - about 35-40%. Therefore, replacing mineral fertilizers with sludge fertilizer can lead to significant economies in large scale utilization.

Table 3. Production, socio-economic and environmental factors for sludge utilization in Bulgarian agriculture

Type	Positive	Negative
Agronomic, technological and production	Improve soil structure Improve aeration and soil moisture retention Faster germination and vegetative development of the plant No need for deep plowing, mineral fertilization and irrigation Better compensation of N and P uptakes and soil enrichment Increase land productivity and yield Improve the quality of produce Water retention Easy to apply to large farms specializing in field crops More efficient use of land, material, labor and financial resources	Technologically limited period of time for transportation and import of large amounts of sludge on many farms Compaction of the soil when applying the sludge Needs to monitor for heavy metals and soil acidity Different results depending on the characteristics of the soil, cultivated crops and varieties, and the amount of rain or irrigation Difficulties for use by small and medium farms Impossibility for use in all crops (vegetables, etc.) Diverse results depending on production conditions and crops Potential sludge shortage for all interested farmers in the area
Social	Increasing amount of sludge produced in the region Lack of alternative use of sludge and lands for disposal Public and international (EU) pressure Increase in the income of farmers Increase of sustainability of agricultural holdings Reduce the amount of waste and the total cost of waste storage and disposal	Conflict between economic and social effects Deteriorate working conditions during periods of sludge application Decrease comfort of the population during periods of sludge application Unfavorable wind direction during delivery, spreading and plowing of sludge Public dissatisfaction with the appearance of a specific odor

Table 3. (Continued)

Type	Positive	Negative
	Improve competitiveness Easy to apply to large and remote from settlements and other businesses farms Quick burial of the sludge to eliminate the unpleasant odor	Landowners reluctance to provide land for rent Need for public regulation and control Conflicts with other farmers and stakeholders Reluctance of beneficiary farmers to share their positive experiences for various reasons Unacceptable for use in fruits, vegetables, etc. crops for direct human consumption New EU goals for significant reduction of greenhouse gases, use of fertilizers and increase of organic farming Needs for long-term social dialogue and costs to promote agricultural use
Economic	The growth of mineral fertilizer prices Minimize or remove the cost of mineral fertilizers for a long period of time Increase the average yield Larger cobs, ears, grains and leaves (for silage, straw) Negotiating a better selling price for better quality grain Bigger profit Savings on material and labor costs Increase sustainability Improve competitiveness Reduce the needs for working capital and/or external lending and payment of interest and liabilities	Increased costs for negotiation and relations with WTP Increased costs for study and implementation of regulations Costs of time and funds for obtaining permits and relations with state bodies Increased costs of information, exchange of experience, training and management related to the use of sludge Increased costs for experimentation and for studying the effects in the conditions of each farm Additional costs for laboratory tests of soil, produce, etc.

Type	Positive	Negative
	Inclusion of farms in the circular economy Better use of farm resources	Increased costs for relationships with landowners, buyers, local government, and the public Additional costs for transportation, covering and plowing of sludge Need to pay for sludge (in the near future) Increased labor compensation costs Need for a certain concentration and specialization of production in the farm
Ecological	Maintaining and improving the fertility and quality of agricultural land Reducing soil erosion Increased water storage on farms Application of sludge in the summer to reduce soil compaction Increased ecological sustainability of agriculture Improved and more efficient waste management Reduction of greenhouse gases in the production and supply of mineral fertilizers Restrictions on use in protected areas	Greenhous gases emission in sludge treatment and use Air and road pollution Risks to natural biodiversity Groundwater pollution Pollution with heavy metals Soil trampling Need for careful use and precise control in coastal, riparian, lakeside and water supply areas Uncertainty related to long-term effects Pre-existing before sludge use contamination of soil and waters

Source: Interview with WTP managers and farmers.

It is reported that the effect is obtained in all types of soils, except sand, and the best results are obtained with corn in the same arrays – 6000-7000 kg/ha with irrigation. Without irrigation, there is no difference in yield, but only different costs of fertilization with mineral fertilizers and sludge, and yields strongly depend on an “external” factor - the amount of rain during

the year. In cereals (wheat and barley) the effect is at the earliest in the third year, as the first and second year burn.

In the utilization of sludge, significant savings are additionaly made to the need for deep plowing, for the application of fertilizers, for irrigation (for needy crops such as corn), for the payment of interest on loans for the purchase of mineral fertilizers, to save on and more productive use of own working capital, available equipment and manpower, etc. These supplementary effects are of great importance since the financial condition of most farms in the country is not good.

In addition to fertilizer savings, the application of sludge also leads to an increase in the total yield during the period, and depending on the crop and the amount of sludge, this increase can be 2 or more times. It should be borne in mind that in the first 1-2-3 years after the introduction of sludge there is a sharp decline in average yields, and loss of profitability of the affected plots of farms. Given the massive underuse of mineral fertilizers in the country, it can be assumed that the total effect of sludge imports is significant, as simultaneously with increasing yields it effectively recover the N, P, and K uptakes and maintain (and improve) soil fertility. Besides, the use of sludge is associated with additional environmental benefits such as improving the structure and quality of soils, reducing soil erosion and more.

The study found that the effect of fertilization with sludge on yield depends on the crop and varieties used, crop rotation, type and stocking of soils with N, P, K and other elements, etc. Yield also depends on the varieties grown, with many farmers preferring foreign varieties because of significantly higher yields other things being equal. A critical factor is the amount of rain, on farms that do not use crop irrigation due to the needs of high investment, the high price of water for irrigation, lack of permits for groundwater extraction, etc. It should be borne in mind that there are cases in which the leggaly permitted norms of sludge per unit area are increased (up to 3 times) and/or sludge is imported on more than the designated areas in order to maximize the yield.

Farmers also report increasing cob size and grades, improving product quality, increasing green mass (for silage and/or hay), which increases sales prices, increases profits and/or facilitates product marketing. These effects are especially important, given the high costs and difficulties associated with the sale of products on many Bulgarian farms.

The utilization of sludge in farms is also associated with maintaining soil fertility, as due to high prices mineral fertilizers are not used sufficiently (optimally). This is also an important indicator of the good environmental sustainability of the farmer. At the same time, however, some farms emphasize that "if possible, they will only apply mineral fertilizers, as they are safer."

The study also found that the application of sludge helps to improve (even double) the retention of moisture in the soil, and can achieve significant additional savings from irrigation and increase yields, in conditions of constant decreses in rainfall in recent years and high costs or lack of technical possibility for irrigation. At the same time, during the delivery and spreading of the sludge, the soil is compacted, its structure is compacted, and the areation is disturbed, hindering the development of the plants and reducing the yield in the first years. To reduce compaction, the sludge is applied in the summer, after harvest, when it is driest.

The import of sludge requires not only a change in agricultural technology, but also a new better organization and management of production. For example, there is a relatively short technological period after the harvest (July-August) for the delivery, spreading and plowing of the sludge. Upon delivery and especially with delayed plowing, an unpleasant odor spreads, which causes dissatisfaction from neighboring farms and businesses and even residents of nearby settlements. In case of strong odors, it is even necessary to interrupt the process in order to "calm the dissatisfaction of the population," which further shortens the practically possible period for the introduction of sludge.

Along with the economic benefits for the farms, the utilization of sludge is also associated with additional costs for relations with WTPs, controlling bodies, soil sampling, etc. For example, contracts between WWTPs and farmers are not complete, require additional costs to

coordinate and resolve potential conflicts, and so on. Non-exhaustive contracts also allow for unilateral "breach" of the agreement by the WTP at the expense of farmers - untimely delivery, delivery of sludge in various quantities and quality, temporary suspension of supplies to calm public discontent, etc. In addition, WTPs usually apply standard contracts that are not adapted to the specific conditions of a particular farm. This further increases the costs in the process of sludge utilization for adaptation, coordination between partners, contestation, etc.

On the other hand, (profit-oriented) WTPs also seek to minimize their costs for agricultural sludge utilization and prefer large farms near sludge landfills as contractors - cost savings for contracting and relationships, for obtaining permits (no fees are charged), on the paperworks and long procedures, soil samples, for transportation of sludge, etc. In all cases where the transaction costs for farmers and/or WTPs are very high, agricultural sludge utilization is reduced or completely blocked, regardless of the potential (production, economic, etc.) benefits for both parties.

The widely used practice of one-year landlease agreements of large farms with numerous landowners also creates an additional risk of damage (loss of one-time long-term investments related to the supply and use of sludge) in case of refusal of the landlords to renew the contract on landplots with sludge or permits, during the new business season (alternative use, sale, provision to another tenant, reluctance to deposit sludge, etc.).

Many of the above costs cannot be measured in monetary terms, but it is obvious that the one-off investment in the supply and import of sludge as fertilizers is recouped many times over from the additional profit received. Moreover, this type of investment has a much higher return (absolute and comparative efficiency) than other (traditional) capital investments in agriculture.

Most sludge using farms do this for a long period of time, in some cases up to two decades. This shows that good relations have been developed between farmers and WTPs, a good reputation and trust has been built between the partners, and mechanisms for coordination and conflict resolution, and for minimizing transaction costs. In addition, the long period of use of sludge from a holding is an important indicator of

efficiency, as with insufficient additional benefits (effects) and high associated costs, farms quickly stop this practice ("low exit costs").

The study found that the revenues of sludge recovery farms are between BGN 350-500/ha after deducting rent, depreciation and wages. The investment is cost-effective, and if allowed, many farmers would fertilize all areas with sludge. The use of sludge increases income, financial opportunities, competitiveness and economic sustainability of the enterprises. This also leads to higher social sustainability, as it provides employment in the region, and increases the viability of agriculture.

The studies also identified the main factors that increase or decrease the interest in the utilization of sludge by farmers who do not currently use sludge (*ИАИ*, 2021). Most of them are "generally" aware of the possibilities for using WTP sludge as fertilizer and its potential benefits. They receive this information informally either from the media, or from other producers, or from scientists, or from various publications in the press, or from direct monitoring of sludge farms. At the same time, however, very few non-using farmers have in-depth knowledge of the multifaceted socio-economic and environmental effects of agricultural sludge utilisation.

A major factor restricting experimentation with or transition to sludge utilization is the release of the specific odor and negative public opinion. The study found that the main reason for this is that sludge is used only by large farms and for a short period of time large quantities are delivered and inputed in certain landplots or areas. In addition, the regulations for maximum permissible sludge moisture, maximum quantities per unit area, obligation to plow on the same day of delivery and laying, etc. are not always observed. To reduce these effects, in case of strong odors, many farmers stop introducing sludge for 1-2 days, and/or comply with the direction of the wind not to be towards the settlements. At the same time, if the sludge is provided to several smaller holdings and distributed to larger areas, and if the established doses and regulations are observed, the odor will not be a significant problem.

Concerns about the possible negative effects on soil quality, the health of workers, the population and animals, guests (tourists, etc.) in the area, etc. are also often mentioned. Many land-leasing holdings and cooperative farms worry that landowners and cooperative members will block such a decision by terminating leases or voting in the general meeting. At the same time, producers whose lands are in remote areas of the settlements point out that the smell is not a significant limiting factor. In addition, in order to reduce the unpleasant odor and dissatisfaction of the population, farmers practice rapid burial after the delivery and spreading of sludge in agricultural plots.

Many farmers also believe that if the sludge is not provided free of charge but sold as a fertilizer product, this would further limit its agricultural use. There is no market for such a product in the country, and the supply will be monopolized (a single supplier) in the respective WTPs regions. At the same time, this product is not very specific to the farm, as there are many alternatives among other (mineral, manure, etc.) fertilizers. Moreover, competition with and from companies supplying mineral fertilizers is high, with mineral fertilizers usually sold in a "package" with additional services (lending, delayed payment, consulting, seed provision, etc.). In addition, it is found that some non-sludge farmers in the area are convinced that farms that use sludge (defined as "waste") receive payment for it from the WTP. Therefore, a strong development of the "sludge market" and trade in sludge at high prices cannot be expected in the coming years. Increased costs for efficient sludge utilisation in general and in agriculture in particular will continue to be mainly covered by WTPs (and water users respectively) and/or public programs (respectively by European, national or local taxpayers).

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CONCLUSION

This study is only the first stage of a larger srudy to establish the diverse effects and factors of sludge utilization in Bulgarian agriculture. The factors and effects of the circular economy are strictly specific to the conditions of each economic organization, the individual sub-sectors of agriculture, the different ecosystems and regions in which the useage takes place. Therefore, efforts will be focused on the next stage of development to clarify the farm, sectoral and regional specificities.

Given their relevance, research of this kind should be continued and deepened and should be based on more representative information from all participating agents and stakeholders. In addition to identifying the factors and their direction (positive, negative), the degree of their significance should be assessed by an interdisciplinary panel of experts in the field. On this basis, specific recommendations can be prepared to improve the utilization of sludge in agriculture to improve the policies, public support and institutional arrangements, and management strategies of WTPs and potential and sludge-using farmers.

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Chapter 3

ON THE EFFECT OF WORKER SKILLS ON QUALITY OF WORK IN CROWDSOURCING ENVIRONMENTS: AN EMPIRICAL APPROACH

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ABSTRACT

Crowdsourcing is a new form of labor market activity which incorporates several dynamic and interactive aspects of Web 2.0. Despite the increased popularity of the crowdsourcing activity worldwide, little is known on the quality of output and the associated determinants of a task-specific outcome. In this chapter we investigate the impact of cognitive and non-cognitive skills on the quality of a task-specific outcome by conducting an experiment on a popular crowdsourcing

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platform. Using linear and non-linear regression techniques and controlling for a wide set of individual characteristics and country-specific indicators, we found that the performance of workers depends on cognitive skills, personality traits and work effort. The results are expected to gain insights on the effective role of worker attributes on crowdsourcing labor induced projects.

JEL Codes: O33, J40, J24

Keywords: crowdsourcing, online labor, quality of work, cognitive abilities, personality traits, workers

1. INTRODUCTION

The emergence of the Web 2.0 paradigm has -among others- transformed the way labor is nowadays demanded and supplied. In such context, crowdsourcing is one prominent example: it refers to a wide range of web-based activities characterized by the contribution from the crowd (Marsden 2009). Crowdsourcing, as a term, is a strategic model to attract an interested, motivated crowd of individuals capable of providing solutions superior in quality and quantity to those that even traditional forms of business can (Brabham, 2008).

Today, crowdsourcing has become a new, complementary form (not necessarily substitute but in many cases supplementary) to traditional employment as companies seek to tap the latent talent of the crowds. Firms and employees have already surged into the crowdsourcing market, seeking the unique advantages of this new model of labor. This on-demand, global workforce is always available, easily accessible, and the hiring entity (requester) only pays if is satisfied with the quality of the results (Felstiner 2011). As this new form of offering and demanding labor is gaining momentum, it introduces also a number of new challenges related to how to organize and manage tasks as well as how to engage capable workers.

In recent years, quality of results in crowdsourcing tasks has received great attention. By the term “quality of results” we refer to the subjective

judgment that the submitted work meets the requesters' criteria, given that the task has been properly designed (Allahbakhsh et al. 2013). Research on quality in such environments centers primarily on categorizing quality factors (Allahbakhsh et al. 2013) or establishing methodologies able to estimate and control the quality of submissions (Howard et al. 2012, Baba & Kashima 2013). In general, few researches are concerned with how quality of work is influenced by either reward or individual worker characteristics. In traditional economic theory for example such issues have been addressed: quality of work is exclusively motivated by reward (i.e., the item which constitutes the most immediate return to express the set of advantages and disadvantages related to transaction costs) (Berardi et al. 2014) or employees' self-determination (Gagne & Deci 2005). In crowdsourcing environments however, it is still unclear which are the exact factors and to what degree they affect the quality of work submitted by workers.

In this chapter we report on how worker characteristics factors influence the quality of work in crowdsourcing environments. In particular, the research focuses in particular if and how worker's cognitive and non-cognitive skills impact on quality of work. Towards this we conducted an experiment on the well-known crowdsourcing website microworkers.com requesting from workers to listen to a music sample containing English lyrics and submit as many correct words as they could. The task was preceded by a demographic survey in which workers were asked to report on their gender, age, country of origin, computer & English language skills as well as their education level. Workers were also asked to fill in a questionnaire related to the Big Five Personality Test (John et al. 1999). Analyzing the results indicates that there is a strong correlation between the quality of work and specific skill groups.

The experiment was set up in a way to collect the data relevant to the question of quality of work in crowdsourcing environments. The assumptions upon which the experiment relied included that workers had the proper audio equipment and that the information asymmetries created by the platform does not affect the outcome of the analysis. Moreover, the inability of such platforms to hire and observe individual workers across

tasks was not considered a drawback in the context of the experiment's research question.

The structure of the chapter is the following. Section 2 presents reviews the related literature. Section 3 presents describes the experiment conducted. Section 4 presents the empirical analysis of data obtained by the experiment. Section 5 presents outlines and the empirical model for estimating quality of results. Section 6 presents assesses the empirical the estimation results model and Section 7 concludes the chapter.

2. LITERATURE

In recent years crowdsourcing environments have attracted the interest of researchers from various fields, who aspire to survey, analyze, comprehend and improve this new form of labour. In general, research has focused on mapping and reviewing crowdsourcing platforms (Mourelatos et al. 2016), how they offer their crowdsourcing services and how they recruit and retain users as workers to enhance their smooth operation (Doan et al. 2011).Other research investigates models of workers supplying labour to paid crowdsourcing projects in an attempt to estimate worker's reservation wage (Horton et al. 2010). Discussions also revolve around workers' motivation when they participate in crowdsourcing platforms (Kaufmann & Schulze 2011), as well as around the relationship workers have with their own job performance (Winter & Duncan 2009). Moreover, many surveys have been conducted to investigate the demographic profiles of both requesters and workers who interact in the context of crowdsourcing (Ipeirotis 2010).

With crowdsourcing gaining momentum and becoming mainstream, collective behavior on social media platforms has attracted increasing attentions from both academia and industry (Cheung and Lee 2010 and Turel and Zhang 2011), while at the same time research efforts focus on developing comprehensive frameworks for managing the accuracy and the quality of the submitted crowdsourcing work (Wang et al. 2013). In this direction, many researchers have designed several mechanisms and

practices in order to make possible the quality control and assurance process in these online labor environments. For example, Donmez suggested the use of confidence scores and gold-standards (Donmez et al. 2009), while Wais suggested the use of empirical and cost contrains (Wais et al. 2010).

In this regard, it may be more appropriate to examine if the quality of results is directly influenced by crowd behavior and their characteristics. In the literature, work quality has been related to crowd demographics (Ross et al. 2010; Sheng et al. 2008), contributors' gender, profession and age (Downs et al. 2010), workers' personality traits (Kazai et al. 2011) and its relationship with workers' incentives (Mourelatos & Tzagarakis 2016). In general, the literature lacks studies that examine the quality of results under a combination of workers' cognitive and non-cognitive skills and effort. This chapter adds to the growing body of research, which seeks to investigate the predictive power of workers' behavior (effort) and skills (cognitive, non-cognitive) on expected quality of results (Kautz et al. 2014).

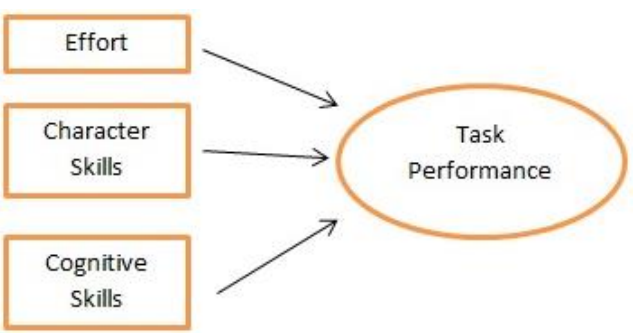

Figure 1. Determinants of task performance (Source: Heckman et al. 2012).

Although non-cognitive skills are overlooked in most contemporary policy discussions and in economic models of choice behavior, personality psychologists have studied these skills for the past century. Psychologists primarily measure non-cognitive skills by using self-reported surveys or observer reports (Cunha et al. 2010). They have arrived at a relatively well-accepted taxonomy of non-cognitive skills called the Big Five Personality

Test, which stands for: Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism (Linden et al. 2010).

3. THE EXPERIMENT

3.1. Objective Tasks

The goal of the research reported in this chapter is to jointly estimate the true answers for the tasks, as well as to investigate the impact of the following groups of variables on the quality of the results provided by the workers. GDP per capita is especially useful when comparing one country to another because it shows the relative performance of the countries. A rise in GDP shows that there is more value addition in the economy or there is a higher income or rise in expenditure which implies that there is a rise in the standard of living of the citizens and due to rise in income there will be a higher spending on various goods and services like healthcare, education, etc (Lovell et al. 1995). In our analysis we included the values of GDP per capita for the year 2015 as published by Knoema (Knoema, 2016).

With regard to the cognitive skills[3] of each worker we group workers according to their computer skills, language skills and education skills variables (Campbell et al. 2001). In addition, the non-cognitive skills[4] of each worker (Borghans et al. 2008) is captured by the Big Five Personality Test variables. Lastly, the work effort[5] being made by the workers (Heckman et al. 2012) is approximated by the (a) workers' task completion time and (b) task number of repeats before the final submission.

[3] with this term we mean the abilities and the skills a worker need to carry out any task from the simplest to the most complex.

[4] with this term we mean the patterns of thought, feelings and behavior of individuals that may continue to develop thought out their lives.

[5] with this term we mean how serious a worker's attempt for a task completion.

3.2. Experimental Design

In order to investigate better the factors that either raise or reduce the overall quality perception, we firstly outline the setup of the experiment. The experiment was related to the task of transcription and was designed to welcome answers from the participants for addressing the problem of Mondegreens (Meyer et al. 2011). The term Mondegreens describes misperceptions as defined by "slips of the ear", denoting that an utterance is perceived differently to what has actually been said. In general, the analysis of these misperceptions permits a deeper insight into speech processing in the human brain. This phenomenon is very widespread in music, when a person mishears or misinterprets the lyrics of a song (Smith 2001).

In particular, we asked the workers to listen to a music sample containing lyrics with an amount of 56 words in English language and then to provide us in a text box with as many correct words as possible they could. The task was preceded by a demographic survey in which we asked them about gender, age, country of origin, computer & English language skills and education level. Last but not least, the task in order to accomplish was required from each participant to fulfill a questionnaire referring to Big Five Personality Test. This type of test had the form of 44-likert scaled personality questions that measures an individual on the Big Five Factors of personality (Goldberg et al. 1993).

3.3. Methodology

In general, a worker's performance on a project is affected by a variety of factors. Monetary incentives frequently are suggested as a method for motivating the performance of a person, yet, in our case the monetary reward is standardized by the crowdsourcing platform (Bailey et al. 1998). Hence, we can't include in our analysis a possible monetary effect. The preceding discussion indicates that a worker's task performance on a crowdsourcing project is affected also by factors related to workers' skills

and effort. A more complete picture with regard to the effects of a worker's skills in a task performance was suggested by Heckman & Kautz (2012) who propose a framework for a better fostering and measuring of a worker's skills. Thus, in order to capture the effect of a worker's cognitive skills, we include in our analysis his educational level, computer skills and English competence. Respectively, in order to capture the non-cognitive skills we use the abovementioned personality test, named Big Five Personality test suggested by Barrick (Barrick & Mount 1991). Moreover, knowing the major role of a worker's effort in the final quality of results, we include this effect by counting a worker's task completion time and if he had a high repeated action of the task or not (Bonner & Spinkle 2002). In addition, following the research of Schulze on quality assurance mechanisms in crowdsourcing platforms, we embody in our analysis a worker's general success rate and experience in crowdsourcing projects (Schulze et al. 2012). Lastly, in order to capture the country specific fixed effect, we used the logarithm values of GDP per capita of each worker's country of origin.

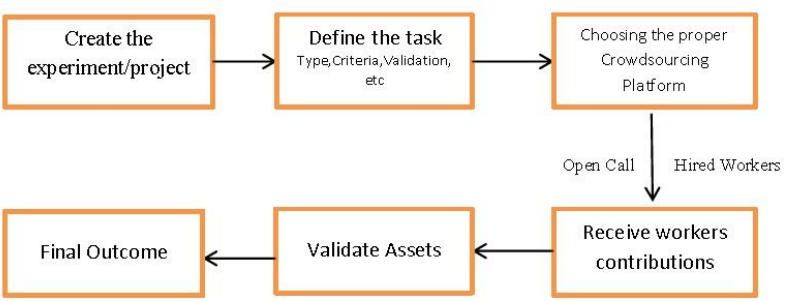

Figure 2. Methodology of the crowdsourcing procedure in our study.

In order to gather the appropriate data for our research we also needed to consider the basic components of crowdsourcing, each of which plays an integral part in the success of our approach (Keating et al. 2013). Having already established the goal of our research and having defined the specific audience segments, we had to identify the suitable crowdsourcing platform in which our experiment would take place. We needed a platform that

would have workers familiar with microjobs (as the type of our task was) and would provide us with a friendly and effective framework for our experiment (i.e mechanisms that would allow us to control from which countries the workers would be) (Gardlo et al. 2012). Hence, taking in consideration the above mentioned, we choose a well-known to the research community platform, named microworkers.com (Hirth et al. 2011). A graphical interpretation of these issues is shown in Figure 2.

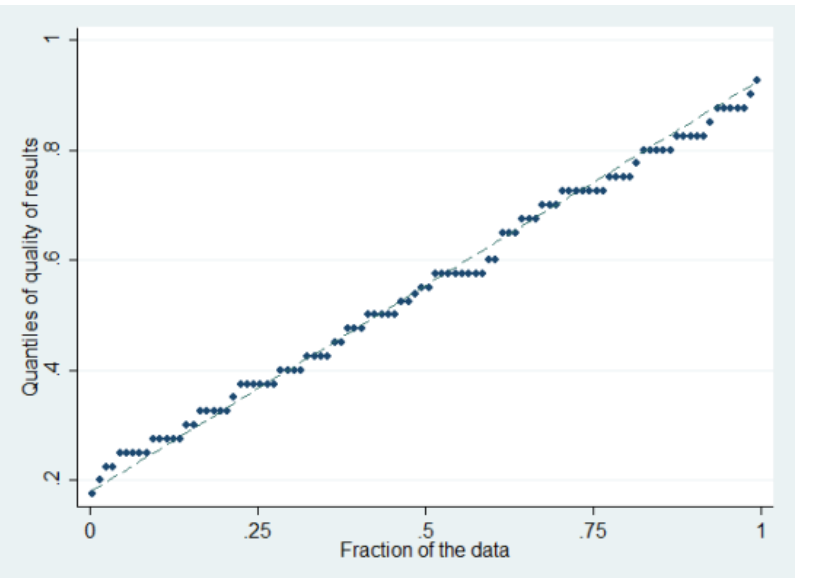

Figure 3. Quantile–normal plot for workers' quality of results.

Under normal circumstances at this point, we should define the quality standards that would be under examination with respect to the incoming answers from our hired workers. With the term quality in crowdsourcing, we mean to what extent the worker output meets requester's task requirements (Allahbakhsh et al. 2013). As shown in Figure 3, where we use a measure of the quality of submissions, we considered the percentage of correctly identified words in the music sample calculated as the ratio of the number of words correctly identified by the worker divided by total number of words in music sample, henceforth referred to as quality of results. Yet, until now there is no a specific quality threshold which will

enables us to segregate the good from the bad quality. Hence, we divide quality into four groups, in respect to the 4-quantiles (the "quartiles") of our dataset. Quantiles are useful measures, which divide our data (in our case the quality of workers' results) into quarters and provide us with some initial results before our quantile regression analysis.

Thus, a microworkers campaign was launched, through which crowdsourcing workers could access a sound cloud link with the music sample and perform the experiment under a 0.75 $ compensation per task.

4. EMPIRICAL ANALYSIS

4.1. Dependent and Independent Variables

For our analysis we solicited approximately hundred answers from workers based on microworkers.com crowdsourcing platform. Any user could participate in our campaign by accepting the task ("open call" format, no exclusions made). As a result, our campaign ran for fifteen hours (15) with an overall cost of 82.12 $. Consequently, we draw our data from the experiment containing information on several variables regarding the participant workers. Then, we grouped the variables in to major skill groups: demographics (age, gender) cognitive skills (education level, computer & English competency), non-cognitive skills (extraversion, agreeableness, consciousness, emotion stability & openness) and work effort (number of repeats & time of task completion) group in order to obtain a better picture of our further analysis. At this point, we considered it important to try to increase the number of our predictor variables. For this reason, we used a web crawler in order to obtain more information about the participant workers. Crawlers are URL discovery tools, with the help of which, someone can get easily, data from the web programmatically (Pant et al. 2004).

Table 1. Summary statistics

	Mean	**Min**	**Max**	**Std. Dev**
Quality of results (Dependent)	.550	.175	.925	.207
Age	28.260	18	59	7.425
Female	.290	0	1	.456
Tertiary education	.650	0	1	.479
High computer competence	.730	0	1	.446
High English competence	.780	0	1	.416
Extraversion	22.480	8	34	5.610
Agreeableness	30.710	11	45	6.850
Consciousness	31.520	15	44	5.990
Emotion stability	19.440	4	29	4.870
Openness	34.890	18	46	5.370
Task completion time	5.420	3	8	1.550
High repeated action	.690	0	1	.465
High General Success Rate	.500	0	1	.502
Crowdsourcing experience	2.960	1	6	1.720
Log GDP per capita	9.540	7.824	11.088	1.032

Source: Dataset with results drawn from Microworkers.com. Authors calculations.

Notes: Number of observations equals to 100. Age and Crowdsourcing experience is measured in years. Task completion time is measured in minutes. High repeated action variable contains workers with over three times of task's repletion before the final submission. High general success rate variable contains workers with general success rate greater than or equal its median (>=.983). Log GDP per capita is measured in USA $.

Hence, in the interest of measuring the general productivity of each participant, we gathered from microworkers.com platform additional information regarding the workers' reputation. As a result, we embodied in our analysis two more variables in order to have a better picture of the participants' traits in our experiments. More specifically, we define crowdsourcing experience as a variable which is created from the subtraction from the year of the experiment (2015), the date of the registration of each worker in microworkers.com. What emerges is an amount of years, which is an indicator of the experience of each worker in crowdsourcing projects. For example a worker who has registered on microworkers.com in 2010, we assume that he has 5 years of experience in crowdsourcing tasks. Moreover, the General Success Rate (GSR) is created by dividing the number of satisfied tasks by the number of all tasks that each worker has ever participated in microworkers.com. For our

analysis we introduce a dummy variable (GSRD), in order to embody in our model only workers with general success rate over the median (GRSD's value 1 >=.983). Table 1, presents our set of variables, which we used in our further analysis.

4.2. Descriptive Statistics

It is noteworthy that, the average quality of results was near 55%, with a minimum value near 17.5% and a maximum near 92.5%, indicating perhaps the existence of outlier values (extreme observations).

Regarding the other group of variables, descriptive statistics revealed some interesting initial results. More specific, regarding the cognitive skills, Table 2 shows in our experiment that education levels differ among participant workers. As a result, in order to capture better the effect of a worker's education level on his task performance, we generate a new dummy variable edulevD, (value 1 : includes workers with at least tertiary education) (Card 1999).

Table 2. Education Levels of participant workers

	Education Levels	**Freq.**	**Percent**	**Cum.**
Level 0	Pre-primary education	0	0.00	0.00
Level 1	Primary education	2	2.00	2.00
Level 2	Lower secondary education	10	10.00	12.00
Level 3	Upper secondary education	23	23.00	35.00
Level 4	Post secondary non-tertiary education	24	24.00	59.00
Level 5	Short –cycle tertiary education	13	13.00	72.00
Level 6	Bachelor's or equivalent level	17	17.00	89.00
Level 7	Master's or equivalent level	11	11.00	100.00
Level 8	Doctoral or equivalent level	0	0.00	100.00
	Total	100		

Source: Dataset with results drawn from Microworkers.com. Authors calculations.
Notes: Number of observations equals to 100.

Similarly, we introduce a dummy variable for computer and English language competency (comlevD & englevD), with value 1, containing

workers with satisfying levels of these skills. In addition, an independent-samples t-test was conducted to compare the quality of results in satisfactory and non- satisfactory levels of education, computer and English language aptitudes.

It is notable, that in all three cases, there was a significant difference in the scores of quality of results (y) for low and high levels of cognitive skills. More specific, there was a strong significant difference in quality of results (y) in the scores of high and low levels of education ($t = 2.74$, $p = 0.000$) and high and low levels of computer expertise ($t = 6.82$, $p = 0.000$) at 1% of level of significance, while at 5% of level of significance for high and low levels of English language competency ($t = 2.44$, $p = 0.016$) (Table 3).

Table 3. Independent Samples t-tests for high and low levels of cognitive skills. Independent-samples t-test for high and low levels of number of repeats descriptive statistics

	Low	**High**	**Difference [2]-[1]**	**t-test**
	[1]	[2]	[3]	[4]
Education	.38	.64	.26	2.74[a]
Computer competence	.36	.62	.26	6.82[a]
English competence	.46	.58	.12	2.44[a]
Repeated action	.52	.56	.04	.92

Source: Dataset with results drawn from Microworkers.com. Authors calculations.
Notes: Statistical significance: [a] 1%, [b] 5% and [c] 10%.

In respect to non-cognitive skills, for our analysis we used the Big Five Personality Test. This test consists of fifty personality items that you must rate on how true they are about you, on a five point scale where 1 = Disagree, 3 = Neutral and 5 = Agree (Goldberg et al. 1992). For our crowdsourcing experiment, we examined the workers under the variables of extraversion (a worker's degree of being talkative, assertive, energetic), agreeableness (a worker's degree of being good-natured, cooperative, trustful), conscientiousness (a worker's degree of being orderly, responsible, dependable), emotional stability versus neuroticism (a

worker's degree of being calm, not neurotic, not easily upset) and openness to experience (a worker's degree of being inventive, consistent, creative) (John et al. 1999).

Figure 4 shows the distribution of responses to the Big Five Personality questionnaire. For Openness we observe a mean score of 34.89 (std. dev. 5.37), suggesting a workers' tendency toward creativity and active imagination. The mean score of Conscientiousness is lower with 31.52 (std. dev. 5.99), suggesting that we mustn't expecting a highly thorough job from workers in our crowdsourcing task. Extraversion has a mean 22.48 (std. dev. 5.61) exhibiting no particular disposition on this trait. Moreover, we observe a good score for agreeableness (mean 30.71 std. dev. 6.85), which indicates an empathetic and altruistic nature of the participant workers. Finally, we find a low mean score for Neuroticism (it is the opposite of emotion stability) in our experiments (mean 23.00 std. dev. 5.44), which suggests a possible relaxed nature of the workers.

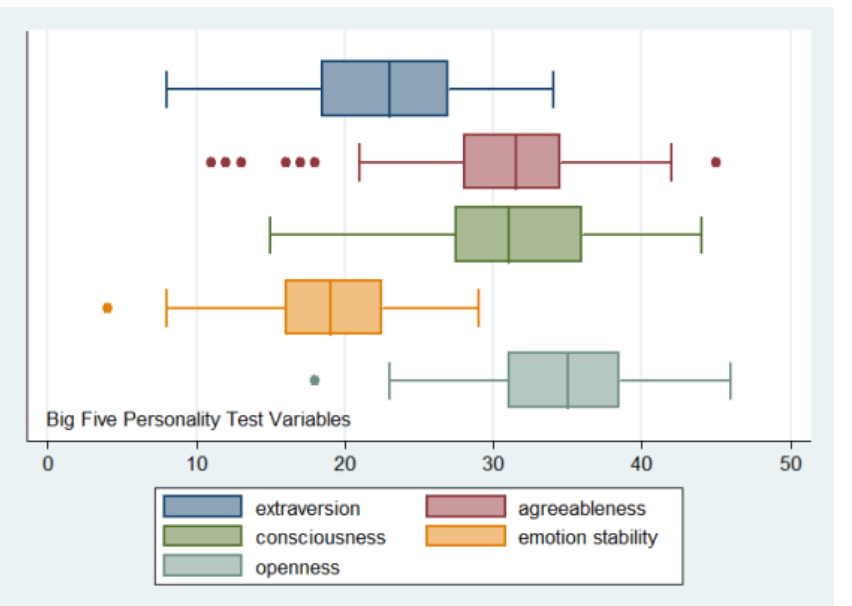

Figure 4. Workers' big five personality test distribution.

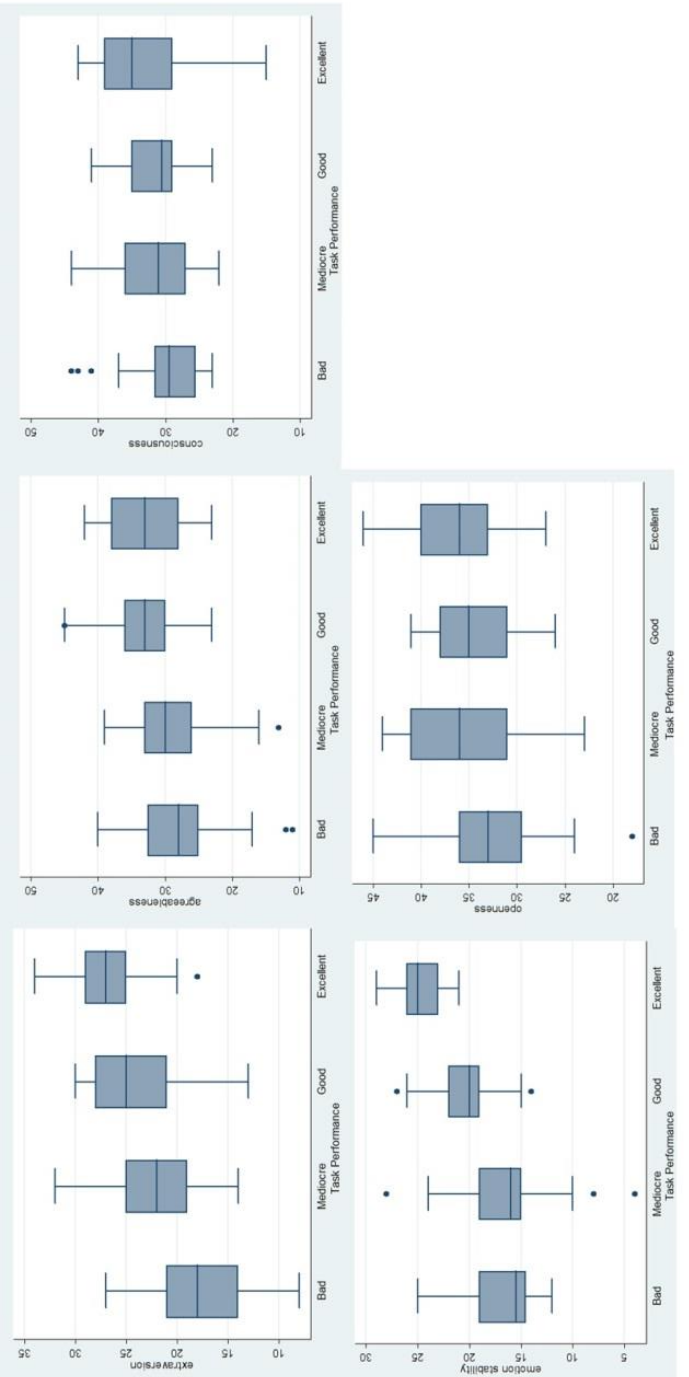

Figure 5. Quality of results towards the big five personality variables.

Concerning the big five personality variables compared with workers' quality of results, Figure 5 (with x-axis showing different levels of quality) reveals some noteworthy remarks. First of all, it is observable, that workers with "poor" task performance had also low scores in almost all variables of personality traits, while for the workers with "good" and "excellent" task performance the opposite is true. Last but not least, in the case of two personality variables (emotion stability and agreeableness), we also observe, a parallel change of values between them and quality of results, which possible indicates their correlation.

Additionally, in order to investigate how serious a worker's attempt was, we gathered some descriptive statistics referring to workers' experience in crowdsourcing projects and task's completion time before the final submission. Thus, we generate a dummy variable named numberD, with its value zero containing workers, who their number of task repetition before the final submission was under 3 times (indicating cheating) in order to capture the repeated action effect. Next, we used an independent-samples t-test in order to investigate if the quality of results in low and high levels of number of repeats of the task, has a statistically significant difference (Table 3)(Figures 6 & 7).

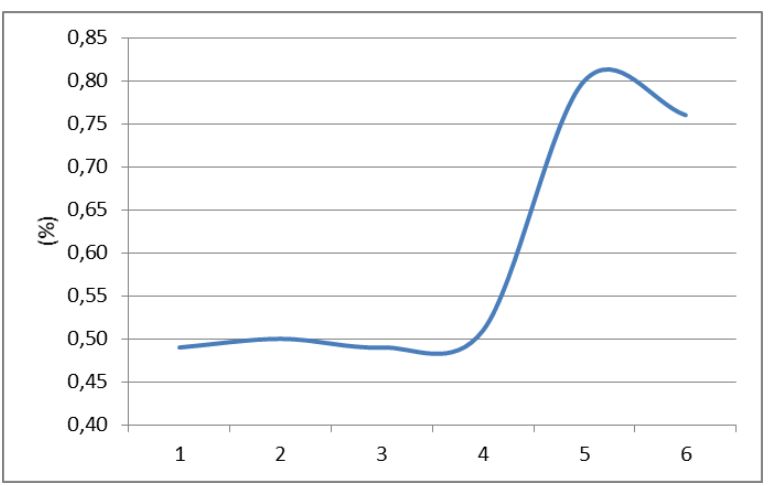

Figure 6. Relationship between quality (% of correct answers) of results (vertical line) and workers' experience (in years) in crowdsourcing (horizontal line).

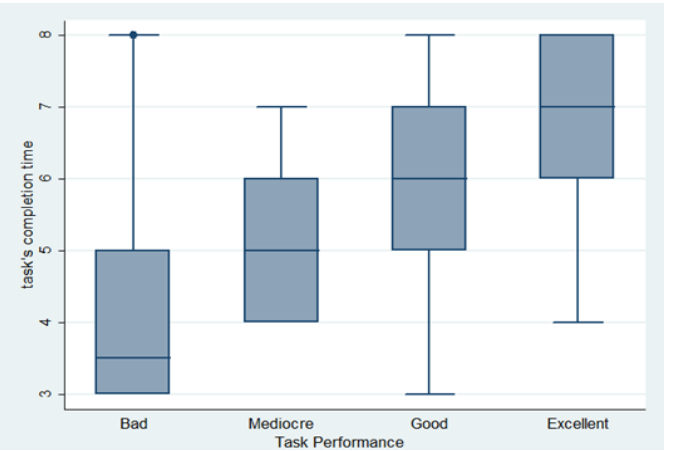

Figure 7. Quality of results towards task's completion time.

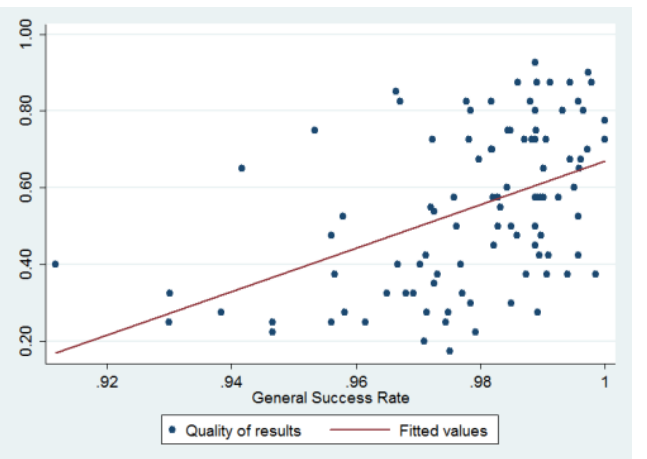

Figure 8. Relationship between General Success Rate (GSR) and quality of results (vertical line).

As we expected, the values of a worker's crowdsourcing experience and task's completion time change parallel with the values of workers' quality of results, which possible indicates a strong relation between them.

On the other hand, it is noteworthy that there was not a significant difference in the scores of quality of results for low and high levels of a task's number of repetition ($t = -0.92$, $p = 0.36$).

Lastly, we examined the relationship between the variables of workers' general success rate (GSR) and the logarithm values of GDP per capita of workers' country of origin, with the workers' quality of results (Figure 8 and 9). In both cases we have scatterplots with overlaid linear prediction plot between variables, indicating a linear relationship between the under examination variables.

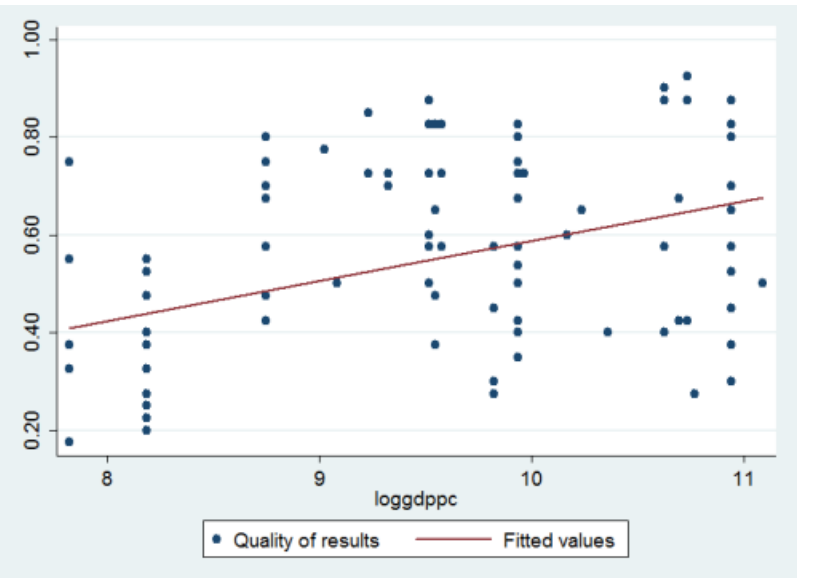

Figure 9. Relationship between log-GDP per capita and quality of results (vertical line).

5. Empirical Model

Towards investigating the impact of the observed variables to the quality of results of workers in crowdsourcing environments, we derived an econometric model which aims at predicting the quality of work based on the skill groups as well as environmental control variables. In particular, we utilize an OLS linear regression model, which is applied to each census separately. This model estimates how, on average, the above variables affect the workers' quality of results. Namely, it can address the question:

"Are skills and demographics important in achieving quality in crowdsourcing tasks?" In linear regression, the regression coefficient represents the increase in the response variable produced by a one unit increase in the predictor variable associated with the coefficient. Nevertheless, we also wanted a more comprehensive picture of predictors' effect on the response variable, in order to investigate, if their effect exists and to what extent, on low and high values of the dependent variable and be compared to their effect on median. For this reason, we also used for our estimation a quantile regression. The quantile regression parameter estimates the change in a specified quantile of the response variable produced by a one unit change in the predictor variable (Bassett et al. 2002). This allows comparing how some percentiles of the quality of results of workers may be more affected by certain workers' characteristics than other percentiles. This is reflected in the change in the size of the regression coefficient (Buchinsky 1998).

Recall, following Heckman and Kautz (2012), we include a variety of "skills" and "environmental" controls for observed performance of crowdsourcing workers. The econometric specification is of the following general form:

$$Q_i = \alpha + \beta D_i + \gamma C_i + \delta NC_i + \varepsilon WF_i + \zeta RV_i + \eta CI_i + e_i \quad (1)$$

where Q_i is the aforementioned quality of results attainment indicator of the i^{th} worker, D_i is a vector of demographics outcomes (age and gender), C_i is a vector of cognitive skills outcomes (education, computer, English levels), NC_i is a vector of non-cognitive skills outcomes (Big Five Personality Test variables), WF_i is a vector which includes the work effort variables (time and number of repeats), RV_i is also a vector of reliability and validity rate of i^{th} worker (general success rate & crowdsourcing experience of each worker) and lastly CI_i is capturing the country specific fixed effect (we used the logarithm values of GDP per capita of i^{th} worker's country of origin).

Table 4. The determinants of task performance on a crowdsourcing task

	OLS	**Quantile Regression**		
	Mean	**0.25**	**0.50**	**0.75**
Independent variables	[1]	[2]	[3]	[4]
Constant	-.499	-.776	-.656	-.342
	(.112)	(.142)	(.138)	(.019)
Age	.001	.004[c]	.001	.001
	(.001)	(.002)	(.001)	(.002)
Female	.005	-.006	.003	.001
	(.024)	(.028)	(.023)	(.040)
Tertiary education	.085[a]	.070[b]	.066[b]	.038
	(.028)	(.034)	(.028)	(.042)
High computer competence	.098[a]	.103[a]	.084[a]	.097[b]
	(.029)	(.028)	(.031)	(.039)
High English competence	-.013	-.043	-.020	-.030
	(.025)	(.025)	(.031)	(.035)
Extraversion	.005[b]	.003	.004[c]	.007[b]
	(.002)	(.003)	(.003)	(.003)
Agreeableness	-.001	-.001	.001	.001
	(.002)	(.002)	(.002)	(.003)
Consciousness	-.001	-.002	.001	.001
	(.002)	(.002)	(.002)	(.003)
Emotion stability	.013[a]	.015[a]	.017[a]	.018[a]
	(.003)	(.003)	(.003)	(.003)
Openness	-.001	.003	-.002	-.002
	(.002)	(.002)	(.003)	(.004)
Task completion time	.031[a]	.035[a]	.046[a]	.033[b]
	(.010)	(.010)	(.009)	(.014)
High repeated action	-.004	-.009	-.018	.085
	(.020)	(.021)	(.020)	(.035)
High General Success Rate	.049[b]	.048[b]	.035	.085[b]
	(.021)	(.021)	(.025)	(.035)
Crowdsourcing experience	.018[a]	.026[a]	.012[a]	.024[a]
	(.005)	(.007)	(.007)	(.009)
Log GDP per capita	.034[a]	.043[a]	.042[a]	.023
	(.010)	(.013)	(.011)	(.020)
R-squared	.846	.638	.656	.629
Observations	100	100	100	100

Source: Dataset with results drawn from Microworkers.com. Authors calculations.

Notes: Dependent variable: Quality of results. In parentheses heteroskedasticity corrected standard errors.

Statistical significance: [a] 1%, [b] 5% and [c] 10%.

6. ESTIMATION RESULTS

If we apply model (1) to our data set, we obtain the following OLS linear regression model and coefficient for the 25th, 50th and 75th quantiles (Table 4).

6.1. OLS Regression

The above results suggest that there are remarked differences across the distribution of workers' quality of results with respect to workers' skills and demographic characteristics.

In particular, the first column in Table 4 presents the coefficients for the OLS linear regression model. The results show that more than half of the independent variables are statistically significant. For example, having higher levels of education and computer competency significantly increased a worker's quality of results (at the 1% level of significance and the right hand variable is positively relate to the left hand variable). Specifically, workers with at least tertiary education scored 8.5 percentage points of quality higher on average than those who did not complete high school and those with good competency at computers scored 9.8 percentage points of quality higher on average than those with poor. Moreover, workers' coming from countries with high levels of GDP per capita, scored 3.4 percentage points of quality higher than the others. The GDP per capita effect on quality of results is strongly significant at the 1% level of significance ($r = 0.034$, p.value = 0.000).

Among the personality traits, we find that emotion stability and extraversion has a remarkable effect on quality of results at 1% and 5% level of significance respectively. There was little evidence, however, that the magnitude of this effect increased with quality levels.

The OLS coefficient for gender and age was positive but not significantly different from zero, suggesting that males did not provide better results in crowdsourcing tasks than females and being older or not it didn't matter.

Regarding the effect of a worker's work effort, our results revealed a strong effort-performance relation. In other words, a worker's task completion time affects significantly at 1% level of significance, his performance on the task confirming the effect of the monetary incentive (Bonner et al. 2002).

Furthermore, the findings of OLS regression also showed a strong correlation between a worker's experience in crowdsourcing tasks and his quality of results, which indicates that maybe crowdsourcing can enable individuals to gain and build work experience, which can result in the improvement of theirs existing skills or in the development of new abilities and opportunities (Barnes et al. 2015).

Last but not least, our data analysis reveals a noticeable correlation (at the 5% level of significance) between the quality of results and the general success rate of a worker, with the right hand variable being positively related to the left hand variable. Workers with high levels of this index of reputation scored about 5 percentage points of quality higher than the ones with low, meaning that probably this crowdsourcing mechanism, which is being adopted more and more by crowdsourcing platforms, as a method of cheat detection and spamming, is working efficiently (Eickhoff et al. 2012).

6.2. Quantile Regression

For further analysis, quantile regression makes it possible to statistically examine the extent to which workers' skills (cognitive, non-cognitive, work effort) and demographic characteristics are valued differently across the distribution of their quality of results (y).

The remaining columns in Table 4 (column 2, 3 & 4) present the regression for the 25^{th}, 50^{th} and 75^{th} quantiles respectively. Recall that quantile regressions were estimated to determine if the impact of the independent variables varied for workers at different points in the distribution of quality of results. Specifically, did the independent variables have a different impact on the quality of results of workers who

scored lower in the distribution versus those who scored higher? The results of the quantile regressions showed that the position of a worker in the quality of results distribution did, in fact, significantly affect the impact that various independent variables had on their level of quality f results.

For example, the quantile analysis showed that the effect of a worker's computer competency was positive and significantly different from zero throughout the conditional distribution of quality of results. Hence, the quantile analysis broadly confirms that the OLS result of a strong, positive effect of computer competency holds throughout the conditional distribution. Regarding the education levels, it is noteworthy that their effect was also positive and significantly from zero (at 5% level of significance) at the 25^{th} and 50^{th} quantiles (columns 2 & 3 of Table 4). However, it also revealed a significant and positive spike in the effect of education around the 50^{th} quantile. This suggests that education had a more positive impact on quality of results for those who didn't achieve moderate or high quality score in our crowdsourcing task and its effect disappears in high values of quality of results of workers (above 75^{th} quantile-column 4 of Table 4). Therefore, it reveals behavior in the high part of the quality of results distribution not evident in the OLS analysis. Lastly, it is notable that neither in OLS or quantile analysis, a worker's English language competency, had any effect on workers' quality of results distribution.

The quantile regressions also point to a more nuanced effect for age than was revealed by the statistically insignificant OLS estimate. At the 25^{th} quantile, the coefficient on age was roughly four times as large as the OLS estimate (0.004 vs. 0.001) and was marginally significant at the 10.0 percent level. One interpretation is that, among those who are less knowledgeable with crowdsourcing tasks, older tend to be slightly more knowledgeable about crowdsourcing tasks than younger. Nevertheless, this differential effect of age across the distribution of quality of results may merit further attention.

Additional evidence revealed that the effect of GDP per capita of a worker's country of origin remains strong (as in OLS regression) in quality of results conditionals distribution, but disappears on high values of the distribution (above 75^{th} quantile). This possible means that, a country's

economic performance may is an indirect indicator of a worker's task performance only in the case of workers with low specialization in crowdsourcing tasks.

With respect to prior results, we found that, unlike OLS, the quantile results showed significant effects of a workers' general success rate only at 25^{th} and 75^{th} quantiles, with the difference that in high values of quality of results this effect doubles (0.085 vs. 0.049). One possible interpretation is that, this cheat-detection mechanism has greater impact among individuals with high specialization in crowdsourcing and its principles (in the right tail of the distribution).

Recall that another striking results from OLS regression was a strong positive effect of a worker's experience in crowdsourcing tasks and its completion time; the quantile analysis confirmed these results throughout the workers' quality of results conditional distribution at 1% level of significance.

In regard to non-cognitive skills, quantile regression proved the strong and positive effect of a worker's emotion stability levels, and its increased tendency, throughout the conditional distribution of quality of results. Similarly, the extraversion level of a worker has a positive and consecutive significant effect on quality of results, with the difference that in the left tail of the distribution, at the 25^{th} quantile, the extraversion effect weakens.

Last but not least, the quantile regressions confirmed the OLS, that some variables such as gender, levels of agreeableness, openness and consciousness and the number of repeats of a crowdsourcing task, have any effect on quality of results of workers.

Figure 10 presents a graphical depiction summary of quantile regression results for our case. We have 15 covariates, plus an intercept. For each of the 16 coefficients, we have estimates which may be interpreted as the impact of a one-unit change of the covariate on quality of results of workers, holding other covariates fixed. Thus, each of the plots has a horizontal quantile, or t, scale, and the vertical scale in grams indicates the covariate effect. The dashed line in each figure shows the ordinary least squares estimate of the conditional mean effect.

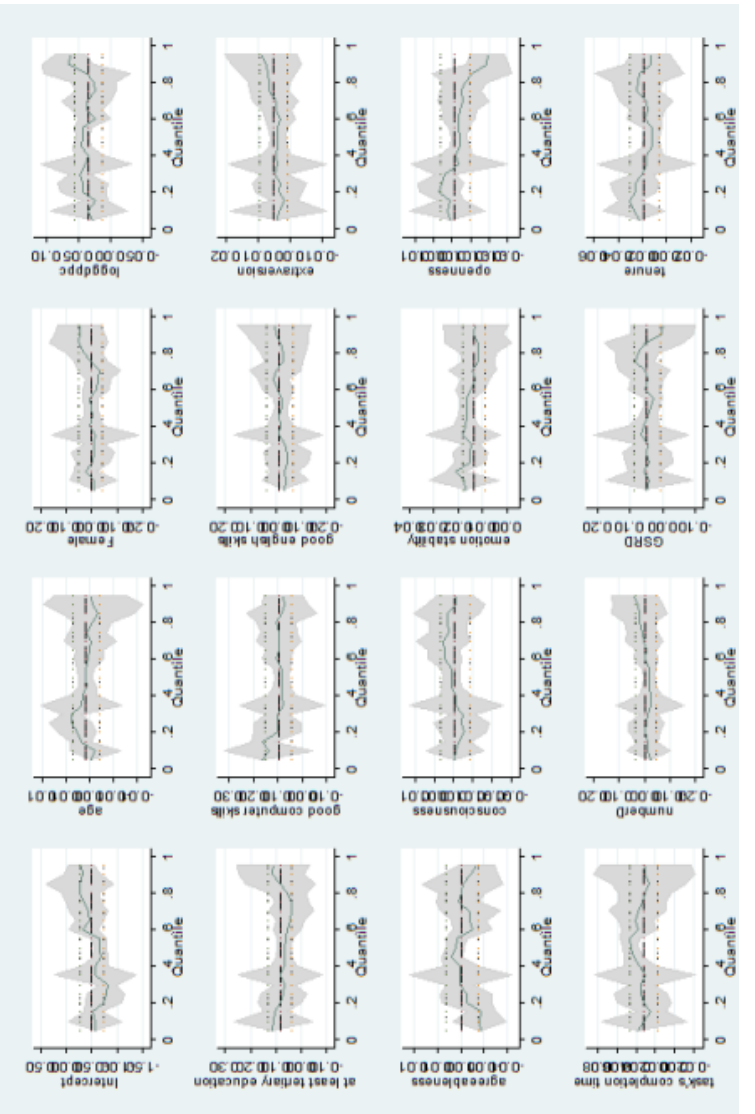

Figure 10. Ordinary Least Squares and Quantile Regression Estimates for Quality of results Model.

The two dotted lines represent conventional 90 percent confidence intervals for the least squares estimate. The shaded gray area depicts a 90 percent point wise confidence band for the quantile regression estimates.

It is noteworthy that, in almost all of the panels of Figure 10, the quantile regression estimates lie at some point outside the confidence intervals for the ordinary least squares regression, suggesting that the effects of these covariates may not be constant across the conditional distribution of the independent variable especially on high values of workers' quality of results (Koenker et al. 2001).

6.3. Discussion

The skills and traits that characterize an individual, which participates on online labor markets as crowdsourcing, can have important effects on his task performance. Cognitive or non-cognitive skills affect workers when it comes to decisions concerning the accomplishment of a crowdsourcing task. It has been proved by the analysis that high educational & computer levels as well as high values of extraversion and emotion stability do play an important role in workers' quality of results in crowdsourcing environments. A positive relationship has been also found between a worker's experience and general success rate on crowdsourcing and quality of results. Moreover, the relative with a worker's effort variable has had an important effect on his tasks performance. Lastly, our research reveals a large impact of a worker's country of origin social-economic status on his job performance on online labor markets as crowdsourcing.

CONCLUSION

Skills are emerging as a critical factor in achieving high quality of work in crowdsourcing tasks. Moreover, measuring and assessing these skills is also a crucial aspect, which has received attention (Stasz 2001). In

this chapter, a first attempt is presented to understand the role of cognitive and non-cognitive skills as well as work effort and demographic characteristics and their interaction on task performance.

This study produces some interesting outcomes. The analysis indicates that, in each level of quality of results, different skills contribute to the quality of work in crowdsourcing tasks. For example, this study shows that the effect of GDP per capita of a worker's country of origin and workers' education level, is significant only at low and moderate levels of quality of results, while in high levels disappears. This may be the aftereffect of the difference in socioeconomic status, among crowdsourcing workers, meaning the social and physical environment in which an individual lives and works and culture he is exposed to i.e., beliefs, values, behavior and material objects that constitute a people's way of life (Sackman, 2011).

Furthermore, quantile results provide also some valuable insights to the different relationships that the explanatory variables have with workers' quality of results. In particular, some variables such as a worker's, emotion stability, crowdsourcing experience, computer level and time of a tasks completion (work effort variable), have a great impact at quality of results regardless its increase. Other variables have a relatively constant effect on quality of results across different quality levels. These include a worker's levels of extraversion, age and general success rate. Lastly, the quantile regressions confirm that most variables showing no statistical significance under OLS remain not significant across the different quality of results ranges.

These results add to the body of research aiming at explaining workers' task performance. Even though variations in the value of workers' skills across different workers' quality of results ranges may have been considered intuitive beforehand, quantile regression provides a way to confirm these expectations and help us to extract significant conclusions and causal relations referring to this new, innovative and internet based labor and employment named crowdsourcing.

With the enhancement and development of internet technologies more online activity is increasing. This in turn will see more organizations turning to online communities and employ individuals for solutions. An

understanding of the nature of crowdsourcing and its aspects becomes vital and will help in creating or correcting its conducive environment because the already-maturing market for crowd labor remains almost entirely unregulated and unstandardized i.e., need for the research to shift towards building labor-appropriate reputation systems and auctions (Ipeirotis et al. 2011).

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Chapter 4

UNDERSTANDING TRADE SHOW VISITORS' OBJECTIVES AND VISUAL ATTENTION TO EXHIBITS

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ABSTRACT

This chapter explores how trade show visitors' objectives impact their visual attention to trade show booths and booth visit likelihood. Trade show attendees were recruited at an industry trade show in Florida. Attendees' objectives were noted as they evaluated a series of trade show booth images. We used eye-tracking cameras to record participants' visual attention while they viewed the series of booth images and answered visit likelihood questions. A follow-up survey collected additional demographic and firm demographic information. Results

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showed that visitor objectives impact their visual attention to and the likelihood of visiting trade show booths. Visitors whose objective was to 'scoping out the competition' visually attended the booth images the most and were more likely to visit the booths. Increased visual attention to the total booth resulted in an increased visit likelihood. Implications and directions for future research are discussed.

Keywords: business-to-business, eye tracking, trade shows exhibits, visitor objectives, visual attention

INTRODUCTION

Trade shows are important in business-to-business (B2B) marketing campaigns. They are effective, cost-efficient marketing tools that provide access to a large volume of potential customers at one time (Smith et al., 2004). Research indicates that trade shows are the second most important element (behind direct sales) in the marketing mix and serve to inform customers about new products, build brand recognition and equity, secure leads/orders, enhance goodwill, increase customer exposure to the company/products, aid in forward contract negotiation, and build relationships (Duncan, 2001; Geigenmuller, 2010; Sarmento et al., 2015; Sarmento and Simões, 2018; Tanner, 2002). In order to present the company and products in the best light and communicate effectively with potential customers, firms spend a fair amount of resources (e.g., money, labor) planning their presence (i.e., exhibits) at trade shows (Bellizzi and Lipps, 1984; Marx Group, 2017). In 2014, U.S. firms spent 41.3% of their marketing budgets on B2B exhibits with an expected return-on-investment (in terms of sales revenue to cost of exhibiting) of 45% (Marx Group, 2017). However, the Center for Exhibition Industry Research (2008) estimates that trade show exhibits reach less than 60% of potential clients. This is especially important since customers have limited exposure to booths and are exposed to large quantities of information and competing companies within that same time period which can result in information overload (Rinallo et al., 2010). In information overload situations, people employ heuristics to decrease their cognitive burden while making

decisions by relying on internal (i.e., top-down) and external (i.e., bottom-up) factors (Jackson and Farzaneh, 2012; Klausegger et al., 2007; Klingner, 2010; Reutskaja et al., 2011). Pairing visual attention metrics with these factors is one means of exploring how they influence and aid the decision-making process at trade shows. Specifically, people direct their visual attention to relevant stimuli when completing tasks (Ares et al., 2013; Nyamsuren and Taatgen, 2013; Orquin and Mueller Loose, 2013; Pieters and Warlop, 1999). Due to potential stimulus overload in the trade show setting (Rinallo et al., 2010) and visitors use of heuristics and visual cues to improve decision making efficiency (Klingner, 2010; Reutskaja et al., 2011), one could argue that a firm's trade show booth must attract visitors' visual attention to positively resonate with them and impact their subsequent behavior. To date, research has not employed visual attention methodologies to study trade show visitors' behavior. The current study explores how trade show exhibitors can improve attendees' booth visit likelihood by utilizing eye tracking technology to investigate the relationship between trade show visitors' show objectives, visual attention to the booth, and likelihood of visiting the booth.

Prior research demonstrates the strong impact of show attendees' objectives (i.e., buying and non-buying) on trade show participation, booth effectiveness, visitor satisfaction, and post-show behavior (Dekimpe et al., 1997; Gopalakrishna and Lilien, 1995; Gopalakrishna et al., 2010; Hansen, 1996; Kim et al., 2013; Kim and Malek, 2017; Sarmento and Simões, 2018; Smith and Smith, 1999; Solman, 2017). For instance, visitor objectives have been used to segment consumers and improve the effectiveness of target marketing promotions (Mair, 2010; Park, 2009; Rittichainuwat and Mair, 2012). At the show, targeted promotional strategies (e.g., attention grabbers, pre-show promotions, competitions, spectacular stands, larger booths, staff and their training) attract more foot traffic to exhibits (Dekimpe et al., 1997; Gopalakrishna and Lilien, 1995; Solman, 2017). Promotions and booth designs serve to increase foot traffic and booth "stickiness" (when attendees linger and acquire more information (Gilliam, 2015)). Both foot traffic and stickiness are important since they provide relationship building opportunities and increases visitors'

exposure to the company and products (Sarmento et al., 2015). Interestingly, non-buying objectives (e.g., seeing products, gathering information, etc.) have been shown to be more important than buying objectives (Smith et al., 2001). Cumulatively, these studies emphasize the importance of accounting for trade show visitor objectives in trade show research; however, many facets related to visitor objectives have not been addressed and more research is needed (Sarmento and Simões, 2018; Tafesse and Skallerud, 2017). Building upon this theme, to the authors' knowledge, this is the first research to incorporate visitor objects (a top-down factor) in the context of visual attention to the trade show booth (a bottom-up factor).

Thus far, research addressing trade show exhibits have primarily utilized surveys and theoretical bases from other lines of research (e.g., consumer behavior, marketing management, organizational studies; Tafesse and Skallerud, 2017; Sarmento and Simões, 2018). Additionally, studies tend to emphasize the exhibitor's perspective rather than the attendees' or organizers' perspectives (Sarmento and Simões, 2018). We propose utilizing eye tracking technology (ETT) to investigate the relationship between trade show attendees' objectives, their visual attention to the booths, and booth visit likelihood. Recently, consumer behavior research has utilized ETT to accurately record consumers' eye movements and investigate the relationship between visual attention and purchasing behavior (Ares et al., 2013; Armel et al., 2008; Behe et al., 2013; Khachatryan et al., 2017; Reutskaja et al., 2011; Zhang et al., 2009). Multiple studies have found consumers direct their gaze to specific information while determining purchase likelihood in retail settings (Ares et al., 2013, Behe et al., 2013; Khachatryan et al., 2017; Zhang et al., 2009). For instance, Armel et al. (2008) determined that fixations on appetitive foods increases end consumers' selection likelihood by 6-11%. To date, research addressing visitors' visual attention to trade show booths are limited. But, there is potential to use ETT in trade show research to investigate attendees' visual attention and subsequent behavior. This information is of interest because visual stimuli can affect consumers' impressions of firms (Tractinsky and Lowengart, 2007) and later decisions

(Janiszewski, 1993). Impressions have long-term effects on consumers' judgements and happen quickly (within 50 ms) but remain consistent over time (Lindgaard et al., 2006). Directly related to trade shows, multiple studies have demonstrated the positive impact booths have on overall appeal, product quality perceptions, firm reputation/impressions, and patronage/visit likelihood (Baker et al., 1994; Baker et al., 2002; Lin, 2004; Whitefield and Webber, 2011).

Given the resources committed to trade show exhibits (Marx Group, 2017), the buying power of attendees (Exhibit Surveys, 2017), and the link between visual attention and behavior (Ares et al., 2013; Armel et al., 2008; Behe et al., 2013; Khachatryan et al., 2017; Reutskaja et al., 2011; Zhang et al., 2009), the lack of utilizing ETT in trade show research is noteworthy. Incorporating ETT into trade show research is especially promising since consumers frequently select the best seen item (Reutskaja et al., 2011), meaning their visual attention may serve as an indicator of which booths they intend to visit and conduct business with. Therefore, research addressing ways to capture attendees' attention and attract more foot traffic would be valuable to firms exhibiting at trade shows.

This manuscript summarizes an exploratory study that was completed at a 2017 B2B trade show. Participants were recruited from an industry trade show in Florida. Participants viewed pictures of trade show booths and rated them based on their booth visit likelihood. While answering these questions, their eye movements were recorded. Data was analyzed using econometric models to identify the relationship between attendees' objectives, visual attention, and their visit likelihood. Understanding this relationship offers practical implications to trade show exhibitors since trade show participation is an important marketing practice that can entice potential customers and have long-term impacts on their perceptions and behaviors. However, to be effective, trade show booths must be visually noticed and visited. The next section provides a brief review on the theory of attention to visual marketing and the research hypotheses. Then the methodology is described, followed by the results, and conclusion.

Theory of Attention to Visual Marketing

Visual attention serves as a means for consumers to gather relevant information to complete a given task (Pieters and Warlop, 1999). Information that is not viewed cannot factor into the consumer's decision-making process and therefore does not impact behavior (Van Loo et al., 2018). Gaze scan paths rarely follow a set pattern, rather visual attention circles between different options while the consumer considers their choices (Orquin and Mueller Loose, 2013). As such, visual attention increases when stimuli are directly related to respondents' goals or the task (Ares et al., 2013). As task difficulty increases (such as with information overload situations), consumers' visual search behavior adjusts to reduce cognitive load by selectively viewing products and decreasing viewing duration while centering on preferred options (Reutskaja et al., 2011; Zhang et al., 2009). Shimojo et al. (2003) demonstrate how people increase their visual attention towards the preferred option (i.e., the gaze cascade effect). Multiple studies provide support to the gaze cascade effect by establishing that consumers increase their visual attention to important information which ultimately impacts choice (Behe et al., 2014; Rihn et al., 2016; Van Loo et al., 2015).

The gaze cascade effect is partially explained by the theory of visual attention and the theory of attention to visual marketing. Bundensen (1990) was the first to introduce the theory of visual attention which states that visual attention is filtered, sorted, processed, and stored in short term memory for future use. Due to limited memory capacity, consumers are very selective in what they view and store. More recently, visual attention and marketing were combined in the theory of attention to visual marketing (Wedel and Pieters, 2006; Wedel and Pieters, 2008). This theory posits visual attention allows people to select, focus and cognitively evaluate elements of the scene. They argue that attention is driven by top-down (goal-relevant) and bottom-up (stimuli-driven) factors. Top-down factors include consumer goals and expectations while bottom-up factors are actual attributes of the stimuli (exhibit factors like brand, design, signage, etc.) Conversely, attention driven by top-down factors is voluntary and

relates to stimuli with greater utility (Koch, 2004; Orquin and Mueller Loose, 2013). Both top-down and bottom-up factors influence visual saliency, cognitive processing, and decisions (Orquin and Mueller Loose, 2013). When visual saliency and goals align, consumers' cognitive demand decreases and decision making is easier (Nyamsuren and Taatgen, 2013; Orquin and Mueller Loose, 2013).

The factors included in the theory of attention to visual marketing have been studied in business-to-consumer (B2C) settings (e.g., retail, marketing) (Ares et al., 2013; Aribarg et al., 2010; Armel et al., 2008; Orquin and Mueller Loose, 2013; Piqueras-Fiszman et al., 2012; Rahimi, 2012; Wedel and Pieters, 2000; Zhang et al., 2009); but, rarely in the B2B context. For example, in the food industry, multiple studies have found that end consumers direct their gaze to important, relevant information or choices when considering different products (Ares et al., 2013; Armel et al., 2008; Piqueras-Fiszman et al., 2012; Rahimi, 2012). This is partially attributed to consumers eliminating irrelevant choices (Reisen et al., 2008) while also using visual stimuli as "external memory space" meaning people fixate on information as needed (Orquin and Mueller Loose, 2013). Using visual cues as external memory space is advantageous to consumers because it reduces the demand on their working memory during decision-making. In advertisements and promotions, additional visual attention has been positively correlated to increased probability of brand memory (Wedel and Pieters, 2000) and sales (Zhang et al., 2009). Likely, some of these concepts transfer to the B2B setting; however, in the B2B context the firm representative's objectives reflect the firm's objectives rather than personal goals. Given the strong influence of objectives on trade show visitors' behavior (Dekimpe et al., 1997; Gopalakrishna and Lilien, 1995; Gopalakrishna et al., 2010; Hansen, 1996; Kim et al., 2013; Kim and Malek, 2017; Sarmento and Simões, 2018; Smith and Smith, 1999; Solman, 2017), one would expect that different objectives in the B2B setting (when compared to personal consumption settings) impact visual attention and behavior differently. This research addresses visual attention in the B2B setting. The overall purpose of this manuscript is to address the association between trade show visitors' objectives and their likelihood of

visiting different booths. Moreover, in addition to examining visitors' motives and booth visit likelihood, their visual attention to the booths and products within the booths are investigated. This research is unique in that it incorporates ETT to study the relationship between bottom-up (booth displays) and top-down (visitor objectives) factors at a B2B trade show. Furthermore, it is one of the first to investigate B2B clients' behavior using ETT.

Based on the existing literature, four hypotheses were developed. First, due to consumer heterogeneity (Gopalakrishna et al., 2010), visitors' visual attention will vary between the booth image, products on display, and brand/logo stimuli (H1) meaning their visual attention to the booth, products, and brands/logos should be significantly different. Secondly, one would expect that visitors' trade show objectives would influence the information that they seek and use while deciding which booths to visit. If this were not the case, there would be no significant differences in visual attendance regardless of why attendees are visiting the show. We hypothesize that visitors attending the show for different reasons will exhibit different visual search behaviors (H2). Third, given that visitors attend trade shows for different reasons (Kim et al., 2013), one would anticipate that participants' trade show objectives will influence their booth visit likelihood (H3). If this hypothesis is not true, there should be no significant differences on booth visit likelihood when considering different objectives. Lastly, since visual attention reflects processing and weighing of options in the decision-making process (Ares et al., 2013; Armel et al., 2008; Behe et al., 2013; Khachatryan et al., 2017; Reutskaja et al., 2011; Zhang et al., 2009), one would expect visitors' visual attention to influence their likelihood of visiting a trade show booth (H4). A graphical representation of conceptual framework is presented in Figure 1.

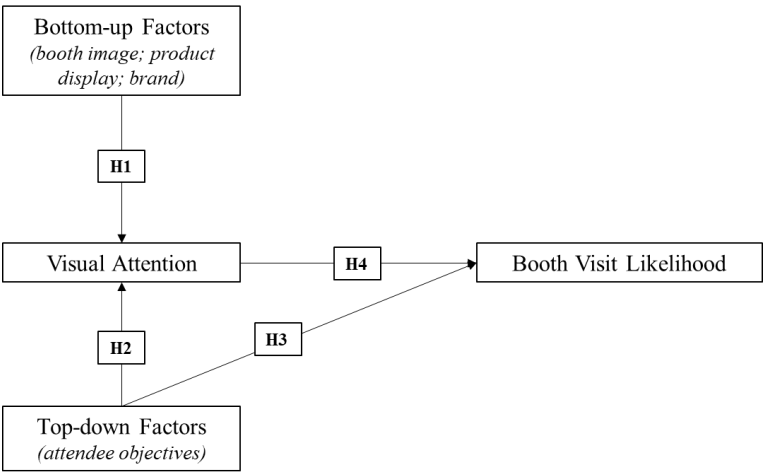

Figure 1. Conceptual Framework of the Experiment.

This study provides several unique contributions to the existing literature. First, this study adds to the research on how visitor objectives' influence behavior by incorporating visitors' visual attention and booth visit likelihood variables. To date, this method combination has not been utilized in the B2B context. Relatedly, many behavioral studies utilizing ETT are in the B2C context while the B2B arena has been largely ignored. Several visual attention and marketing theories should hold in the B2B context, but this has not been investigated. Lastly, research addressing trade show visitor objectives primarily focuses on those objectives and how they impact behavior without including a measure of bottom-up factors. Therefore, the inclusion of both top-down and bottom-up factors is unique.

METHODS

This experiment quantifies industry-specific trade show visitors' show objectives and visual attention to the booths. This section discusses the experimental set-up and procedure, gaze data, and econometric analysis.

Experimental Set-up and Procedure

Data was collected at the 2017 Tropical Plant Industry Exhibition (TPIE) from January 18 – 20, 2017, in Fort Lauderdale, Florida. TPIE is an industry trade show that showcases the latest products and trends in the tropical plant industry. Florida is of interest because it is the fourth largest state (behind Nevada, Texas, and California) in terms of exhibition space in the U.S. with 4.77 million square feet available (Statista, 2018). To address the research objective, pictures were taken of 17 TPIE booths prior to the show floor opening to attendees. For consistency purposes, only booths selling plants (versus equipment, chemicals, media, etc.) were included in the experiment.

The 17 images were uploaded on a computer with a stationary eye tracking camera (Tobii X2-60) attached at the base of the monitor (Figure 2). A 23-inch monitor with 1920 x 1080-pixel resolution was used to display the images and collect data. After each image, a 7-point Likert scale was used to elicit participants' likelihood of visiting the booth (1 = very unlikely; 7 = very likely). A fixation cross was shown for 2 seconds between each image to standardize participants' initial fixation location.

Figure 2. Experimental Set-up Demonstrating the Postiion of the Eye Tracking Camera.

A total of 30 trade show attendees participated in the experiment. At the beginning of the experiment, participants read and signed the informed

consent form and were given instructions. Then, the eye tracking camera was calibrated using a 5-point system for each participant. After the eye tracking portion of the experiment, participants completed a brief survey to collect personal and business demographic information.

Trade Show Objectives

Participants were provided an existing list of trade show attendance objectives and selected up to 3. The list was developed from existing literature on trade show attendance objectives (Duncan, 2001; Geigenmuller, 2010; Kim et al., 2013; Sarmento et al., 2015; Tanner, 2002) and included making contracts, purchasing product(s), scoping out the competition, obtaining new product information/ideas, visiting and networking, and attending educational sessions. An 'other' category was also provided to capture all additional objectives for attending the trade show. For analysis purposes, the objectives are coded as binary where 1 indicates the objective was selected and 0 otherwise.

Gaze Data

In order to extract gaze data from the images, areas of interest (AOIs) were generated. AOIs are geometric shapes drawn around visual stimuli of interest in each image and are used to extract visual attention metrics for individual image features. For instance, in this experiment AOIs were generated for the entire booth image and around each booth's brand/logo and products, where applicable. The number of fixations (i.e., fixation counts) were extracted for each AOI. A fixation occurs when the eye is relatively still for 80-100 ms and focused on a single stimulus (Buscher et al., 2009). Fixation counts are the cumulative number of fixations per AOI. Fixation counts were used since additional fixations on stimuli have been correlated with increased importance (Orquin and Mueller Loose, 2013;

Rihn et al., 2016), perceptions (Ares et al., 2013; Khachatryan et al., 2017), and product selection (Armel et al., 2008; Reutskaja et al., 2011).

In this study, the mean number of fixations per AOI was estimated. These estimates were used in the econometric analysis where a significant positive fixation count coefficient indicates that for each additional fixation the attendees' visit likelihood increased and vice versa for a significant negative coefficient. The mean time to first fixation is also provided. Time to first fixation is the duration of time (in seconds) between when the image is viewable and the first fixation within each AOI occurs. It is used as an indication of how well the stimuli attracts visual attention (Buscher et al., 2009; Underwood and Foulsham, 2006).

Econometric Analysis

Since the dependent variable (booth visit likelihood) was measured using an ordinal scale (7-point Likert scale), an ordered logit model was used to assess the relationship between different visitor objectives and visual attention to booths. The ordered logit model was developed by McElevy and Zavoina (1975) where the error component in the ordered probit model was changed to a standard logistic distribution rather than a standard normal distribution. Hence, the variable parameters are equal to the distance between the ordinal scale values. For model specifics and a more detailed description on ordered logit models, see Long and Freese (2006) or Khachatryan et al. (2017).

Summary Statistics

A total of 30 trade show attendees participated in the experiment. Participants averaged 56 years old and 59% were male (Table 1). Although participants exhibited a wide variety of years as managers/decision makers within the industry, their average number of years of experience was 25 years. The majority of participants' firms were classified as 'other' (e.g.,

consultant, writer/editor/speaker/media, public garden, finance, government, garden manager/educator, designer), followed by growers, interiorscapers, brokers/marketers, landscape services, and garden centers/retailers. Attendees' firms primarily sold to end customers (37%), followed by 'other' (30%), growers (20%), garden centers/other retailers (6%), wholesalers/marketer (3%), and brokers (3%). Regarding firms' 2016 gross income, the mean income was $4.5M with 33% of participants' firms earning $1M to $5M, 23% did not know, 17% between $0-$250k, 10% in the $250k to $500k range, 7% earned more than $50M or indicated 'other,' and 3% between $10M and $20M.

Table 1. Summary socio-demographics (n = 30)

Variable	Definition	Mean (SE)
Age	Age of participant in years.	55.862 (12.78)
Gender	1 = male; 0 = female	0.586 (0.501)
Years of Experience	Participant's number of years as a decision maker / manager in the green industry.	25.05 (15.508)
Firm Type	Type of firm where the participant works. 1 = Other 2 = Grower 3 = Interiorscaping 4 = Broker/Marketer 5 = Landscape Services 6 = Garden Center/Retail	 46% 16% 11% 11% 8% 8%
Primary Customers	The primary customers of the participant's firm. 1 = End Customer 2 = Other 3 = Growers 4 = Wholesaler/Marketer 5 = Broker 6 = Garden Center/Other Retailers	 37% 30% 20% 3% 3% 6%
2016 Gross Income	Gross income of the participant's firm in 2016 (in $1,000s).	4558.333 (13540.6)

RESULTS

Attendance Objectives

Visitors selected a variety of reasons for attending the trade show (Figure 3). The main objective selected was to visit and network (80%), followed by obtain new product information and ideas (77%), and attend education sessions (50%). Less frequently cited objectives included making contracts (27%), other (20%), purchase products (13%), and scoping out the competition (10%). The emphasis on alternative attendance objectives (i.e., beyond buying/selling products) indicates that the sample likely included a fair number of "peripheral market actors." As discussed by Tafesse and Skallerud (2017), peripheral market actors in trade show research are important players but often overlooked.

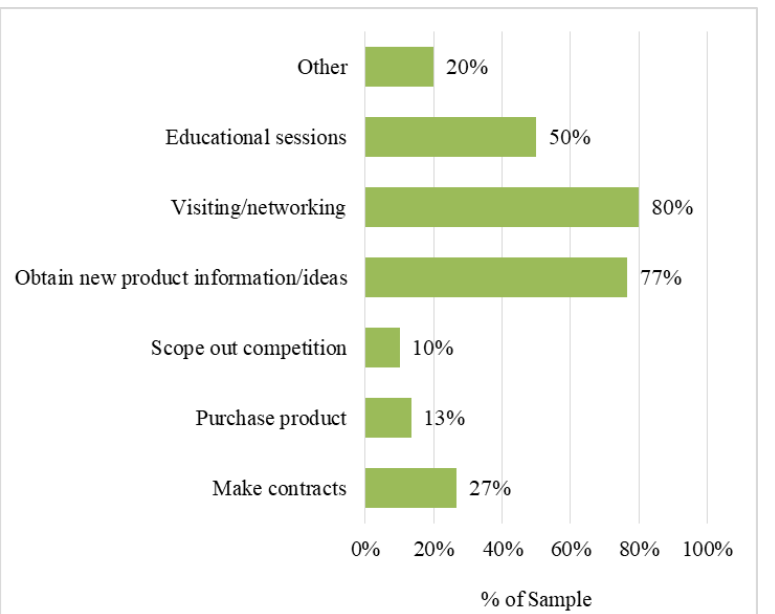

Figure 3. Respondents' Trade Show Objectives.

Visual Attention

Regarding visitors' gaze data in each AOI, they had the highest number of fixations on the total booth (22.7 fixations), followed by the products (12.5 fixations), and brand/logo (2.3 fixations), supporting hypothesis 1 (Figure 4). T-tests demonstrate that visitors' objectives for attending the trade show influenced their visual attention to the booths, supporting hypothesis 2 (Table 2). Specifically, visitors attending the show to scope out the competition viewed the booths the most (32.2 fixations; p-value < 0.001; Figure 5). Visitors that were attending for the educational sessions (23.99 fixations), visiting/networking (23.1 fixations), or to obtain new product information/ideas (22.2 fixations) had the next highest number of fixations on the booths.[1] Visitors attending to make contracts (20.7 fixations) or for other reasons (19.9 fixations) viewed the booths the next most frequently. Lastly, those attending to purchase products viewed the booths the least (12.5 fixations).

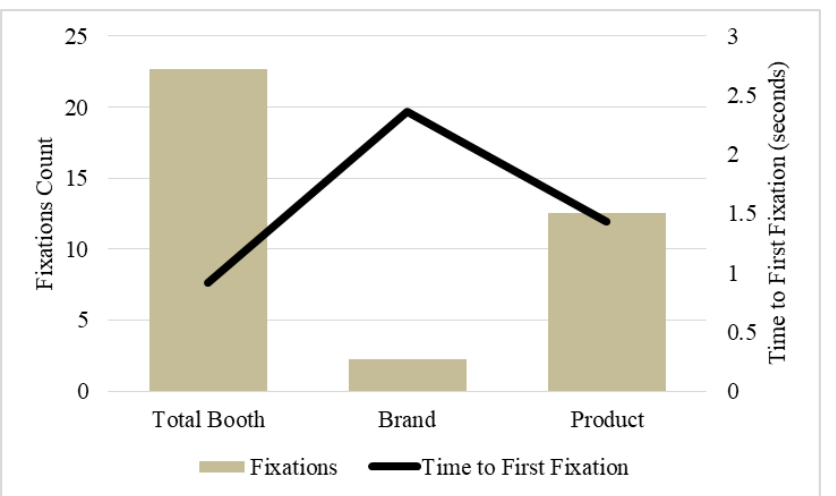

Figure 4. Visitors' Fixations and Time to First Fixation on the Trade Show Booths, Brands, and Products.

[1] The fixation counts were not significantly different between these three groups.

Table 2. T-test values for total booth fixation counts

	Make contracts[a]		**Purchase product[a]**		**Scope out competition[a]**		**Obtain new product information or ideas[a]**		**Visiting & networking[a]**		**Educational sessions[a]**		**Other[a]**	
Make contracts	-		4.756	***	-5.781	***	-1.627		-2.757	**	-3.071	**	0.559	
Purchase product	-		-		-15.333	***	-6.56	***	-7.337	***	-7.833	***	-5.681	***
Scope out competition	-		-		-		5.911	***	5.431	***	4.995	***	8.213	***
Obtain new product information or ideas	-		-		-		-		-1.165		-1.8		1.799	
Visiting & networking	-		-		-		-		-		-0.786		2.609	**
Educational Sessions	-		-		-		-		-		-		3.107	**
Other	-		-		-		-		-		-		-	

[a] ***, **, * indicate significance at <0.001, 0.010, and 0.050, respectively.

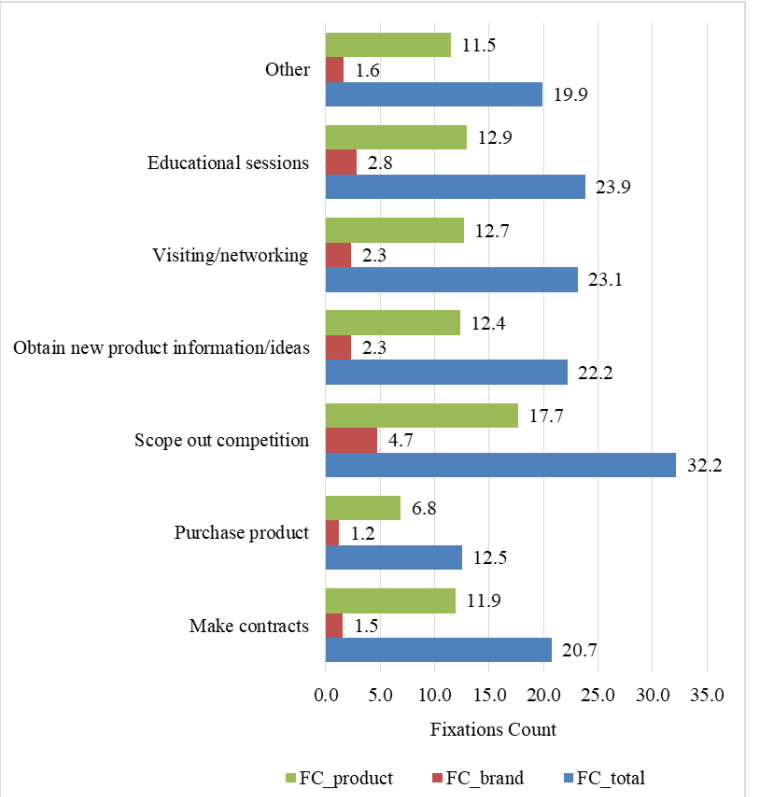

Figure 5. Number of Gaze Fixations, by Trade Show Objective.

Overall, the visual attention results are not surprising since the total booth is the largest area with products often covering the second largest area of the images. Furthermore, the products frequently consisted of bright colored foliage plants and flowers which would likely attract more visual attention than other booth features. To demonstrate this phenomena, Figure 6 provides mean time to first fixation results for the AOIs. Not surprisingly, the total booth and products were fixated on sooner than the brands/logos (as indicated by the lower time to first fixation values) demonstrating they attract visual attention more quickly. Another possible explanation is provided by Lee and Ahn (2012) who found consumers will ignore visual objects (such as brands/logos) if they are irrelevant to the task (here, determining booth visit likelihood).

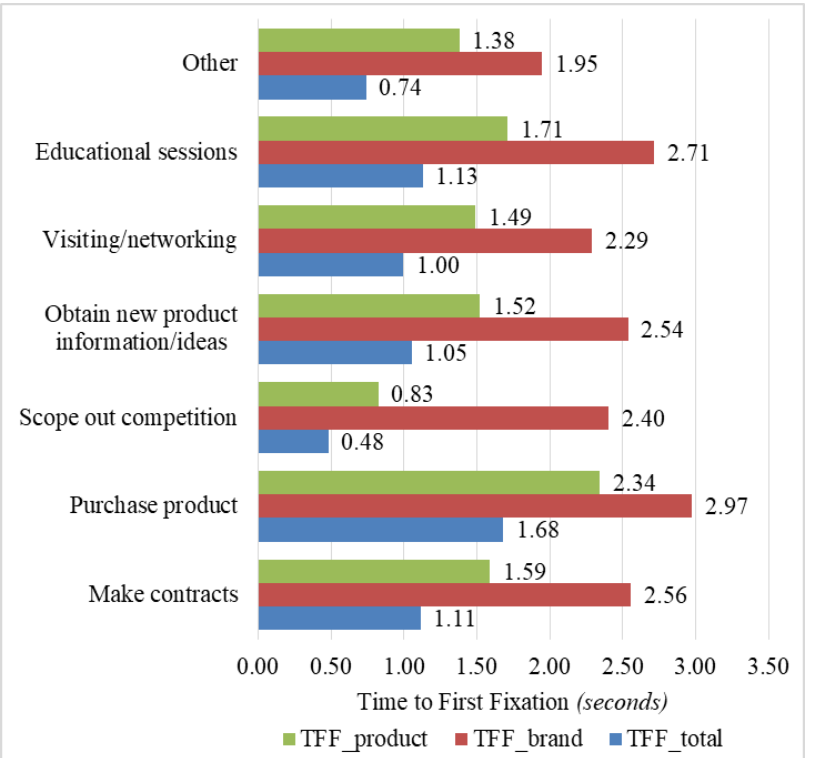

Figure 6. Time to First Fixation (in seconds), by Trade Show Objective.

OLS regression was used to further test hypothesis 2 that visitors' trade show objectives impact their visual attention. The fixation counts on the total booth, displayed products, and brand/logo were used as the independent variables resulting in three models. The 'other' objective category was used as a base for comparison. For the total booth, fixation counts increased for visitors that were attending to scope out the competition, visit/network, attend educational sessions, and/or negotiate contracts when compared to other reasons (model 1; Table 3). Total booth fixation counts decreased for visitors who attended to purchase products or gather new product ideas. Older respondents and male respondents fixated on the total booth less than younger or female respondents. As income increased, fixations increased.

Table 3. The impact of trade show objectives on visitors' visual attention to booths

	Model 1			Model 2			Model 3		
	Total Booth Fixations			Displayed Products Fixations			Brand/Logo Fixations		
Objective	**Coef.[a,b]**	**Std. Err.**		**Coef.[a,b]**	**Std. Err.**		**Coef.[a,b]**	**Std. Err.**	
Make contracts	2.131	1.254	*	1.755	0.758	**	-0.266	0.143	*
Purchase product	-4.858	1.873	**	-3.927	1.133	***	0.804	0.214	***
Scope out competition	16.623	2.111	***	7.612	1.277	***	4.433	0.241	***
Obtain new product information/ideas	-6.703	1.502	***	-2.288	0.908	**	-1.556	0.171	***
Visiting/networking	4.862	1.550	**	1.794	0.938	*	1.354	0.177	***
Educational sessions	3.711	1.258	**	1.176	0.761		0.732	0.143	***
Other	---			---			---		
Socio-demographics									
Age	-0.281	0.068	***	-0.165	0.041	***	-0.074	0.008	***
Gender	-3.946	1.064	***	-2.237	0.644	***	-0.496	0.121	***
Years' experience	0.020	0.058		0.009	0.035		0.016	0.007	**
Income	0.000	0.000	**	0.000	0.000		0.000	0.000	***
Constant	38.086	3.719	***	21.975	2.249	***	5.751	0.424	***

[a] ***, **, and * indicates significance at p-value <0.100, 0.050, and 0.001 when compared to the base objective ("other").

[b] Linear regression was used to estimate coefficients (regress command in Stata).

Table 4. The impact of visitors' objectives and fixations on booth visit likelihood

	Model 4			Model 5		
Objective	**Coef.[a,b]**	**Std. Err.**		**Coef.[a,b]**	**Std. Err.**	
Make contracts	0.431	0.230	*	0.368	0.241	
Purchase product	0.504	0.324		0.773	0.364	**
Scope out competition	1.705	0.418	***	2.308	0.587	***
Obtain new product information/ideas	-1.013	0.284	***	-1.140	0.346	***
Visiting/networking	1.208	0.286	***	1.381	0.334	***
Educational sessions	-0.220	0.234		-0.204	0.255	
Other	---			---		
Socio-demographics						
Age	0.068	0.013	***	0.054	0.014	***
Gender	-0.031	0.196		-0.028	0.204	
Years' experience	-0.068	0.011	***	-0.065	0.011	***
Income	0.000	0.000	**	0.000	0.000	***
Fixation Counts (FC)						
FC_total booth	---			0.105	0.060	*
FC_products displayed	---			-0.130	0.099	
FC_brand/logo	---			-0.303	0.093	***
/cut1	-2.244	0.793		-2.968	0.934	
/cut2	-0.815	0.709		-1.523	0.863	
/cut3	0.301	0.689		-0.393	0.846	
/cut4	1.217	0.685		0.535	0.842	
/cut5	2.121	0.689		1.457	0.845	
/cut6	3.249	0.701		2.618	0.854	

[a] ***, **, and * indicate significance at p-value <0.001, <0.050, and <0.100 when compared to the base variables ("other" for objectives).

[b] Ordered logit models were used to estimate coefficients (ologit command in Stata).

Regarding participants' fixations on the displayed products, visitors who were attending the trade show to scope out the competition, make contracts, or visit/network fixated on the products more than visitors attending for other reasons (model 2; Table 3). Visitors who were attending to purchase products and gain ideas fixated on the products less than those visiting for other reasons. Similar to the total booth, older respondents and male respondents fixated on the products less than younger or female respondents.

The company brand/logo was fixated on more frequently by visitors who were scoping out the competition, visiting/networking, purchasing products, or attending educational sessions when compared to those attending for other reasons (model 3; Table 3). Visitors attending to gather ideas and negotiate contracts were less likely to fixate on the brand/logo than those attending for other reasons. Older and male participants were less likely to fixation on the brand/logo. However, those with more years' experience and higher incomes were more likely to fixate on the brand/logo. Together, hypothesis 2 is supported.

Econometric Model Results

Ordered logit models were used to test hypotheses 3 and 4. Specifically, booth visit likelihood (1 = very unlikely; 7 = very likely) was used as the independent variable and "other" was used as the base for comparison among the attendance objectives. Two models were conducted where the first (model 4) included the visitor objectives and socio-demographic variables (to address hypothesis 3) while the second model (model 5) expanded the first model by including fixations on the total booth, displayed products, and brand/logo (to assess hypothesis 4).

Model 4 represents the impact of visitors' objectives and socio-demographics on booth visit likelihood (Table 4). For individuals who are attending the trade show to check out the competition, one expects a 1.70 increase in their booth visit likelihood when compared to other objectives if all other variables are held constant. For visitors attending to visit and

network, an increased booth visit likelihood of 1.21 is observed. Visitors intending to make contracts also have an increased likelihood of visiting a booth. Conversely, those who are attending the trade show to gather ideas are 1.01 times less likely to visit the booths. Visitors who are older and have higher income means are more likely to visit the booths while those with more years' experience are less likely to visit the booths. Collectively, these estimates support hypothesis 3.

Model 5 goes a step further by incorporating visual attention data (Table 4). Again, one observes that checking out the competition has the strongest, significant impact on booth visit likelihood (coefficient = 2.31), followed by visiting/networking. Unlike model 4, making contracts is now insignificant while purchasing products is significant and positive indicating increased booth visit likelihood when compared to other objectives. However, gaining ideas is negative and significant demonstrating a decreased booth visit likelihood. Older visitors with higher incomes are more likely to visit the booths while individuals with more years' experience are less likely to visit the booths. For each additional fixation on the total booth, visitors are 0.10 more likely to visit the booth demonstrating the importance of having an "eye catching" display, supporting hypothesis 4. Interestingly, there is an inverse relationship between fixations on the brand/logo and booth visit likelihood (-0.30).

CONCLUSION

This manuscript addresses the relationship between trade show visitors' motives for attending a trade show, their visual attention to the booths, and their booth visit likelihood at a B2B trade show. Results provide several unique contributions. First, although studies have utilized Theory of Attention to Visual Marketing in other fields of research (e.g., marketing, retail), it has not been addressed in the trade show context. Secondly, results support that trade show visitor goals impact their behavior. Previously, this has been addressed using pre- and post-show

surveys. Here, a new biometric measure (i.e., eye tracking) was utilized to accurately record behavior and cross tabulate results based upon the visitors' overall objectives for the show. For instance, visitors intending to gather new product information and ideas were less likely to visit the booths and were less likely to fixate on the booths, displayed products, and brands/logos. Conversely, visitors who were scoping out the competition were more visually attentive to the booths and were more likely to visit the booths.

Theoretical Implications

This study demonstrates that both bottom-up and top-down factors impact visitors' behavior and visual attention at B2B trade shows. Top-down factors (i.e., objectives) influence visual attention to different exhibit elements (booths, products, brand/logo). Bottom-up factors (i.e., products displayed, brand/logo) impact visit likelihood. In general, the top-down factors seem to have a larger influence than the bottom-up factors on visit likelihood. This suggests that in the B2B context, the overall objective (which likely reflects the firm's primary attendance goal) is more likely to influence the visitor's booth visit likelihood than exhibit-specific attributes. However, exhibits that capture additional visual attention are on attendees' radars and are more likely to be visited than those who capture less attention.

Managerial Implications

Trade show booths are an important marketing component where firms allocate a substantial portion of their economic resources. Results highlight how different objectives drive visual attention to trade show booths, displayed products, and the brand/logo. When considering how to design one's trade show booth, these results could help managers as they develop their trade show booths. For instance, the econometric results indicate that

attracting visual attention increases the likelihood of that attendee visiting the booth. The implication is that developing an eye-catching display may result in increased foot traffic and business. On average, 55% of participants' total booth fixations were spent looking at the displayed product while 10% of the fixations were on the company's brand/logo which highlights the importance of both of these marketing components.

LIMITATIONS AND FUTURE RESEARCH

Although this is an exploratory study that provides a roadmap for future studies, there are several limitations that should be mentioned. First, a small, localized sample at a single trade show was used to facilitate the use of the ETT. Thus, the extrapolation of the results to other regions, product categories, and industries should be approached cautiously; however, this study can serve as an outline for future research addressing how visitors' goals impact behavior through the use of ETT. Research could expand on this study by using similar methods at different trade shows with different products and audiences (i.e., international). Multiple study locations could also enable collecting a larger sample size.

Subsequent studies could also facilitate collecting data equally from different types of trade show attendees. For instance, participants in this study were primarily not buyers. However, depending upon the industry and type of trade show, the trade show floor is an important contract negotiation/buying opportunity with an eclectic mix of clients. Therefore, investigating the differences between attendees with buying and non-buying objectives could provide additional managerial insights to exhibiting firms as well as trade show agencies and sponsors.

Lastly, this research addressed trade show visitors in the B2B context. Although outside the scope of this study, additional studies in the B2C arena could serve as an interesting contrast to B2B sellers and provide firms with additional insights in attracting end consumers. Theories and research using eye tracking in the retail setting could be used to frame research questions in a B2C trade show booth study.

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Chapter 5

R&D EXPENDITURES IN CEE AND CIS COUNTRIES: TRENDS, ISSUES AND RESEARCH HORIZON

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ABSTRACT

The market transformation of the former socialist countries of the Central and Eastern Europe and the former USSR posed a serious challenge to integrate in the world economy in various dimensions. The ability to stand the technological competition is one of the most crucial ones, which is important at all levels – in domestic market, within regional economic unions and within the whole world economy. The countries of Eastern and Central Europe and the former USSR followed K-shape in their R&D aggregate national financing paths in the course of development after the end of transformation recession in the years of 2000-2018. The proposed chapter aims to summarize some trends in R&D expenditures in post-socialist countries in the course of market transformation on the basis of comparative statistical analysis of relative R&D effort in this group of countries and to outline some important

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issues which are to be investigated more closely in future research efforts on the matter. The research methodology of the chapter uses the comparative analysis of relative R&D input measured as % of GDP throughout the period of 2000-2018 both inside the group and with some external countries.

Keywords: central and eastern Europe, commonwealth of independent states, development, financing, innovation, R&D

1. INTRODUCTION

The market transformation of the former socialist countries of the Central and Eastern Europe and the former USSR posed a serious challenge to integrate in the world economy in various dimensions. The ability to stand the technological competition is one of the most crucial ones, which is important at all levels – in domestic market, within regional economic unions and within the whole world economy. This is really complex multidimensional phenomenon with several phases of which R&D has its own importance since it forms the basis for next phases – this however doesn't imply the one-way linear causality.

In paragraph 2 we discuss the available data on the R&D financing in the CEE and CIS countries in the period of 2000-2018 at the macroeconomic level and present the results of comparative analysis. In paragraph 3 we go on with pointing out of some issues which are important for further research in light of the relevant literature. Finally, the chapter concludes. The research methodology of the chapter uses the comparative analysis of relative R&D input measured as % of GDP throughout the period of 2000-2018 both inside the group and with some external countries.

2. R&D EXPENDITURES: DIVERSE TRENDS IN CEE AND CIS COUNTRIES

2.1. On Some Important Trends

Table 1 of the Supplement provides the data on Gross Expenditures on R&D (GERD) as percent of GDP for each country for the period of the years 2000-2018. The figures are drawn from UNESCO Institute of Statistics database, which provides the data coverage for all UN member states. The figure directly shows the ratio of monetary value of aggregate input in R&D to monetary value of final aggregate output of the economy. The choice of the time period is determined by the end of transformation recession in both CEE and CIS countries.

The simple statistical computation allows drawing some immediate conclusions. First, the group follows the K-shape in dynamic change of levels of R&D effort relative to the economy – some countries experienced increase and some countries demonstrated decrease throughout the period. The divergence is supported also by basic descriptive statistics such as variance measured as difference between maximum and minimum for each year (Table 2 of the Supplement). Second, on average there is no big increase of R&D effort for the group as a whole measured by mean and median. And third, all countries which are classified as advanced economies - Czech Republic, Slovakia, Lithuania, Latvia, Estonia and Slovenia – increased the aggregate national R&D effort throughout the analyzed period.

On international context. Table 3 of the Supplement provides the data on GERD as % of GDP for two countries of Western Europe – Germany and Italy – and two countries important participants of international technological competition outside Western Europe and North America – Israel and South Korea. The direct comparison makes it immediately clear that on average the analyzed group of countries lags behind not only the most innovative economies outside of Anglo-Saxon world, but also such country as Italy. It's worth to note that the largest economy in the group,

the Russian Federation experienced the decrease in relative aggregate national R&D effort throughout the whole period of 2000-2018.

3. DISCUSSION

As was briefly sketched by K. Marx and later developed by J. Schumpeter, the dynamic technological competition plays the key role in the processes of growth and development in the capitalist market economy [3, 5, 8, 9, 10]. The process of creative destruction allows installing the new technologies, products and social forms of economic organization and management as replacement of the obsolete ones – the process which is in actual reality is rather painful and complicated by various kinds of instability and crises.

While there is vast both theoretical and empirical literature on the R&D expenses at the firm and industry level which highlights important determinants and subsequent economic effects of their magnitude and structure in the course of technological competition, there is still much less understood in this respect with regard to macroeconomic level. Such situation has, in our view, the objective reasons. The developed market economy has heterogeneous economic agents from different institutional sectors who have different objectives, incentives and economic and financial constraints. It follows that the aggregate outcome should depend on the interrelationships between these agents in institutional and functional context.

The market transition means that the newly emerging market economies face the challenge to develop the institutions and functional mechanisms which support the technological competition on the whole and the R&D activities as part of it on the new market principles which differ substantially from the previous ones in the socialist system. The most important distinction is that major share of economic activities is transferred from the state sector to the private sector, and the private firms start to play the fundamental role in the processes of innovation in the course of national and global technological competition.

Table 1. Gross Expenditures on R&D (GERD) as percent of GDP for each country for the period of the years 2000-2018

GERD as % of GDP by years 2000-2018	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Albania	..	..	..	..	..	..	..	0.09	0.15	..	..	..	..	..	..	..	..	..	..
Armenia	0.19	0.28	0.25	0.32	0.26	0.26	0.24	0.21	0.22	0.29	0.24	0.27	0.24	0.22	0.24	0.25	0.23	0.23	0.19
Azerbaijan	0.34	0.34	0.30	0.32	0.30	0.22	0.17	0.17	0.17	0.25	0.22	0.21	0.21	0.21	0.21	0.22	0.21	0.18	0.18
Belarus	0.72	0.71	0.62	0.61	0.63	0.68	0.66	0.96	0.74	0.62	0.67	0.68	0.65	0.65	0.51	0.50	0.50	0.58	0.60
Bosnia and Herzegovina	..	..	..	0.02	0.02	0.03	0.02	0.03	0.02	0.02	..	..	0.27	0.32	0.26	0.22	0.22	0.20	0.19
Bulgaria	0.50	0.45	0.46	0.47	0.47	0.44	0.44	0.43	0.45	0.49	0.57	0.53	0.60	0.64	0.79	0.95	0.77	0.74	0.76
Croatia	1.05	0.92	0.95	0.95	1.03	0.86	0.74	0.79	0.89	0.84	0.74	0.75	0.75	0.81	0.78	0.84	0.86	0.86	0.97
Czechia	1.11	1.10	1.10	1.15	1.15	1.17	1.23	1.30	1.24	1.29	1.34	1.56	1.78	1.90	1.97	1.93	1.68	1.79	1.93
Estonia	0.60	0.70	0.71	0.76	0.85	0.92	1.11	1.06	1.25	1.39	1.57	2.28	2.11	1.71	1.42	1.46	1.25	1.28	1.40
Georgia	0.22	0.24	0.19	0.22	0.24	0.18	..	..	..	..	..	..	..	0.08	0.17	0.30	0.29	0.27	0.28
Hungary	0.79	0.91	0.98	0.92	0.86	0.92	0.98	0.96	0.98	1.13	1.14	1.19	1.26	1.39	1.35	1.35	1.19	1.33	1.53
Kazakhstan	0.18	0.22	0.26	0.25	0.25	0.28	0.24	0.21	0.22	0.23	0.15	0.15	0.17	0.17	0.17	0.17	0.14	0.13	0.12
Kyrgyzstan	0.16	0.17	0.20	0.22	0.20	0.20	0.23	0.23	0.19	0.16	0.16	0.16	0.17	0.15	0.13	0.12	0.11	0.11	0.10
Latvia	0.44	0.40	0.41	0.36	0.40	0.53	0.65	0.55	0.58	0.45	0.61	0.70	0.66	0.61	0.69	0.62	0.44	0.51	0.64
Lithuania	0.58	0.67	0.66	0.66	0.75	0.75	0.79	0.80	0.79	0.83	0.79	0.91	0.90	0.95	1.03	1.04	0.84	0.90	0.94
Mongolia	0.19	0.27	0.25	0.25	0.27	0.24	0.19	0.24	0.34	0.30	0.24	0.23	0.24	0.23	0.22	0.15	0.18	0.13	0.10
Montenegro	..	..	..	0.80	1.02	0.92	1.23	1.15	..	..	..	0.31	..	0.37	0.36	0.37	0.32	0.35	0.36

Table 1. (Continued)

GERD as % of GDP by years 2000-2018	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
North Macedonia	0.42	0.29	0.24	0.21	0.23	0.23	0.19	0.17	0.22	0.20	0.22	0.22	0.33	0.44	0.52	0.44	0.44	0.35	0.37
Poland	0.64	0.62	0.56	0.54	0.55	0.56	0.55	0.56	0.60	0.66	0.72	0.75	0.88	0.87	0.94	1.00	0.96	1.03	1.21
Republic of Moldova	..	..	..	0.32	0.35	0.40	0.41	0.55	0.53	0.53	0.37	0.34	0.35	0.30	0.31	0.31	0.28	0.25	0.25
Romania	0.37	0.39	0.38	0.40	0.39	0.41	0.46	0.51	0.55	0.44	0.46	0.50	0.48	0.39	0.38	0.49	0.48	0.50	0.50
Russian Federation	1.05	1.18	1.25	1.29	1.15	1.07	1.07	1.12	1.04	1.25	1.13	1.02	1.03	1.03	1.07	1.10	1.10	1.11	0.98
Serbia	0.85	0.30	0.64	0.49	0.29	0.40	0.44	0.58	0.67	0.82	0.70	0.68	0.85	0.68	0.72	0.81	0.84	0.87	0.92
Slovakia	0.64	0.62	0.56	0.56	0.50	0.49	0.47	0.45	0.46	0.47	0.61	0.66	0.80	0.82	0.88	1.16	0.79	0.89	0.84
Slovenia	1.36	1.47	1.44	1.25	1.37	1.42	1.54	1.43	1.63	1.81	2.05	2.41	2.56	2.56	2.37	2.20	2.01	1.87	1.95
Tajikistan	..	0.09	0.07	0.07	0.07	0.10	0.11	0.07	0.07	0.09	0.09	0.12	0.11	0.12	0.12	0.11	0.11	0.12	0.10
Ukraine	0.96	1.02	1.00	1.11	1.08	1.03	0.95	0.85	0.85	0.86	0.83	0.74	0.75	0.76	0.65	0.61	0.48	0.45	0.47
Uzbekistan	0.36	0.35	0.29	0.27	0.27	0.24	0.22	0.22	0.19	0.20	0.16	0.16	0.16	0.16	0.16	0.17	0.18	0.16	0.13

Source: UNESCO, Institute of Statistics. Dataset: Science, technology and innovation. Data extracted on 26 Mar 2021 10:37 UTC (GMT) from UIS.Stat.

Table 2. Basic descriptive statistics measured as difference between maximum and minimum for each year, 2000-2018

Basic descriptive statistics	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Minimum	0.16	0.09	0.07	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.09	0.12	0.11	0.08	0.12	0.11	0.11	0.11	0.10
Maximum	1.36	1.47	1.44	1.29	1.37	1.42	1.54	1.43	1.63	1.81	2.05	2.41	2.56	2.56	2.37	2.20	2.01	1.87	1.95
Variance	1.20	1.38	1.37	1.27	1.36	1.39	1.52	1.40	1.61	1.79	1.96	2.29	2.45	2.49	2.25	2.09	1.90	1.76	1.85
Standard deviation	0.34	0.37	0.37	0.36	0.38	0.37	0.41	0.41	0.42	0.46	0.50	0.61	0.63	0.60	0.57	0.56	0.50	0.51	0.56
Median	0.58	0.43	0.51	0.47	0.40	0.44	0.47	0.55	0.54	0.49	0.61	0.66	0.65	0.61	0.52	0.50	0.48	0.50	0.50
Mean arithmetic unweighted by years	0.60	0.57	0.57	0.55	0.55	0.55	0.59	0.58	0.58	0.63	0.66	0.70	0.73	0.69	0.68	0.70	0.63	0.64	0.67

Source: Author's calculations upon data in Table 1.

Table 3. GERD as % of GDP for two countries of Western Europe and two countries important participants of international technological competition outside Western Europe and North America

GERD as % of GDP for the years 2000-2018, selected advanced economies	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Germany	2,41	2,40	2,44	2,47	2,44	2,44	2,47	2,46	2,62	2,74	2,73	2,81	2,88	2,84	2,88	2,93	2,94	3,07	3,13
Israel	3,93	4,18	4,13	3,89	3,87	4,05	4,14	4,42	4,34	4,13	3,94	4,02	4,16	4,10	4,17	4,27	4,51	4,82	4,94
Italy	1,00	1,04	1,08	1,06	1,05	1,04	1,08	1,13	1,16	1,22	1,22	1,20	1,26	1,30	1,34	1,34	1,37	1,37	1,39
Republic of Korea	2,13	2,28	2,21	2,28	2,44	2,52	2,72	2,87	2,99	3,15	3,32	3,59	3,85	3,95	4,08	3,98	3,99	4,29	4,53

Source: UNESCO, Institute of Statistics. Dataset: Science, technology and innovation. Data extracted on 26 Mar 2021 10:37 UTC (GMT) from UIS.Stat.

The private firms have incentives to invest privately in R&D if and only if they are able to generate and absorb private returns from innovative activities in the existing institutional and functional environment in accordance with the general investment criteria. On the one hand, for generation of returns there should be the technological opportunities, and on the other hand, for private appropriation of potential returns it requires the patent system, protection of commercial secrecy, trademarks and licenses and might lead to the subsequent monopoly effects which turn out to be necessary prerequisite and result of the innovative activities in private entrepreneurial economy. The innovation cycle provides opportunities not only to established firms, but also to potential entrants. The potential competition is crucial element to the Marx-Schumpeter scheme of dynamic technological competition in the capitalist market economy.

The private sector also needs the developed financial markets with various financing instruments and financing mechanisms for the different phases of innovation cycle, which have substantially different levels of uncertainty and risk [1, 2, 4, 6, 7, 11, 12]. However, the financial development takes time and in fact is quite uneven in the course of market transformation - the countries still are quite behind the advanced economies in relative sizes of the financial systems and their sophistication (though the EU accession improved the situation for new member states via access to common capital market and vehicles of EU public financing for innovation). Some phases of R&D – primarily basic research but not only – have substantial positive social external effects and limited possibilities for internalization of returns privately, and as such they cannot be performed by the private sector in the capitalist market economy and require the instruments and mechanisms of public financing.

The optimal macroeconomic level of the R&D investment depends on all institutional sectors. But the criteria for optimal level of private investment in R&D are much better understood in comparison with the criteria for public investment due to complications related to positive external social effects many of which are prolonged in time and are hard to express in monetary terms in current net present value.

And the whole analysis is seriously complicated by the effects of liberalized foreign economic relations and integration to the world economy. All economic actors have the choice between internal financing of R&D and transfer of results of R&D performed abroad within their objectives, incentives and constraints. All post-socialist countries – with the only exception of the Russian Federation – are small open economies with the limited abilities to develop the large-scale and diversified R&D therefore it might be expected that in their catch-up efforts in economic development they would rely on transfer of the external knowledge. The comparative research of gross acquisition of nonproduction and nonfinancial assets vs. national R&D effort may be important step in such research and may offer some valuable insights in the process.

The public policy faces rather complicated choices between direct public funding of R&D, development of stimuli for domestic private funding and transfer of foreign knowledge to speed up the domestic development. At present the regional economic unions – primarily European Union and Eurasian Economic Union – stay at rather different levels of development of financing instruments and mechanisms.

CONCLUSION

The countries of Eastern and Central Europe and the former USSR followed K-shape in their R&D aggregate national financing paths in the course of development after the end of transformation recession in the years of 2000-2018. The key findings are as follows:

1) The countries of region spend on the whole on R&D relative to the output of their economies less than not only the leading countries of Western Europe (e.g., Germany), but also such innovative and dynamic economies as Israel and South Korea;
2) The largest economy of this group of countries – the Russian Federation – experienced the declining trend in relative R&D input and found itself by 2018 at the level of less than 1% of GDP.

3) All countries in this group of countries which crossed the threshold of advanced economies in accordance with IMF classification increased their relative R&D input.

However, these findings are not sufficient for the drawing conclusions on the innovative efforts in this group of countries. The process can take form of original innovation as well as imitation. And one of the important questions for future research – in line with the standard approaches of comparative analysis of determinants of various inputs in own national innovative activities including the level of financial development including depth and sophistication of financial system - include the determinants of choice between own R&D effort and transfer of external knowledge and expertise.

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Chapter 6

REFLECTIONS ON TOURISM HUMAN RESOURCES DEVELOPMENT: LESSONS FROM EGYPT

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ABSTRACT

African countries depend on the tourism industry to boost their infant economies; hence, the industry's human resources development is a critical area requiring attention in recent years. However, tourism human resources development is an under researched subject in the African context. Because Africa is underperforming in global tourism competitiveness, the aim of this research is to establish the best tourism human resources development practices utilised by Egypt as one of the African countries leading in this industry. This is anticipated to shed light on strategies that other African countries can adopt to improve their tourism human resources skills. Literature review research methodology was used to gather data for this study, and the results indicated that factors such as government funding and lead role in various tourism

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human resources development initiatives led to Egypt's tourism success story. Short and medium-term policy recommendations emanating from identified practices from Egypt provided guidance and development actions for African less tourism competitive countries.

Keywords: human resources development, tourism, policy, Egypt, Africa

INTRODUCTION

The tourism industry includes various sub-sectors leading to a high necessity of various human resources skills (Gruescu, Nanu and Pirvu 2008:168); hence, the sector caters for high and low skilled workers (European Commission 2016:1). Adequate skills are key to meet the mounting demand of tourists especially in the Small and Medium Enterprises as this sector struggles to find skilled labour. Lack of tourism skills has been noted as an impediment that disallows competitiveness especially in the hospitality industry as this sector seem to have challenges such as communicating in foreign languages (Luka 2015:75). The United Nations World Tourism Organisation (2017:12) also confirms inadequate skills in this industry as a factor that prohibits tourism development globally. Although issues surrounding tourism human resources are critical, less research has been conducted in this area (Baum, Kralj, Robinson and Solnent 2016; Ladkin 2011; Baum 2007).

Egypt is an African country with a total population of 91,635,232 on a total land of 995450 square kilometres. It is the most populous country in the Arab world as well as the most populous countries in Africa. Egyptian languages are Arabic (official), English and French. These languages are widely understood by educated classes (Country Watch-Egypt 2018:2). The 2012 first democratic election was a great achievement after a prolonged struggle for democracy that was at its highest intensity in 2011. The 2011 revolution was intensified by a widespread sense of political, economic, and social exclusion (especially among youth). Egypt managed to progress well economically afterwards (United Nations Development Programme 2013:12). For example, in 2017, tourism in Egypt supported

2,425,500 jobs which accounted for 8.5% of total jobs in the country (World Travel and Tourism Council 2018:1). The industry creates millions of jobs, contributes to billions of dollars into the economy, and reduces the country's dependency on foreign debt, which in-turn fuels Egypt's journey to economic success (United States Agency for International Development, 2021). Additionally, Elbayoumi, Awadallah and Basuony (2019:205) shed light that the business environment in Egypt has improved and this new setting has been dynamic as the country has witnessed developments in several areas inclusive of economic, legal, cultural, and political frameworks.

Irrespective of the political turmoil of 2011, in the African continent, Egypt's tourism industry has shown a steady growth since 2015. Table 1 indicates the country's tourism ranking on the Travel and Tourism Competitive Index (TTCI) reports between 2015 and 2019. While the majority of African countries ranked above 100, Egypt's ranking has improved more than any other African country as observed from the TTCI reports (World Economic Forum 2015; 2017; 2019). For example, in the 2019 TTCI report, Egypt out-performed more than 32 African countries. Only Mauritius, Seychelles, and South Africa were ranked better than Egypt. However, since the 2015 TTCI report, Egypt has been improving in ranking more than these three countries. For example, Egypt had the fourth-highest TTCI performance improvement in the 2019 report, moving up nine places to rank 65th globally. For this reason, Egypt had been selected to be a benchmarking country for the less tourism competitive countries in Africa to learn best tourism practices specifically focusing on tourism human resources development.

Africa is currently facing challenges inclusive of inadequate human resources skills to tackle key developmental issues (Mweetwa, Patrick, Rukwara, Waswa and Ekwamu 2021:33), and one of the major tourism development impediments facing the continent is inadequate tourism human resources skills (Dieke 2020:9).

From Table 1, it can be depicted that in a period of four years, Egypt has climbed 17 steps to rank number 65 in the TTCI latest report.

Table 1. Egypt's Travel and Tourism Competitiveness Index Ranking

Ranking in 2015	Ranking in 2017	Ranking in 2019
83 out of 141 countries	74 out of 136 countries	65 out of 140 countries

Adapted from the World Economic Forum (2015); (2017); (2019).

METHODOLOGY

This study utilised a literature-based approach, and as highlighted by Blaikie (2009:160), research data could be collected through utilisation of primary, secondary, and tertiary data means. Literature can serve as a basis for knowledge development, create guidelines for policy and practice, provide evidence of an effect, and have the capacity to create new ideas and directions for a particular field (Snyder 2019:339). Literature review methodology was adopted as there seemed to be a satisfactory pool of data to enable the researcher to provide reliable findings. The means to collect data in this study were inclusive of online databases, Google Scholar, books, reports, newspapers, and government and non-governmental organisations' websites to learn about issues related to tourism human resources development in Egypt. An analysis of the collected data was used as guiding principles towards a progressive tourism human resources development; therefore, these findings highly influenced this study's policy recommendation to be considered by other African economies who aspire to develop the tourism human capital.

A CASE STUDY OF EGYPT

To support its initiative of gaining economic independence as it goes through a major economic transition, the Egyptian government has realised

that effective education is the key to achieve this initiative successfully. While gains have been realised in the past two decades in improving literacy and increasing educational participation, major deficiencies have however been visible (Organisation for Economic Co-operation and Development 2015:5). One of the strategies to improve higher education in the country has been through a financial investment injected in the sector. For example, the government has invested $5.57 billion for a higher education plan which is to run in two phases between 2014 and 2022. This includes 61 initiatives targeted towards building more market-ready graduates and promoting a knowledge-based economy (Sawahel 2014). In response to this, the government of Egypt had planned to construct eight international universities by 2020 to supplement and to reinforce labour development (Egypt Independent 2019). In August 2021, the Ministry of Higher Education and Scientific Research announced that 12 to 15 new universities will enter service in 2022. It was noted that 19 private universities have also been established which includes branches of foreign universities from the United Kingdom and the United States (Egypt Today 2021).

The standard of human resources in the tourism sector is considered crucial, especially during service delivery to the tourists, as a result, a country that has invested in human resources development can ensure effectiveness in quality services delivery and tourists' satisfaction (Msuya 2015:226). To ensure open access to tourism studies, one strategy that Egypt utilised was to spread tourism education through e-learning. In 2011, 27 tourism colleges were already offering some e-learning services or had newly introduced this service (Afifi 2011:363). To boost cultural heritage and tourism, the Egyptian government secured funding from the United States Agency for International Development for the training of semi-skilled workers on conservation and preservation. The programme also included improving capacity and technical skills of archaeologists to ensure sustainability and emphasising heritage education as a key factor to heritage management (United States Agency for International Development 2017:2). The Organisation for Economic Co-operation and Development (2014:361) also notes that various education and training

programmes have been implemented to advance the standard of the hospitality sector. These included the Egyptian Tourism Workforce Development Project which has been aimed to:

- Ensure a mobile training approach in tourism governorates;
- Capacitate employees through providing skills and offering improved levels of services and food safety;
- Provide vocational training that is aligned to national priorities and international standards;
- Develop a Human Resources Development Unit to administer short-term training for workers at minimum costs and helping educational institutions to respond to the needs of the market, and
- Introduce programmes that equip employees with managerial skills required for hotels and restaurants.

Shazly and Soliman (2014:7) share that to develop skills for tourism personnel, the Ministry of Tourism has developed five approaches to achieve this objective. These approaches included enhancing language skills by offering language programmes (English, French, German, Spanish, Turkish, and Hebrew), improvement in information technology and technical tourism skills, exchange of experiences in the tourism field, and encouraging tourism research studies by the employees, and providing support to researchers in tourism areas from other organisations by publishing their research works and articles in the Ministry of Tourism research magazine.

According to the Organisation for Economic Co-operation and Development (2014:361), to reduce the narrow skills gap, the Egypt Tourism Federation in collaboration with the Ministry of Tourism have a mandate to develop qualified workers to take advantage of tourism's job opportunities. They ensured promoting professionalism of employees in tourism governorates by improving their qualifications, establishing some institutions and professional training centres in key tourism areas, and forming partnerships with tourism training schools and institutions. To strengthen the country's workforce, the Al-Youm (2017) highlights that

Egypt migrant labour in 2016 increased by 1.1%. These labour groups constitute people from Asia, Europe, Arab Africa, America, Australia, and non-Arab Africa with a high number coming from Asia and Europe. In 2017 only, foreign workers in the Egyptian government administration increased by 27.3%, where 58.1% of these workers were from European countries (Mubasher 2018).

In a mission to respond to tourism market skills need, the European Bank for Construction and Development has partnered with the Sawiris Foundation (a partner in development in Egypt whose key mandate is skills development) to support high quality training through the expansion of a local hospitality school (Gauna Hospitality School). This initiative aims to establish a new state of art practical workshop for culinary professionals, to develop the curriculum for with-in company training of trainers, and to enhance the capacity of partnering hotels to deliver work-based learning modules (European Bank for Reconstruction Development 2020).

CONCLUSION AND POLICY RECOMMENDATIONS

It can be noted that in Egypt, government intervention is playing a major role in tourism skills development. The government improved tourism skills through supporting e-learning, tourism research, and sourced funding for tourism development skills initiatives especially for cultural heritage and the hospitality management skills. However, as mentioned by Luka (2015:75), language barriers in tourism destinations had been noted as a generic challenge across countries. In addressing this problem, the Egyptian government is offering language programmes to tourism personnel. In addition, tourism skills shortages had been identified by the United Nations World Tourism Organisation (2017:12) also as a generic challenge; therefore, the Egyptian government solved this by establishing training institutions to improve skills for the tourism labour force. Tourism skills development have also been attained through the support of international banks and local non-governmental organisations. The Egyptian government again opened doors for labour migration to

supplement skills shortages in the tourism industry. Therefore, short and medium-term strategies recommended for tourism human resources development to less tourism competitive African countries are as follows.

Short-Term Policy Strategies

- Governments to conduct tourism skills audits to identify skills shortages and the country's tourism human resources strengths;
- Governments to form partnerships with universities and other non-formal training institutions to develop tailor made courses to close the skills gaps;
- Governments to play a front role in developing tourism skills. This could be through the national manpower development organisations already established within a country; and
- Governments to facilitate benchmarking studies to learn from best performing countries.

Medium-Term Policy Strategies

- National Strategic Development Plans should include tourism human resources development strategies, and incorporate measures of establishing collaborations between the public and private sector organisations;
- There is a need for tertiary institutions manpower development support. This should include funding training programmes for educators in reputable institutions to enable positive spill-over effects to the trainees;
- Governments should open doors for foreign nationals with tourism expertise to work in host countries to supplement local skills;
- Governments to steer tourism human resources development collaborations between local non-governmental organisations, international aid agencies, and international financial institutions;

- Government to facilitate curriculum revisions for tertiary institutions in collaboration with the industry to avoid a mismatch of skills; and
- Governments to fund tourism research to generate knowledge regarding new trends and critical requirements for tourism development in host countries. This in turn would assist in skills development planning and enable policy improvements.

The policy recommendations highlighted here do not require high government funding; therefore, they can easily be implemented. Future research could explore the generic tourism labour challenges in Africa as this would avail rich information and point out critical areas of concern to be noted by decision-makers in both public and private sector organisations.

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Chapter 7

IMF AND INTERNATIONAL CAPITAL MOBILITY: FREEDOM, REGULATION, CONTROL

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ABSTRACT

The chapter intends to outline the major aspects of the shift in the IMF stance on international capital mobility from the point of view of search of the right balance between freedom, regulation and control. The sequence of financial crises and other episodes of financial instability in the last three decades most of which included the input of international capital flows made it impossible to follow the linear route to capital account liberalization and made it necessary to broaden the theoretical and methodological foundations of the discussion moving from the first-best to the second-best approach. In practice the Fund is trying to put in place the internally coherent new operational framework which serves as basis for policy advising which goes beyond the conventional macroeconomic policies and relies on heterogeneous mix of instruments. The job is far from being completed and tested while the COVID-19 brought the test of new unprecedented external shock which caused the new level of uncertainty in all social and economic processes.

Keywords: International Monetary Fund, international capital mobility, second-best approach, capital flows management, COVID-19, uncertainty

INTRODUCTION

The sequence of financial crises and numerous episodes of financial instability from 1997 onwards caused the changes in IMF approaches to international capital mobility from the point of view of relation between freedom, regulation and control. These changes developed in line with the debate between economists, political scientists and applied analysts on the theoretical and methodological foundations of the causes and consequences of international capital flows in the highly globalized pre-pandemic world. The standard conclusions of the mainstream on the positive effects of free capital movements based on the first-best approach of the perfectly competitive world had to be augmented by the inclusion of various market imperfections inherent in the real world which led the whole debate to shift to second-best approach. Even more important was the recognition of the fundamental fact that the world is heterogeneous from the point of view of the level of social, political and economic development and different IMF member countries have different institutional structures which might be very far away from such structures of IMF key shareholders and don't match their experience.

The chapter proceeds as follows. In paragraph 1 the general framework of IMF on international capital mobility and prior evolution of the position is outlined and assessed. In paragraph 2 the emerging new operational framework which serves as basis for policy advice is analyzed and assessed. And finally we conclude.

1. IMF Articles of Agreement: General Framework and Actual Practices

The general framework of the IMF official stance on international capital mobility is set by the IMF Articles of Agreement and remains unchanged from the signing of the document. The most important proposition is formulated as follows: "Members may exercise such controls as are necessary to regulate international capital movements, but no member may exercise these controls in a manner which will restrict payments for current transactions or which will unduly delay transfers of funds in settlement of commitments, except as provided in Article VII, Section 3(*b*) and in Article XIV, Section 2."

This view reflects the ideas which were shared by both cofounders of the Bretton-Woods institutions Lord John Maynard Keynes and Harry Dexter Wight. The principal purpose of the new international monetary order after the II World War was the stability of conditions for international trade which should be supported by stable and predictable exchange rates and possibilities of access to international liquidity in case of necessity. The large and unpredictable international capital flows driven by speculative financial motives were clearly not part of this picture both in theory and in real post-war practices.

Though the basic foundation of IMF stance on international capital mobility, the changing landscape of the world economy requested the changes to operational routines of the Fund to put it in line with the new developments. Chwieroth (2010) provides thorough story of modifications of IMF operational practices throughout the second half of the XX century and at the turn of the millennium. But the author who really presented the voluminous factual qualitative evidence on the subject places too much emphasis on the impact of dominant economic theories on Fund's practices via the channel of staff technical background while misses the changing interests and motives of the IMF key shareholders in shaping the above mentioned practices.

The development of the world economy experienced the growing volumes and sophistication of international capital mobility. Such

processes as greater extent of convertibility of currencies, regional economic integration in Western Europe with formation of single capital market, development of transnational companies and banks, emerging offshore financial markets clearly were changing the landscape of the whole world economy and interests and motives of its major actors. The collapse of the Bretton-Woods system and transition to the reality of floating exchange rates, various exchange rate regimes and more and more liberal capital account regimes in different parts of the world via regional unions, inter-governmental agreements or OECD membership led to the higher level of financial instability, emergence and rapid growth of new branches of financial industry and new financial instruments.

The neoliberal counterrevolution accelerated the processes of financial liberalization both at the national and international level. The dissolution of the Soviet Union and the former socialist bloc led to the reintegration of the former socialist countries in the world economy on the market-based principles including the integration into the international financial market. The 90th marked the peak to the pressure for capital account liberalization including the discussions on the possible amendment to the IMF Articles of Agreement with obligation for member countries to open their capital accounts. These ideas were put to discussion at the IMF-World Bank Meetings in Hong-Kong in 1997, but ironically just at that moment of time and at that place the history was changing its currents.

2. The Development of New Operational Framework: Issues and Perspectives

The Asian financial crisis opened the new chapter in discussions on international capital mobility from the above mentioned point of view of freedom, regulation and control. The issues of financial instability emerged as the central focal point for economists, financiers and political decision-makers. The general summary of the analytical discussions on the economic benefits and cost at the second-best level vs. first-best level can be presented as follows:

Table 1. Arguments for and against the unrestricted flow of international capital under market conditions

PRO	CONTRA
A free market offers the most efficient means of distributing capital (or any other resource).	Real-market mechanisms are imperfect.
It promotes the diversification of funding sources.	The flow of capital is unstable and procyclical.
It promotes investment in diverse areas.	International investment benefits only a small proportion of society.
It imposes discipline on policymakers.	The predominance of short-term decision-making.

Author's summary of theoretical and methodological discussions on international capital mobility on the basis of Ocampo, Stiglitz (2008) in Sherstnev (2014).

The key point is unstable and widely procyclical nature of international capital flows. It means that under the conditions of various booms (regular economic cycle, commodity cycle, financial cycle, etc.) the capital tends to flow to recipient countries causing the various positive spiraling macroeconomic processes (capital inflow - increase in banking liquidity - credit expansion - asset price inflation - capital inflow). However, the change of macroeconomic conditions for whatever reason - some of which may be not directly linked to the particular national economy at all - leads to reversal of the above mentioned macroeconomic processes to negative (capital outflow - shortage in banking liquidity - credit crunch - asset price collapse - capital outflow). The situation became even more acute during the global economic crisis of 2008-2009.

Certainly the financial instability phenomena of such magnitude and complexity which in many aspects is linked to the international capital mobility requested from the IMF to adjust first of all its operational framework which forms the basis for Fund's recommendations and conditionality. The pressure for movement in this direction was also supported by extensive critique of the ways how the IMF dealt with the financial crises on the turn of the XXI century.

The IMF staff members published several documents on the international capital mobility under various conditions of financial

instability some of which were discussed and got approval of the Board. (IMF 2010, 2011, 2012, 2013, 2015, 2016, 2017, IMF IEO 2020, Kelemly-Ozcan 2020). It's worth to outline the key points of the emerging new Fund's operational framework to make the ongoing discussion in the literature more structured and focused.

CAPITAL FLOWS MANAGEMENT

The new documents recognize that the scale and scope of the new financial instability phenomena justifies the introduction of the separate structured toolkit for management of international capital mobility (capital flows management or CFM). This toolkit may include both conventional measures of macroeconomic policy and regulation by central banks and treasuries and - when and if such measures are not enough - the administrative measures of capital controls (and this second part is pragmatic shift in the IMF position on the matter though by IMF staff it's seen as the last in turn).

CAPITAL ACCOUNT LIBERALIZATION: INSTITUTIONS MATTER

The emerging new operational framework contains the clear view that member countries are at different levels of social, political and economic (including financial!) development many of which are quite far from the levels of the key IMF shareholders. And the nature and functioning mechanisms of their institutions are also quite different from those of the key Fund's shareholders. This circumstance cannot be ignored any longer in the operational activities of the Fund since it's impossible to apply directly the tools justified by the empirical experience of the economies at one particular level of development to the economies at quite different levels of development.

Since the story after the II World War begins with the capital account liberalization and the process is far from completion up to now the new documents of the Fund clearly propagates the view that such liberalization cannot be done in any kind of uniform manner and by any uniform recipes and should be executed in accordance with the existing institutional structures and their functional mechanisms of the member countries each step being considered under concrete circumstances of space and time.

INFLOWS MANAGEMENT

The new documents of the Fund pay more attention to surges in capital inflows since they launch the process of mounting external financial imbalances. The proposed measures in line with the basic ideology start with the conventional ones - let the exchange rate to appreciate, to use these periods for reserve accumulation and to strengthen the fiscal stance and lower the policy rate - but then goes on to CFM components - macroprudential and even microprudential policies in the financial sector, taxation on certain kinds of inflows and even restrictions on short-term speculative inflows. But CFM toolkit is justified for employment only in the cases when the conventional macroeconomic policies are not sufficient. Therefore the Fund's documents don't treat the CFM toolkit on the equal basis with the conventional macroeconomic policies making it some kind of the reserve vehicle.

OUTFLOWS MANAGEMENT

This side of international capital mobility got somehow less attention in the emerging IMF operational framework. The issue might be delicate from the point of view of the interests and motives of the key IMF shareholders but it clearly cannot be ignored. The most important aspect is that at the turn of the XX century the nature, structure and direction of international capital flows went through serious transformation. Though

the most volume of gross flows circulates between the advanced countries, we face the net outflow of capital from the developing world to the developed world (primarily to countries with global and large international financial centers). It means that the developing world finances the further development of the advanced countries in the XXI century. There is number of rational economic reasons for this but how does this situation benefit the capital exporters in the developing world by inclusive sustainable development and growth criteria? And the situation becomes even more acute in case of various financial crises when the capital outflow surges from the developing world to the safe havens of developed world or offshore financial centers.

CONCLUSION

The framework is far from being completed up to now to balance the real interests of different actors in the world economy with regard to international capital mobility from the intertemporal well-being criteria under stable and inclusive development and growth. The COVID-19 pandemic caused the unprecedented external shock to highly globalized economic processes, mixed the picture of economic cycle and - being the highly uncertain process by itself - substantially reduced the predictability of major global economic and wider social processes. There is no sign at the moment that any of contemporary policy makers would like to rely solely on market forces to manage international capital mobility. Therefore the search for right balance between market stimuli and indicators and government interference in international capital flows is doomed to go on based on new practical experience. It's very important for the IMF to play constructive role in this search and its analytical representation - especially in relation between advanced countries and developing world - in order to keep the position of leading international financial institution in the XXI century.

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Chapter 8

STOCHASTIC IMPULSE CONTROL AND OPTIMAL EXCHANGE RATES

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Abstract

Stochastic control of exchange rates via discretionary central bank intervention is the topic of our chapter. We modify the monetary model, allowing the central bank to set exchange rate targets while it practices diffusion monetary policy augmented by sudden, discretionary monetary interventions. Deviations between exchange rates and their targets are costly for central bankers. The monetary interventions affect exchange rates directly, moderating deviations from targets, but are costly to engineer. Central bankers choose interventions to minimize target deviation and intervention costs while preserving credibility by constraining interventions across time. Cost function restrictions ensure intervention never occurs, meaning freely floating exchange rates are optimal. The value function is linked to a PDE involving monetary dynamics.

JEL Classifications: C61, E58, F31

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1. INTRODUCTION

Central bank intervention to adjust exchange rates sometimes plays an important role in economic policy. During the 1980's policymakers used coordinated intervention to influence the U.S. dollar under the Plaza Accord Agreement and after the stock market crash of 1987. Yen sales by the Bank of Japan figured prominently during the 1990's as it strove to engineer an export stimulus. Stochastic impulse control theory analyzes sudden policy changes so is a natural vehicle for modelling central bank intervention in currency markets. At the heart of this theory lies a variable modelled by a continuous time stochastic process that wanders away from target values set by controllers, who may be government policymakers. Controllers can implement countably many random adjustments to keep the process close to targets. Deviations from targets as well as interventions are costly for controllers. Hence, the optimal policy minimizes the joint costs of interventions and target deviations.

Jeanblanc-Picqué (1993), Mundaca and Øksendal (1998), Cadenillas and Zapatero (1999, 2000) as well as Gagnon (2019) apply impulse control theory to exchange rates. In all these papers the exchange rate, given by a continuous time process, is the control variable and the central bank acts as the impulse controller. Determining whether intervention is optimal and proving theorems to characterize the value function are key issues. Like Gagnon (2019) this chapter focusses on impulse control of exchange rates in the monetary model, which derives exchange rates from monetary dynamics. Controversy surrounded the monetary model when Meese and Rogoff (1983) showed random walk forecasts of exchange rates outperformed forecasts based on money supplies, but more recent studies present empirical evidence supporting this model c.f. Rapach and Wohar (2002), Mark and Sul (2001), Abhyankar, Sarno and Valente (2005), MacDonald and Taylor (1994).

Our control problem incorporates some novel features. Floating exchange rates are generated by monetary policy which solves a stochastic differential equation (SDE) where the drift and diffusion coefficient may be nonlinear functions, a feature allowing complex monetary dynamics. Countably many money supply changes made at the discretion of the cen-

tral bank augment SDE monetary policy and play the role of impulse controls because they impact on exchange rates directly, in a one-to-one fashion. Discretionary money supply changes are constrained across time and cannot be forecast by investors. Both these assumptions are motivated by conditions in real economies. Every intervention questions the wisdom of established policy so actual currency intervention may be limited to preserve central bank credibility. Abrupt policy swings often take markets by surprise, suggesting investors in the model should not be able to forecast discretionary changes.

Questions of whether pure floating, managed floating or fixed exchange rates are optimal are foundational to macroeconomics. Ongoing intervention appears in both fixed and managed floating regimes while the absence of intervention implies a pure float reigns. Restrictions on total intervention as well as target deviation and intervention costs lead the central bank to refrain from all intervention in our control problem, implying optimality of a pure float. This view runs counter to much of the exchange rate impulse control literature where central banks intervene across an infinite horizon c.f. Jeanblanc-Picqué (1993), Cadenillas and Zapatero (1999, 2000), Mundaca and Øksendal (1998). Gagnon (2019) also presents a control problem where central banks refrain from exchange rate intervention, but significant differences exist between the present paper and earlier one. For example, constraints on total intervention are absent from Gagnon (2019), which employs strong conditions restricting money growth to model anti-inflationary policy, but anti-inflationary dynamics are absent here. A partial differential equation (PDE) linked to monetary dynamics illuminates the value function here but no such result appears in Gagnon (2019).

Deriving conditions where central banks forsake exchange rate intervention is more than an exercise in theoretical completeness because econometric evidence questions the benefits of intervention. For example, Dominguez (1998) finds that exchange rates are not meaningfully affected by sterilized intervention. Fatum and Hutchison (2005) conclude that while large occasional Bank of Japan interventions may be effective in altering the yen-U.S. dollar exchange rate, small frequent interventions are often ineffective. From 1999-2002 yen intervention was effective but ineffective during 2003. Ito (2005) points to reduced impact of Bank of Japan intervention on the yen-dollar rate during 2003-2004. LeBaron (1999) suggests that currency speculation is more probable when Federal Reserve interven-

tion is high. Chang and Taylor (1998) reveal that Reuters announcements of Bank of Japan intervention raised exchange rate volatility. Clearly, central banks have incentives to abandon intervention, a finding validating our vanishing intervention theorem.

The paper is organized as follows. Section 2 discusses the control problem. Section 3 presents theorems about the value function and optimal regime while section 4 concludes.

2. THE STOCHASTIC CONTROL PROBLEM

Everything happens on complete probability space $(\Omega, \mathcal{F}, P)$ endowed with a right continuous filtration $(\mathcal{F}_t, t \geq 0)$ where $\mathcal{F}_0$ contains $\mathcal{N}$, the class of all P-null sets. When we say a stochastic process is adapted $(\mathcal{F}_t, t \geq 0)$ is the relevant filtration. Also the process $(W_t, t \geq 0)$ is a one dimensional standard Brownian motion relative to $(\mathcal{F}_t, t \geq 0)$. For example, we could take $(\Omega, \mathcal{F})$ to be the Wiener measurable space, P the Wiener measure, $(\mathcal{F}_t, t \geq 0)$ the augmented natural filtration and $(W_t, t \geq 0)$ the canonical Brownian motion. Some terminology is important: a real number can be viewed as a trivial random variable but we reserve the term random variable for a more general measurable function on Ω. The distinction is useful because in our model the initial exchange rate is constant and in a few other places variables that might be genuinely random are in fact constant. Now we turn to basic ideas of the monetary model and their connections to control theory.

The nominal exchange rate is the number of domestic currency units needed to purchase one unit of foreign currency. Actually, the variable referred to as the exchange rate is the logarithm of the nominal exchange rate, but by convention the exchange rate is never distinguished from its logarithm. At any time $t \geq 0$ the monetary model floating exchange rate is denoted by y_t. Flood and Garber (1983) show the stochastic process $(y_t, t \geq 0)$ arises from domestic and foreign money market equilibrium, purchasing power parity and interest parity. Forecasts of a stochastic process $(k_t, t \geq 0)$ are key to forming $(y_t, t \geq 0)$. Investors in our model have rational expectations meaning given any $s, t \geq 0$ with $s \geq t$ they forecast k_s at time t via $E(k_s|\mathcal{F}_t)$, the conditional expectation of k_s given $\mathcal{F}_t$. More precisely, let $\alpha > 0$ be the absolute value of interest elasticity of

both domestic and foreign money demand, then at any time $t \geq 0$ Flood and Garber (1983) shows y_t satisfies

$$y_t = \alpha^{-1} \int_t^{\infty} \exp(\frac{t-s}{\alpha}) E(k_s|\mathcal{F}_t)\, ds \tag{2.1}$$

At any $t \geq 0$, k_t is a linear combination of the time t domestic and foreign money supplies as well as potential GDPs. Since potential GDP changes slowly k_t may be regarded as a combination of the domestic and foreign money supplies. In practice k_t is usually regarded as the domestic money supply at $t \geq 0$ because much of the literature focusses on policy switching by the domestic central bank c.f. Flood and Garber (1983), Froot and Obstfeld (1991), Smith (1991). Viewing k_t as the domestic money supply is justified if foreign money supplies are constant across time. Our paper also employs the convention that $(k_t, t \geq 0)$ is domestic monetary policy to fix attention on actions of domestic central bankers. Herein $(k_t, t \geq 0)$ is often referred to as money supplies since there is a money supply for each $t \geq 0$; likewise $(y_t, t \geq 0)$ is often referred to as exchange rates.

Controlling exchange rates via domestic money supply changes is the focus of our paper. However, affecting $(y_t, t \geq 0)$ via (2.1) when $(k_t, t \geq 0)$ solves a SDE and is influenced by continuous time controls as in Yong and Zhou (1999) is not on the agenda. Instead, domestic central bank interventions in the form of countably many sudden money supply changes that augment $(k_t, t \geq 0)$ adjust $(y_t, t \geq 0)$. At any $t \geq 0$ the exchange rate arising from intervention can be close to a preassigned target. Money supply interventions are therefore impulse controls in our model. Central bank use of impulse controls is interpreted as policymakers engaging in discretionary interventions that alter exchange rates. Of course, zero intervention is always a policy option, a fact motivating the following definition.

Definition 2.1. Domestic monetary policy without discretionary interventions is the process $(k_t, t \geq 0)$ and $(y_t, t \geq 0)$ is the floating exchange rate process without interventions.

Researchers specify a stochastic process for $(k_t, t \geq 0)$, a practice reflecting the view that central banks implement a basic monetary policy.

Since $(k_t, t \geq 0)$ is not the process being controlled it is treated as exogenous. By convention $(k_t, t \geq 0)$ solves a SDE. We refer to a SDE solution as a diffusion process or a diffusion. Brownian motion with drift is often used for $(k_t, t \geq 0)$ c.f. Flood and Garber (1983), Froot and Obstfeld (1991), Jeanblanc-Picqué (1993), Smith (1991). However, these random dynamics may violate historic central bank policy. During the 1980's and 1990's central banks crafted anti-inflationary monetary policies. Suppose $(X_t, t \geq 0)$ is a Brownian motion with drift. Given any $M > 0$, provided $(X_t, t \geq 0)$ has positive drift, a.s. there exists some time $s > 0$ such that $X_s > M$. So Brownian motion with drift monetary policy fails to capture tight money growth.

Even if actual monetary policy is not structured to restrain inflation one expects it is generally too complex to be represented by Brownian motion with drift. To remedy this situation our paper considers more general SDE monetary policy with the aim of modelling complex monetary dynamics. However, $(k_t, t \geq 0)$ is not part of a coupled system where dynamics of other economic variables affect monetary policy and vice-versa. Neither is modelling anti-inflationary policy one of our goals, rather we desire to analyze stochastic control in the monetary model with monetary policy more involved than Brownian motion with drift. Very few monetary model researchers have contemplated monetary policy other than Brownian motion with drift. Using a more involved SDE for $(k_t, t \geq 0)$ is a step towards coupling monetary dynamics with dynamics of variables that may affect monetary policy in actual economies, such as GDP growth or interest rates.

Assumption 2.1. The process $(k_t, t \geq 0)$ solves a SDE with drift b, diffusion coefficient σ and initial condition k_0 where k_0 is a real number. Also, the following conditions hold:

(1) $b : [0, \infty) \to \mathbb{R}$ and $\sigma : [0, \infty) \times \mathbb{R} \to \mathbb{R}$ are measurable.

(2) For some constant $K > 0$

$$(A) \quad |\sigma(t, x)| \leq K(1 + |x|) \quad \text{for all} \quad (t, x) \in [0, \infty) \times \mathbb{R}$$

$$(B) \quad |\sigma(t, x) - \sigma(t, y)| \leq K|x - y| \quad \text{for all} \quad (t, (x, y)) \in [0, \infty) \times \mathbb{R}^2$$

(3) $b \in C^*([0, \infty), \mathbb{R})$ and $\sigma \in C^*([0, \infty) \times \mathbb{R}, \mathbb{R})$ where for any topological space Y, $C^*(Y, \mathbb{R})$ is the space of bounded continuous real valued functions on Y.

Hence, $(k_t, t \geq 0)$ satisfies the SDE given by

$$k_t = k_0 + \int_0^t b_s \, ds + \int_0^t \sigma(s, k_s) \, dW_s \tag{2.2}$$

A few points are important to note. Defining y_t as the logarithm of the exchange rate implies y_t may assume any sign. This fact allows a SDE with nonlinear drift and diffusion coefficient to model $(k_t, t \geq 0)$. If y_t is the nominal exchange rate a linear SDE is required for $(k_t, t \geq 0)$ to ensure y_t is a.s. positive, a clear implication of (2.1). Nonlinear b and σ allow complex monetary dynamics and the sample paths of $(k_t, t \geq 0)$ assume positive and negative values. Via (2.1) it follows y_t may assume any sign, which is permitted by our definition. Condition (1) simplifies the model since b depends on time but not space, while (2) and (3) are required for existence-uniqueness of a solution to (2.2). Also k_0 is a real number rather than a random variable, a feature useful when defining the value function V of the control problem, as made evident below. When defining V we allow k_0 to vary since, as one determinant of $(k_t, t \geq 0)$, it affects exchange rates via (2.1), but otherwise k_0 is fixed for expositional clarity. Condition (3) is also important in section 3 for analyzing a function that reveals sample path properties of $(y_t, t \geq 0)$.

Nonlinearities in the drift and diffusion coefficient may capture anti-inflationary policy, a theme of Gagnon (2019) where restrictions on b and σ in (2.2) capture slow money growth. In Gagnon (2019), $b : [0, \infty) \times \mathbb{R} \to \mathbb{R}$ and restrictions deeper than a Lipschitz condition capture slow money growth. When b depends on time and space greater complexities arise in the control problem, as manifested in Gagnon (2019). Interesting results still unfold when b depends only on time. Since Gagnon (2019) relies on very restrictive assumptions on b to get control theoretic results it is possible that simplifying b is a better approach.

Employing (2.1) for any $t \geq 0$ we have

$$y_t = k_t + \alpha^{-1} \int_t^\infty \exp(\frac{t-s}{\alpha}) \int_t^s b_u \, du \, ds \tag{2.3}$$

Validating that (2.1) yields (2.3) illuminates key issues behind monetary model exchange rates. Given any $t \geq 0$ and $s \geq t$, $E(k_s|\mathcal{F}_t) = k_t + \int_t^s b_u \, du$ a.s. Deterministic b implies $k_t + \int_t^s b_u \, du$ is $\mathcal{F}_t$-measurable

so this can be used identically for $E(k_s|\mathcal{F}_t)$, which is our convention. Define $h(\omega,\cdot):[t,\infty)\to\mathbb{R}$ for every $\omega\in\Omega$ by $h(\omega,s)=E(k_s|\mathcal{F}_t)(\omega)$ when $s\geq t$. It follows $h(\omega,\cdot)$ is measurable on $[t,\infty)$ for each $\omega\in\Omega$, which is preliminary to considering the integral in (2.1). Connections between improper Riemann and Lebesgue integrals easily establish $\int_t^\infty \exp(\frac{t-s}{\alpha})\int_t^s b_u\ du\ ds$ exists and is finite, a result formalized when proving theorem 3.1 in section 3. Since $\alpha^{-1}\int_t^\infty \exp(\frac{t-s}{\alpha})\ ds=1$ for every $t\geq 0$, using our version of $(E(k_s|\mathcal{F}_t),s\geq t)$ in (2.1) ensures (2.3) holds for every $\omega\in\Omega$. By convention the version of conditional expectation used in (2.1) must be specified because conditional expectation of a random variable is not unique, though any versions are equal a.s. Economists assume (2.1) holds a.s. but rarely confirm the integral in (2.1) exists. Our calculation shows the integral in (2.1) exists and is finite for every $\omega\in\Omega$ when monetary dynamics are given by (2.2). Hence y_t can be taken to satisfy (2.1) identically, which is key to establishing the decomposition (2.3) holds for every $\omega\in\Omega$ rather than just almost surely. Equation (2.3) is far more useful in analyzing the exchange rate than (2.1).

Now a structure is presented for monetary interventions. In what follows if τ is a stopping time relative to $(\mathcal{F}_t,t\geq 0)$ then $\mathcal{F}_\tau$ is the stopping time σ-field generated by τ. Also U is a bounded open subset of $\mathbb{R}$ with $0\in U$ that is fixed throughout the discussion.

Definition 2.2. An impulse control is a pair of sequences $((\tau_n)_{n=1}^\infty,(\xi_n)_{n=1}^\infty)$ where

(1) For all $n\geq 1$, τ_n is an $(\mathcal{F}_t,t\geq 0)$ stopping time.

(2) For all $n\geq 1$ and every $\omega\in\Omega$, $0<\tau_n(\omega)<\tau_{n+1}(\omega)<\infty$.

(3) For every $\omega\in\Omega$ we have $\lim_{n\to\infty}\tau_n(\omega)=\infty$.

(4) For all $n\geq 1$, ξ_n is a random variable such that $\xi_n(\Omega)\subset U$.

(5) For all $n\geq 1$, ξ_n is $\mathcal{F}_{\tau_n}$-measurable.

Impulse controls have economic significance. Given impulse control $((\tau_n)_{n=1}^\infty,(\xi_n)_{n=1}^\infty)$ the random variables $(\tau_n)_{n=1}^\infty$ are the times when the domestic central bank engineers its interventions and $(\xi_n)_{n=1}^\infty$ are the interventions themselves. Equation 2.4 defines a money supply consistent with this interpretation. In what follows if $A\subset\Omega$ then 1_A is the indicator function of A. Impulse controls are what the central bank chooses in the

model, as detailed below, so policymakers can be regarded as selecting both intervention times and levels.

Definition 2.3. Let $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty})$ be an impulse control. For any $t \geq 0$ let $m_t(\tau, \xi)$ be the money supply at time t generated by interventions (τ, ξ). At any $t \geq 0$

$$m_t(\tau, \xi) = k_t + \sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n \tag{2.4}$$

Clearly $m_t(\tau, \xi)$ modifies k_t via $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$, accumulated interventions up to t. Inspecting (2.4) we see at τ_n the bank creates a jump of size ξ_n in any sample path of $(m_t(\tau, \xi), t \geq 0)$. Both features capture the kind interventionist policy we desire to model. We refer to $(m_t(\tau, \xi), t \geq 0)$ as the money supply process with intervention.

Notice ξ_n may be positive, negative or zero since U is an open subset containing zero. Forcing ξ_n to reside in a bounded set U for all $n \geq 1$ means intervention at any time is constrained, though this is not the only constraint on intervention, as discussed below. Central bankers can only engage in a limited amount of intervention at any time in the model because of a need to maintain credibility. Excessive intervention in a real currency market suggests regular monetary policy is less powerful than it should be; a loss of credibility with catastrophic consequences could easily ensue. Definition 2.2 really has force when $\xi_n \neq 0$ for all $n \geq 1$ almost surely since this together with $\lim_{n \to \infty} \tau_n = \infty$ implies nonzero interventions occur across an infinite horizon. If $\xi_n(\omega) = 0$ for every $n \geq 1$ and all $\omega \in \Omega$ there is never any intervention. In this case we show below that the central bank engineers a freely floating exchange rate, an important case in both theory and practice.

Definition 2.4. Fix some constant $R^* > 0$. Suppose $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty})$ is an impulse control. The control is admissible if the following conditions are satisfied:

1) Either $\xi_n(\omega) = 0$ for every $n \geq 1$ and all $\omega \in \Omega$ or $\xi_n \neq 0$ for all $n \geq 1$ a.s.

2) For every $\omega \in \Omega$ we have $\sum_{n=1}^{\infty} |\xi_n(\omega)| \leq R^*$.

Definition 2.5. The set of all admissible impulse controls is denoted by $\mathcal{A}$.

Imposing $\sum_{n=1}^{\infty} |\xi_n(\omega)| \leq R^*$ for every $\omega \in \Omega$ further restricts intervention because central bankers are forced to constrain total intervention across time. Several considerations motivate restricting total intervention via this condition. Real central banks cannot engage in unlimited intervention because their foreign currency reserves are finite. Furthermore, central banks want to maintain critical levels of foreign currency reserves. Flood and Garber (1984) show a fixed exchange rate collapses before all reserves are exhausted, something that mirrors actual policy experience. Although we do not formally build foreign currency reserves into the model, a time constraint on intervention moves in that direction. Constraining intervention across time is also motivated by central banks needing to maintain credibility. As we already observed, discretionary interventions make regular monetary policy appear ineffective. Viewed in this light restricting total intervention across time is even more important to maintaining credibility than bounding individual interventions.

Endogenous evolution of foreign currency reserves arising from intervention is difficult to analyze, in fact reserves have not been built into impulse control of exchange rates in any way because of complications that would ensue. To illustrate key issues assume policymakers use impulse controls to keep the exchange rate in a target zone that is given by a bounded interval. Reversing repeated depreciations may deplete foreign currency reserves to a point where they are insufficient to engineer another appreciation. Whether or not enough reserves exist to force an appreciation at any time $t > 0$ depends on how often the exchange rate hit the upper bound of the target zone across $[0, t)$ and what strain has been placed on reserves over $[0, t)$ as a result. Depending on the hitting properties of the exchange rate process, intervention over infinite horizons may be possible or impossible with endogenous reserves. The question is how often the exchange rate process hits the upper bound of the target zone versus how often it hits the lower bound. Maintaining a target zone means reserves rise when the lower bound is hit and fall when the upper bound is hit, so the hitting frequency determines whether or not the target zone survives. Hitting properties of stochastic processes are difficult to analyze, c.f. Freidlin and Wentzell (1998), so endogenous reserves in exchange rate impulse control is left for future research.

Assumption 2.2. Given any $t \geq 0$ investors cannot forecast money supply intervention times or levels across (t, ∞) made via impulse controls even though they know interventions are possible. All they can forecast is the SDE component of monetary policy $(k_s, s \geq t)$.

Even if investors can forecast $(k_s, s \geq t)$ via $(E(k_s|\mathcal{F}_t), s \geq t)$ there is no guarantee they have abilities to forecast surprise money supply interventions across (t, ∞) via conditional expectation, the only formal forecasting device in the model. Monetary policy in real economies may well have a structural component which investors can forecast because it is linked to economic fundamentals as well as discretionary changes they cannot anticipate. Discretionary changes can be affected by the character of central bankers as much as economic circumstances and therefore may be highly random, perhaps even virtually impossible to forecast as a result, a view motivating assumption 2.2.

Investors' inability to forecast interventions together with their knowledge intervention is possible, must be built into exchange rate determination. According to Froot and Obstfeld (1991 p.242), the exchange rate at any $t \geq 0$ satisfies (2.1) even when monetary policy exhibits sudden switches. Their view reflects a deep belief in the drive of investors to predict monetary policy and apply these predictions to exchange rate pricing. Using this reasoning, an exchange rate process created by $(k_t, t \geq 0)$ and any impulse control $(\tau, \xi) \in \mathcal{A}$ should naturally arise in the monetary model even when investors cannot forecast interventions because given any $t \geq 0$ they can forecast $(k_s, s \geq t)$ and observe interventions made over $[0, t]$. Enough predictive power over monetary policy exists to validate using (2.1) to construct the exchange rate even though interventions cannot be predicted. Of course it is necessary to revise investors' views of random variables for money supplies so they account for possible interventions before applying (2.1), our next major topic.

Definition 2.6. Given impulse control $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty}) \in \mathcal{A}$ let $x_t(\tau, \xi)$ be the exchange rate with intervention at $t \geq 0$ when monetary policy is $(m_t(\tau, \xi), t \geq 0)$. We say $(x_t(\tau, \xi), t \geq 0)$, the exchange rate process with intervention, is generated by (τ, ξ).

Coupling the view in Froot and Obstfeld (1991 p.242) that investors

construct the exchange rate by predicting monetary policy, no matter what form monetary dynamics take, with the restriction that they can forecast $(k_t, t \geq 0)$ but not interventions, given $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty}) \in \mathcal{A}$ and any $t \geq 0$ it follows $x_t(\tau, \xi)$ satisfies

$$x_t(\tau, \xi) = k_t + \alpha^{-1} \int_t^{\infty} \exp(\frac{t-s}{\alpha}) \int_t^s b_u \, du \, ds + \sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n \quad (2.5)$$

Since $\lim_{n\to\infty} \tau_n = \infty$, $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} |\xi_n| < \infty$ for all $t \geq 0$ because only finitely many τ_n reside in any bounded interval $[0, T]$ where $T > 0$. Hence, $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$ exists and is finite so that (2.5) is well defined. In fact only finitely many τ_n residing in any bounded interval means $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$ is actually a finite sum. For any $t \geq 0$ and $n \geq 1$ observe $1_{\{\tau_n \leq t\}} \xi_n$ is $\mathcal{F}_t$-measurable implying all interventions up to t are observed by investors. Moreover, $(\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n, t \geq 0)$ is a right continuous, left limit (càdlàg), adapted, bounded variation process, a fact useful later on when considering properties of $(x_t(\tau, \xi), t \geq 0)$.

To see (2.5) holds fix any $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty}) \in \mathcal{A}$. Given any $t \geq 0$ let $m_s(t)$ be the money supply investors believe policymakers will engineer at $s \geq t$. Notice for any $s > t$, $m_s(t)$ is a random variable that will usually be different from $m_s(\tau, \xi)$, the actual money supply with intervention. Instead $m_s(t)$ is a random variable for the potential money supply at $s \geq t$ that is crafted from what investors observe over $[0, t]$ and the knowledge future central bank interventions are possible. Assumption 2.2 implies $m_s(t)$ satisfies

$$m_s(t) = k_s + \sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n \quad (2.6)$$

Equation (2.6) follows from investors constructing $m_s(t)$ to approximate $m_s(\tau, \xi)$ as closely as possible. Invoking (2.4), $m_s(\tau, \xi)$ incorporates k_s and interventions across $[0, s]$, $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq s\}} \xi_n$. Since k_s is a basic money supply created by central bankers at time s it must appear in $m_s(t)$. Since $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$ is $\mathcal{F}_t$-measurable it must also appear in $m_s(t)$ because this is the only approximation to $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq s\}} \xi_n$ available at t. Conditional expectation is the only forecasting device permitted in the model but it cannot be applied to forecasting interventions

made over (t, ∞) because they are shrouded in deep mystery. This does not mean investors cannot form rudimentary views about discretionary changes. Knowing intervention may occur, investors approximate the discretionary money supply at any $s \in (t, \infty)$ by $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$. Thus, (2.6) gives the money supply investors perceive will appear at $s \geq t$ because of central bank actions.

For any $s > t$ recall k_s is unobservable until time s but that investors forecast k_s via $E(k_s|\mathcal{F}_t)$. Investors also need to need to forecast $m_s(t)$ via $E(m_s(t)|\mathcal{F}_t)$ for the same reason. Allowing investors to forecast $m_s(t)$ does not violate assumption 2.2 because the only link to intervention in $m_s(t)$, namely $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$, is observable at t. Since $\sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$ is $\mathcal{F}_t$-measurable, for any $s \geq t$ almost surely $E(m_s(t)|\mathcal{F}_t)$ satisfies

$$E(m_s(t)|\mathcal{F}_t) = E(k_s|\mathcal{F}_t) + \sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n \tag{2.7}$$

Since $E(k_s|\mathcal{F}_t) + \sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$ is $\mathcal{F}_t$-measurable we can take it to be $E(m_s(t)|\mathcal{F}_t)$ identically. Notice $m_t(t) = k_t + \sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n = m_t(\tau, \xi)$ so at any t there is consistency between the perceived money supply and actual observed money supply $m_t(\tau, \xi)$. Of course it must be confirmed that the mathematics of the model yield such a rational conclusion. Via (2.6) and (2.7) investors intelligently account for potential interventions over (t, ∞).

To summarize, fix any $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty}) \in \mathcal{A}$ and $t \geq 0$ then consider the process $(m_s(t), s \geq t)$ defined by (2.6) it generates, which is the monetary regime perceived by investors to hold over $[t, \infty)$. Recalling conditional expectation of a random variable is not unique we always fix the version used in the monetary model calculation (2.1) given any monetary dynamics. Accepting the reasoning of Froot and Obstfeld (1991 p.242), money supply forecasts $(E(m_s(t)|\mathcal{F}_t), s \geq t)$ enter (2.1) so $x_t(\tau, \xi)$ satisfies

$$x_t(\tau, \xi) = \alpha^{-1} \int_t^{\infty} \exp(\frac{t-s}{\alpha}) E(m_s(t)|\mathcal{F}_t)\, ds \tag{2.8}$$

Since $\alpha^{-1} \int_t^{\infty} \exp(\frac{t-s}{\alpha})\, ds = 1$, invoking (2.7) we see (2.8) becomes (2.5). Thus, at τ_n the bank engineers a jump of size ξ_n in the exchange rate via its money supply intervention, as asserted above. Frequently,

$(x_t(\tau,\xi), t \geq 0)$ is referred to as exchange rates with intervention since there is an exchange rate for each $t \geq 0$. Also if the impulse control $(\tau,\xi) \in \mathcal{A}$ is understood $x_t(\tau,\xi)$ may simply be denoted x_t. Some exchange rate properties deserve mention. First, section 3 establishes continuity of $(y_t, t \geq 0)$. Let $((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty}) \in \mathcal{A}$ generate $(x_t, t \geq 0)$. Notice $x_t = y_t + \sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$ for all $t \geq 0$ implying $(x_t, t \geq 0)$ is a càdlàg process. Second, $(y_t, t \geq 0)$ and $(x_t, t \geq 0)$ are adapted. Third, since b is a deterministic function and k_0 a real number y_0 is a real number, not a random variable. Finally by (2.5) we have $x_0 = y_0$; in fact if $t < \tau_1$ it follows that $x_t = y_t$.

Zero intervention is captured by $(\eta, 0) = ((\eta_n)_{n=1}^{\infty}, (0_n)_{n=1}^{\infty}) \in \mathcal{A}$ where $\eta_n(\omega) = n$ and $0_n(\omega) = 0$ for all $n \geq 1$ and $\omega \in \Omega$. Positive integer stopping times are chosen here since they satisfy properties of intervention times in definition 2.2. Many controls actually capture zero intervention. The key point for a zero intervention control is that interventions $(\xi_n)_{n=1}^{\infty}$ satisfy $\xi_n(\omega) = 0$ for all $n \geq 1$ and $\omega \in \Omega$ but any sequence of stopping times satisfying the conditions of definition 2.2 suffices for intervention times. Therefore $\mathcal{A}$ consists of $(\eta, 0)$ and similar controls capturing zero intervention as well as impulse controls $((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty})$ such that $\xi_n \neq 0$ for all $n \geq 1$ a.s. while $\sum_{n=1}^{\infty} |\xi_n| \leq R^*$. Essentially either the central bank intervenes across an infinite horizon or never intervenes.

Inspecting (2.5) we see $x_t(\eta, 0) = y_t$ for every $t \geq 0$ so that zero intervention creates freely floating exchange rates. While this is what one expects it is necessary to affirm the mathematics of the model correspond to intuition. Of course (2.5) implies freely floating exchange rates arise from any zero intervention control. By contrast, ongoing intervention captures a managed floating or fixed rate regime. Central bank intervention to maintain the exchange rate in a target zone around a central parity features in fixed exchange rate regimes and may appear in managed floating regimes. A central parity, namely an exchange rate preferred by policymakers, may be fixed or variable over time. Maintaining small deviations between the exchange rate and a central parity is enforceable by application of suitable impulse controls. Having introduced impulse controls and discussed their economic significance we now formalize the choice problem confronted by the central bank.

Assumption 2.3. The following conditions hold:

(1) The domestic central bank specifies target exchange rates given by the adapted, bounded, measurable process $(\beta_t, t \geq 0)$.

(2) Deviations between actual exchange rates and $(\beta_t, t \geq 0)$ incur costs given by the measurable function $f : \mathbb{R} \to [0, \infty)$. Specifically, given $(\tau, \xi) \in \mathcal{A}$ and any $t \geq 0$ the cost of the target deviation at t is $f(x_t(\tau, \xi) - \beta_t)$.

(3) Also, $f \leq M$ for some finite constant $M > 0$, $f(0) = 0$ and $f(z) > 0$ for all $z \neq 0$.

While policymakers specify $(\beta_t, t \geq 0)$ it is an exogenous process, not part of the choice problem. Discretionary interventions given by $(\tau, \xi) \in \mathcal{A}$ are the central bank's vehicle for attaining its exchange rate targets. Impulse controls affect exchange rates via (2.5) so can facilitate attainment of targets or moderate deviations from targets, thereby avoiding or reducing costs associated with target violations respectively. Macroeconomics often considers fixed rate systems where the central parity is constant rather than variable over time, regarding all deviations from this parity as undesirable. Provided $\beta_t = m$ for all $t \geq 0$ where m is a nonrandom constant or $\mathcal{F}_0$-measurable random variable, the target process represents such a central parity. Impulse control theory clearly fits into rigorous modelling of this classic scenario of keeping the exchange rate close to a central parity. Recalling sudden interventions by the Federal Reserve and other central banks during the Plaza Accord era, one sees impulse control theory is an important technique for modelling central bank intervention when policymakers have any exchange rate targets in mind.

Via control of b and σ central bankers could use $(k_t, t \geq 0)$ to attain exchange rate targets, which is evident from (2.3). However, monetary policy is usually constructed to attain income and inflation targets, not exchange rate targets. Natural conflicts may arise from having exchange rate as well as inflation and GDP targets. For example, suppose via control of b and σ central bankers reduce inflation. With restrictive money growth exchange rates may appreciate excessively, but by using impulse controls to affect exchange rates central bankers can prevent exports from collapsing. So impulse control can resolve problems even when the model allows for control of b and σ. Building multiple targets into monetary model impulse control theory coupled with control of b and σ is a task

for future research. The key point is that impulse control is an important vehicle for attaining currency targets even if multiple targets exist and control of b and σ is allowed.

Definition 2.7. Let $(\tau, \xi) \in \mathcal{A}$ generate $(x_t, t \geq 0)$. Let $\lambda > 0$ be the central bank's discount rate then the total cost of deviating from $(\beta_t, t \geq 0)$ is

$$E \int_0^\infty \exp(-\lambda t) f(x_t - \beta_t)\, dt \tag{2.9}$$

Since $(x_t, t \geq 0)$ generated by $(\tau, \xi) \in \mathcal{A}$ is a càdlàg process, $(x_t - \beta_t, t \geq 0)$ is measurable. Notice $E \int_0^\infty \exp(-\lambda t) f(x_t - \beta_t)\, dt < \infty$ since f is bounded. Also, note λ must be viewed as a discount factor employed by the central bank that reflects its time preferences since changes in the money supply alter market interest rates.

Assumption 2.4. Intervention involves costs for the central bank given by the bounded function $\gamma : \mathbb{R} \to [0, \infty)$ where $\gamma(0) = 0$. Specifically, if $((\tau_n)_{n=1}^\infty, (\xi_n)_{n=1}^\infty) \in \mathcal{A}$ is an impulse control the total intervention cost is

$$E \sum_{n=1}^\infty \exp(-\lambda \tau_n) \gamma(\xi_n) \tag{2.10}$$

Definition 2.8. Let $(\tau, \xi) = ((\tau_n)_{n=1}^\infty, (\xi_n)_{n=1}^\infty) \in \mathcal{A}$ generate $(x_t, t \geq 0)$. The total cost of the impulse control is $J(\tau, \xi)$ where

$$J(\tau, \xi) = E \int_0^\infty \exp(-\lambda t) f(x_t - \beta_t)\, dt + E \sum_{n=1}^\infty \exp(-\lambda \tau_n) \gamma(\xi_n) \tag{2.11}$$

Definition 2.9. The stochastic control problem is to minimize $J(\tau, \xi)$ for $(\tau, \xi) \in \mathcal{A}$.

Our control problem formalizes the idea that central bankers choose intervention times and levels to minimize target deviation and intervention costs. This optimization problem can be solved for any initial money supply k_0. Notice k_0 plays a pivotal role in creating exchange rate sample paths and, by consequence, $J(\tau, \xi)$. More precise notation would acknowledge this dependence. We could write $y_t(k_0)$, $x_t(\tau, \xi, k_0)$ and $J(\tau, \xi, k_0)$

but to simplify the presentation we often ignore dependence of these objects on k_0. In our discussions k_0 tends to be treated as given, effectively fixed at a particular value, justifying the convention of not building it into our notation, although we sometimes make exceptions.

Despite γ being bounded some $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty}) \in \mathcal{A}$ may yield $J(\tau, \xi) = \infty$ since $E \sum_{n=1}^{\infty} \exp(-\lambda \tau_n)\gamma(\xi_n) = \infty$ is possible. Our control problem can restrict the minimization to $J(\tau, \xi)$ such that $J(\tau, \xi) < \infty$ because there is at least one control $(\tau, \xi) \in \mathcal{A}$ where $J(\tau, \xi) < \infty$. Specifically, with the zero intervention control $(\eta, 0)$, because $0_n = 0$ for all $n \geq 1$ and $\gamma(0) = 0$, $J(\eta, 0)$ satisfies

$$J(\eta, 0) = E \int_0^{\infty} \exp(-\lambda t) f(y_t - \beta_t)\, dt \tag{2.12}$$

If (ζ, ξ) is another zero intervention control then $J(\zeta, \xi) = J(\eta, 0)$. Also notice that if b and σ do not vanish outside some bounded sets profound deviations between $(y_t, t \geq 0)$ and $(\beta_t, t \geq 0)$ are likely so that $J(\eta, 0)$ may be high. By (2.3), k_t is a component of y_t for every $t \geq 0$. One expects $(k_t, t \geq 0)$ to have wild enough fluctuations with nontrivial b and σ to ensure $(y_t, t \geq 0)$ wanders significantly away from $(\beta_t, t \geq 0)$ since $(\beta_t, t \geq 0)$ defines a bounded function on $[0, \infty) \times \Omega$. Thus, policymakers have strong incentives to intervene especially if target deviation costs are high. At the same time costly interventions discourage discretionary changes, so central bankers confront a meaningful control problem.

Definition 2.10. The value function $V : \mathbb{R} \to [0, \infty)$ is defined by

$$V(k_0) = \inf \{J(\tau, \xi, k_0) : (\tau, \xi) \in \mathcal{A}\} \tag{2.13}$$

Defining V requires showing dependence of control costs on k_0. Also notice that since $\inf \{J(\tau, \xi, k_0) : (\tau, \xi) \in \mathcal{A}\} \leq J(\eta, 0, k_0)$ it follows $V(k_0) < \infty$ so V defines a real rather than extended real valued function, as we assert. Key goals are to characterize the value function and determine if intervention occurs in equilibrium. If $J(\eta, 0, k_0)$ is high some $(\tau, \xi) \in \mathcal{A}$ may yield $J(\tau, \xi, k_0) < J(\eta, 0, k_0)$ in which case intervention is optimal, meaning a managed floating regime or fixed rate regime is optimal. Application of impulse controls to keep exchange rates close to a central parity or more general targets will yield high costs if γ is high. In this case a freely floating exchange might be optimal.

3. Optimal Intervention and the Value Function

Stochastic impulse control theory often shows a solution of an ordinary differential equation (ODE) is connected to the value function via Ito's lemma. This method appears in Jeanblanc-Picqué (1993), Mundaca and Øksendal (1998) as well as Cadenillas and Zapatero (1999, 2000). In the absence of impulse control interventions exchange rate processes in all these papers are semimartingales. If $(z_t, t \geq 0)$ is a process altered by application of impulse control $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty})$, the resulting process $(z_t(\tau, \xi), t \geq 0)$ is given by $z_t(\tau, \xi) = z_t + \sum_{n=1}^{\infty} 1_{\{\tau_n \leq t\}} \xi_n$ for all $t \geq 0$. Hence, if $(z_t, t \geq 0)$ is a semimartingale $(z_t(\tau, \xi), t \geq 0)$ is also a semimartingale. As a result, the aforementioned researchers are justified in applying Ito's lemma to exchange rate processes with or without intervention.

Mundaca and Øksendal (1998) as well as Cadenillas and Zapatero (1999, 2000) assume the exchange rate without intervention is a semimartingale. Unlike Jeanblanc-Picqué (1993) none of these researchers work with the monetary model. Consider the monetary model exchange rate without intervention $(y_t, t \geq 0)$. Jeanblanc-Picqué (1993 p.169) asserts $(y_t, t \geq 0)$ is a semimartingale based on loose interpretation of a random ODE (RODE) the exchange rate satisfies. Economic theory states (2.1) arises from solving this RODE, which is linked to financial market equilibrium and purchasing power parity c.f. Flood and Garber (1983). Viewed thus, (2.1) gives a precise exchange rate linked to economic fundamentals and properties of $(y_t, t \geq 0)$ need to be derived. Given $(\tau, \xi) \in \mathcal{A}$, inspection of (2.3) and (2.5) reveals it is uncertain $(y_t, t \geq 0)$ and $(x_t(\tau, \xi), t \geq 0)$ are semimartingales. Establishing this property holds is critical to connecting the value function to a PDE solution via Ito's lemma, one of our objectives. Illuminating value functions via connections to PDE is also a tradition in stochastic control c.f. Benth and Karleson (2005).

As mentioned when introducing the decomposition (2.3), $\int_t^{\infty} \exp(\frac{t-s}{\alpha}) \int_t^s b_u \; du \; ds$ exists and is finite for every $t \geq 0$ where every integral in question is a Lebesgue integral. Proving this integral exists and is finite emerges when proving theorem 3.1. To this end recall that if $g \in C([t, \infty), \mathbb{R}) \bigcap L^1([t, \infty), \mathbb{R})$ then the improper Riemann

integral of g on $[t,\infty)$ exists and equals its Lebesgue integral, $\int_t^\infty g(s)\,ds$. Another fact useful in proving theorem 3.1 is that if $g \in C([t,\infty),\mathbb{R})$, $g \geq 0$ and g has an improper Riemann integral on $[t,\infty)$ it is Lebesgue integrable on $[t,\infty)$ and the two integrals are equal.

Theorem 3.1. Given any $(\tau,\xi) \in \mathcal{A}$, $(x_t(\tau,\xi), t \geq 0)$ is a *càdlàg* semimartingale and $(y_t, t \geq 0)$ is a continuous semimartingale.

Proof. Let $(\tau,\xi) = ((\tau_n)_{n=1}^\infty, (\xi_n)_{n=1}^\infty) \in \mathcal{A}$ so $x_t(\tau,\xi) = y_t + \sum_{n=1}^\infty 1_{\{\tau_n \leq t\}}\xi_n$ for all $t \geq 0$. Since $(\sum_{n=1}^\infty 1_{\{\tau_n\leq t\}}\xi_n, t \geq 0)$ is adapted, *càdlàg* and of bounded variation it follows $(x_t(\tau,\xi), t \geq 0)$ is a *càdlàg* semimartingale provided $(y_t, t \geq 0)$ is a continuous semimartingale, a fact we now establish. To this end, for any $t \geq 0$ define v_t by

$$v_t = \alpha^{-1}\int_t^\infty \exp(\frac{t-s}{\alpha})\int_t^s b_u\,du\,ds \tag{3.1}$$

Since $|b| \leq M$ where $M > 0$ is a constant,

$$\exp(\frac{t-s}{\alpha})\int_t^s |b_u|\,du \leq M\exp(\frac{t-s}{\alpha})(s-t) \tag{3.2}$$

Define $g : [t,\infty) \to [0,\infty)$ by $g(s) = M\exp(\frac{t-s}{\alpha})(s-t)$ then via integration by parts the improper Riemann integral of g exists on $[t,\infty)$, implying g is Lebesgue integrable on $[t,\infty)$. Using (3.2) we have

$$\int_t^\infty \exp(\frac{t-s}{\alpha})\int_t^s |b_u|\,du\,ds \leq \int_t^\infty M\exp(\frac{t-s}{\alpha})(s-t)\,ds < \infty \tag{3.3}$$

so that v_t is exists and is finite for every $t \geq 0$.

Now since $\exp(\frac{t-s}{\alpha})(s-t) \to 0$ as $s \to \infty$ it follows that

$$\exp(\frac{t-s}{\alpha})\int_t^s b_u\,du \to 0 \quad \text{as} \quad s \to \infty \tag{3.4}$$

Recall b is bounded and continuous then observe $\int_0^\infty \exp(\frac{-s}{\alpha})|b_s|\,ds < \infty$. So we can define $g : [t,\infty) \to \mathbb{R}$ by $g(s) = \exp(\frac{t-s}{\alpha})b_s$ and be certain its improper Riemann integral exists on $[t,\infty)$. Armed with these facts and (3.4), integration by parts on $[t,\infty)$ yields

$$v_t = \int_t^\infty \exp(\frac{t-s}{\alpha}) b_s \, ds \tag{3.5}$$

For any $t \geq 0$ equation (3.5) implies

$$v_t' = \alpha^{-1} \int_t^\infty \exp(\frac{t-s}{\alpha}) b_s \, ds - b_t = \alpha^{-1} v_t - b_t \tag{3.6}$$

Again because $\int_0^\infty \exp(\frac{-s}{\alpha})|b_s| \, ds < \infty$ we have $(v_t, t \geq 0)$ is continuous. Combining this fact with (3.6) and continuity of b we have $v \in C^1([0,\infty), \mathbb{R})$. As a result, for any $t \geq 0$ we have $v_t = v_0 + \int_0^t (\alpha^{-1} v_s - b_s) \, ds$. Since $y_t = k_t + v_t$ for all $t \geq 0$ we have

$$y_t = k_0 + v_0 + \alpha^{-1} \int_0^t v_s \, ds + \int_0^t \sigma(s, k_s) \, dW_s \tag{3.7}$$

Clearly, $(\int_0^t \sigma(u, k_u) \, dW_u, t \geq 0)$ is a continuous square integrable martingale. Furthermore, $(\int_0^t v_s \, ds, t \geq 0)$ is a continuous process of bounded variation. Via the representation (3.7) $(y_t, t \geq 0)$ is a continuous a semimartingale. q.e.d.

Proving $(y_t, t \geq 0)$ and $(x_t(\tau, \xi), t \geq 0)$ are semimartingales for any $(\tau, \xi) \in \mathcal{A}$ is interesting in its own right. Semimartingales are fundamental in the theory of stochastic processes c.f. Karatzas and Shreve (1991), Protter (1990). As a result of theorem 3.1 more techniques from Ito's calculus may now be applied to monetary model exchange rates. The semimartingale property also endows exchange rates with a well understood structure. Another reason theorem 3.1 is important resides with definition of target deviation costs (2.9). Section 2 mentioned $(x_t(\tau, \xi), t \geq 0)$ is *càdlàg* for all $(\tau, \xi) \in \mathcal{A}$ while $(y_t, t \geq 0)$ is continuous, results ensuring $(x_t(\tau, \xi) - \beta_t, t \geq 0)$ and $(y_t - \beta_t, t \geq 0)$ are measurable. Without this basic measurability result total target deviation costs (2.9) are not well defined.

Assumption 3.1. The cost function f is Lipschitz continuous. Specifically, there exists a constant $H > 0$ such that for all $u, v \in \mathbb{R}$

$$|f(u) - f(v)| \leq H|u - v| \tag{3.8}$$

Jeanblanc-Picqué (1993) as well as Cadenillas and Zapatero (1999, 2000) prove intervention when the exchange rate strikes endpoints of a bounded interval $[p, q]$ yields minimum total control costs. Intervention takes the exchange rate to either z_1 or z_2 where $z_1, z_2 \in (p, q)$. All these researchers actually conjecture such a policy is optimal then find conditions when it becomes optimal. Differential equation theory is used to construct a function that gives control costs for their interventionist strategy. Via Ito's lemma they show this function is actually the value function. Cost functions in these papers are quite specialized, a factor contributing to success of their method. More general control problems might not be amenable to conjecturing a control with certain properties is optimal then validating the initial guess via ODE theory and Ito's lemma.

Qualitative properties of equilibria are of great interest in economics. Maintaining a target zone is optimal in Jeanblanc-Picqué (1993) as well as Cadenillas and Zapatero (1999, 2000) which suggests managed floating or fixed exchange rates are optimal. Saying these regimes dominate a floating rate regime is an interesting qualitative statement. Deriving a precise equation for the value function of an impulse control problem without an initial guess at an optimal control or other simplifications would typically be very difficult. Even if this can be done, identifying the optimal control or qualitative features of the equilibrium it creates may be challenging. Some method is ultimately required to illuminate qualitative properties of the equilibrium created by an optimal control. Theorem 3.2 shows restrictions on target deviation and intervention costs yields floating exchange rates are optimal without recourse to PDE or ODE analysis. Cost restrictions might yield a simple method for identifying optima of control problems.

Definition 3.1. We say $(\tau, \xi) = ((\tau_n)_{n=1}^{\infty}, (\xi_n)_{n=1}^{\infty}) \in \mathcal{A}$ is a nontrivial control if $\xi_n \neq 0$ for all $n \geq 1$ a.s. In this case we speak of nontrivial interventions (τ, ξ).

Recall if (ζ, v) is a zero intervention control $J(\eta, 0) = J(\zeta, v)$ so given $(\tau, \xi) \in \mathcal{A}$, when comparing $J(\eta, 0)$ with $J(\tau, \xi)$, we may assume (τ, ξ) is a nontrivial control. Also, as noted in section 2, k_0 helps generate exchange rates with and without intervention as well as associated control costs, but we only build this dependence into our notation when needed.

Theorem 3.2. Let $L \equiv \inf\{\gamma(z) : z \in \mathbb{R}, z \neq 0\}$ and assume $\frac{HR^*}{\lambda} < L$ then zero intervention is the unique policy attaining $V(k_0)$ for all $k_0 \in \mathbb{R}$. Hence, a freely floating exchange rate is optimal and appears in equilibrium as central bank policy.

Proof. Fix any $k_0 \in \mathbb{R}$ then recall from section 2 that

$$V(k_0) = \inf\{J(\nu, \zeta) : (\nu, \zeta) \in \mathcal{A}^*\}$$

where

$$A^* = \{(\nu, \zeta) \in \mathcal{A} : J(\nu, \zeta) < \infty\}$$

Since $(\eta, 0) \in \mathcal{A}^*$ generates $(y_t, t \geq 0)$

$$E\int_0^\infty \exp(-\lambda t) f(y_t - \beta_t)\, dt \geq V(k_0) \tag{3.9}$$

Let impulse control $(\tau, \xi) = ((\tau_n)_{n=1}^\infty, (\xi_n)_{n=1}^\infty) \in \mathcal{A}^*$ generate $(x_t, t \geq 0)$. We show that

$$E\int_0^\infty \exp(-\lambda t) f(y_t - \beta_t)\, dt \leq J(\tau, \xi) \tag{3.10}$$

for then $E\int_0^\infty \exp(-\lambda t) f(y_t - \beta_t)\ dt \leq V(k_0)$ implying $E\int_0^\infty \exp(-\lambda t) f(y_t - \beta_t)\ dt = V(k_0)$. Establishing that $V(k_0)$ is attained by zero intervention qualifies zero intervention as a candidate for equilibrium policy. If nontrivial interventions (τ, ξ) yield $J(\tau, \xi) = V(k_0)$ equilibrium behaviour is indeterminate. To prove zero intervention is equilibrium policy we show that when $(\tau, \xi) \in \mathcal{A}^*$ is a nontrivial control generating $(x_t, t \geq 0)$ then

$$E\int_0^\infty \exp(-\lambda t) f(y_t - \beta_t)\, dt < J(\tau, \xi) \tag{3.11}$$

Consequently, zero intervention will be the unique policy attaining $V(k_0)$ which establishes it as equilibrium policy as well as guaranteeing optimality of a pure float. Notice if (3.11) holds for any nontrivial control then (3.10) also holds, so we concentrate on proving (3.11). Thus, assume nontrivial interventions $(\tau, \xi) = ((\tau_n)_{n=1}^\infty, (\xi_n)_{n=1}^\infty) \in \mathcal{A}^*$ generate $(x_t, t \geq 0)$. Now, let $\tau_0 = 0$ then since $\tau_n \uparrow \infty$

$$E\int_0^\infty \exp(-\lambda t)f(y_t-\beta_t)\,dt = \sum_{n=1}^\infty E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)f(y_t-\beta_t)\,dt \tag{3.12}$$

Via (3.8), for every $t \geq 0$ we have

$$f(y_t-\beta_t) \leq f(x_t-\beta_t) + H|y_t-x_t| \tag{3.13}$$

Now for $t \in [0,\tau_1)$ we have $y_t = x_t$ implying

$$E\int_0^{\tau_1} \exp(-\lambda t)f(y_t-\beta_t)\,dt = E\int_0^{\tau_1} \exp(-\lambda t)f(x_t-\beta_t)\,dt \tag{3.14}$$

Also since $\xi_n \neq 0$ a.s. for every $n \geq 1$, it follows that for all $n \geq 1$

$$LE\exp(-\lambda\tau_n) \leq E\exp(-\lambda\tau_n)\gamma(\xi_n) \tag{3.15}$$

For any $n \geq 2$ and $t \in [\tau_{n-1},\tau_n)$ we have $x_t - y_t = \sum_{i=1}^{n-1}\xi_i$. Also, $\frac{HR^*}{\lambda} < L$ means $\frac{HR^*}{\lambda}E\exp(-\lambda\tau_n) < LE\exp(-\lambda\tau_n)$ for all $n \geq 1$. Combining these facts with (3.13) and (3.15) we have

$$\begin{aligned}
&E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)f(y_t-\beta_t)\,dt \leq E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)(f(x_t-\beta_t)+H\sum_{i=1}^{n-1}|\xi_i|)\,dt \leq \\
&\quad E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)f(x_t-\beta_t)\,dt + \frac{HR^*}{\lambda}E(\exp(-\lambda\tau_{n-1})-\exp(-\lambda\tau_n)) \leq \\
&\quad\quad E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)f(x_t-\beta_t)\,dt + \frac{HR^*}{\lambda}E\exp(-\lambda\tau_{n-1}) < \\
&\quad\quad\quad E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)f(x_t-\beta_t)\,dt + LE\exp(-\lambda\tau_{n-1}) \leq \\
&\quad\quad\quad E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)f(x_t-\beta_t)\,dt + E\exp(-\lambda\tau_{n-1})\gamma(\xi_{n-1})
\end{aligned} \tag{3.16}$$

Recall that if $0 \leq a_n < b_n$ for all $n \geq 1$ then $\sum_{n=1}^\infty a_n < \sum_{n=1}^\infty b_n$ when $\sum_{n=1}^\infty b_n < \infty$. Since $J(\tau,\xi) < \infty$ we have

$$\sum_{n=2}^\infty E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)f(x_t-\beta_t)\,dt + E\exp(-\lambda\tau_{n-1})\gamma(\xi_{n-1}) < \infty \tag{3.17}$$

Hence by (3.16),

$$\sum_{n=1}^{\infty} E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t) f(y_t-\beta_t)\,dt = E\int_0^{\tau_1} \exp(-\lambda t) f(y_t-\beta_t)\,dt +$$

$$\sum_{n=2}^{\infty} E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t) f(y_t-\beta_t)\,dt \leq$$

$$E\int_0^{\tau_1} \exp(-\lambda t) f(x_t-\beta_t)\,dt + \sum_{n=2}^{\infty} E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t)(f(x_t-\beta_t) + H\sum_{i=1}^{n-1}|\xi_i|)\,dt <$$

$$E\int_0^{\tau_1} \exp(-\lambda t) f(x_t-\beta_t)\,dt +$$

$$\sum_{n=2}^{\infty} E\int_{\tau_{n-1}}^{\tau_n} \exp(-\lambda t) f(x_t-\beta_t)\,dt + \sum_{n=2}^{\infty} E\exp(-\lambda\tau_{n-1})\gamma(\xi_{n-1}) =$$

$$E\int_0^{\infty} \exp(-\lambda t) f(x_t-\beta_t)\,dt + \sum_{n=1}^{\infty} E\exp(-\lambda\tau_n)\gamma(\xi_n) = J(\tau,\xi) \tag{3.18}$$

Thus by (3.12), $E\int_0^{\infty} \exp(-\lambda t) f(y_t-\beta_t)\,dt < J(\tau,\xi)$ as required. q.e.d.

Freely floating exchange rates prevail in thirty-six countries c.f. Wang (2009 p.19). Economic theory must therefore present a rationale for countries adopting floating exchange rates. Constrained intervention across time plus relatively high intervention costs, captured by assuming $\frac{HR^*}{\lambda} < L$, generate the optimality of floating exchange rates in our model. High intervention costs might be a real world phenomenon, the manifestation of a loss of credibility that comes about as investors reassess policymakers' ability to guide economies after intervention corrects an excess. Intervention ultimately points to something being wrong with existing policy and may lessen investors' confidence in central bankers. Viewed thus, building investor confidence into γ, even loosely as we have, is rational.

Empirical studies cited in the introduction question the benefits of intervention or suggest collateral damage results from intervention. Such phenomena would validate the assumption of high intervention costs and lead policymakers away from discretionary changes designed to affect exchange rates. Ultimately this econometric work validates the conclusions of theorem 3.2. Quite apart from econometric work, one can observe there have been fewer episodes of coordinated central bank intervention since the Plaza Accord era. Although the central banks of Japan and China certainly engaged in abundant currency manipulation in recent years, coordinated

exchange rate intervention by central banks in the United States and Europe to guide the U.S. dollar has not grabbed newspaper headlines for some time, another fact suggesting there is some validity in theorem 3.2.

Suppose $\beta_t(\omega) = 0$ for all $(t, \omega) \in [0, \infty) \times \Omega$ and that policymakers believe it is important to keep exchange rates in bounded interval $[a, c]$ where $a < 0 < c$, reflected by $f(z) = 0$ for $z \in [a, c]$ and $f(z) > 0$ for $z \notin [a, c]$. This scenario captures a central bank wanting to maintain an exchange rate target zone, a common feature of managed floating and fixed rate regimes. If b and σ are nontrivial functions one expects $(k_t, t \geq 0)$ exits bounded regions in finite time a.s. implying $(y_t, t \geq 0)$ inevitably wanders away from $[a, c]$ repeatedly. Discretionary interventions constrained via condition (2) of definition 2.4 would then be insufficient to keep the exchange rate in $[a, c]$ for all time. However, preserving the target zone over a finite time horizon would be an option. According to theorem 3.2 the central bank does not attempt this, an interesting result in light of historical experience.

The Bretton Woods fixed rate regime dominated the first three decades which followed the Second World War before collapsing c.f. Wang (2009 ch. 2). Bretton Woods kept currencies in narrow bands around central parities via active central bank intervention. Floating rates became much more widespread in the aftermath of Bretton Woods collapsing and have remained prominent. This historical experience suggests impulse control theory should seek conditions where intervention happens over a finite horizon before ceasing entirely. A collapsing target zone result like this appears in a very specialized model c.f. Gagnon (2017 theorem 4.7), but should also be shown to hold in a more general stochastic calculus based model. A fixed exchange rate regime with such broad international participation as Bretton Woods has not emerged to dominate international finance. This fact, coupled with prevalence of floating exchange rates, suggests theorem 3.2 still has merit.

Having determined the domestic central bank never intervenes in equilibrium we now seek a deeper characterization of the value function. Theorem 3.2 yields a precise expression for $V(k_0)$ as $V(k_0) = E\int_0^\infty \exp(-\lambda t) f(y_t(k_0) - \beta_t)\, dt$ for every $k_0 \in \mathbb{R}$ but this is not particularly revealing, motivating an alternate characterization of V. To obtain deeper insights into V we assume exchange rate targets are given by a nonrandom function rather than a stochastic process. Throughout the

discussion let $C_b^{1,2}([0,\infty)\times\mathbb{R},\mathbb{R})$ be the space of bounded continuous real valued functions on $[0,\infty)\times\mathbb{R}$ with bounded continuous partial derivatives up to order one in time and two in space.

Theorem 3.3. Let exchange rate targets $\beta:[0,\infty)\to\mathbb{R}$ be continuous. Assume $\phi\in C_b^{1,2}([0,\infty)\times\mathbb{R},\mathbb{R})$ satisfies the following PDE for $t\geq 0$ and $x\in\mathbb{R}$:

$$\frac{\partial\phi}{\partial t}(t,x)+\alpha^{-1}v_t\frac{\partial\phi}{\partial x}(t,x)+\frac{1}{2}\sigma^2(t,x-v_t)\frac{\partial^2\phi}{\partial x^2}(t,x)-\lambda\phi(t,x)=-f(x-\beta_t) \tag{3.19}$$

where $v_t=\int_t^\infty \exp(t-s)\int_t^s b_u\,du\,ds$ for all $t\geq 0$. Define $x_0(k_0)$ for any initial money supply k_0 by $x_0(k_0)=k_0+v_0$ then $\phi(0,x_0(k_0))=V(k_0)$ for all $k_0\in\mathbb{R}$.

Proof. Fix any k_0 then by theorem 3.2, $V(k_0)=J(\eta,0)=E\int_0^\infty\exp(-\lambda t)f(y_t-\beta_t)\,dt$. From the proof of theorem 3.1 we have $v\in C^1([0,\infty),\mathbb{R})$ and for any $t\geq 0$ by (3.6) v_t satisfies

$$v_t=v_0+\alpha^{-1}\int_0^t v_s\,ds-\int_0^t b_s\,ds \tag{3.20}$$

Invoking (3.7), $y_t=k_0+v_0+\alpha^{-1}\int_0^t v_s\,ds+\int_0^t\sigma(s,k_s)\,dW_s$ for all $t\geq 0$. Since $y_0=k_0+v_0$,

$$y_t=y_0+\alpha^{-1}\int_0^t v_s\,ds+\int_0^t\sigma(s,k_s)\,dW_s \tag{3.21}$$

for all $t\geq 0$. Clearly, $x_0(k_0)=k_0+v_0=y_0$ is nonrandom and because $k_t=y_t-v_t$ for every $t\geq 0$ we have $\sigma^2(t,k_t)=\sigma^2(t,y_t-v_t)$ for all $t\geq 0$. Applying Ito's lemma and integration by parts ensures that for any $t\geq 0$

$$\begin{aligned}\exp(-\lambda t)\phi(t,y_t)&=\phi(0,y_0)+\int_0^t\exp(-\lambda s)\frac{\partial\phi}{\partial s}(s,y_s)\,ds\\&\quad+\int_0^t\exp(-\lambda s)\sigma(s,k_s)\frac{\partial\phi}{\partial x}(s,y_s)\,dW_s\\&\quad+\int_0^t\exp(-\lambda s)(\alpha^{-1}v_s\frac{\partial\phi}{\partial x}(s,y_s)+\frac{1}{2}\sigma^2(s,y_s-v_s)\frac{\partial^2\phi}{\partial x^2}(s,y_s)-\lambda\phi(s,y_s))\,ds=\\&\phi(0,y_0)-\int_0^t\exp(-\lambda s)f(y_s-\beta_s)\,ds+\int_0^t\exp(-\lambda s)\sigma(s,k_s)\frac{\partial\phi}{\partial x}(s,y_s)\,dW_s\end{aligned} \tag{3.22}$$

Recalling assumption 2.1, σ is bounded and since $\phi \in C_b^{1,2}([0,\infty) \times \mathbb{R}, \mathbb{R})$, $\frac{\partial \phi}{\partial x}$ is bounded so $E\int_0^t \exp(-\lambda s)\sigma(s,k_s)\frac{\partial \phi}{\partial x}(s,y_s)\ dW_s = 0$ for any $t \geq 0$. Hence, for all $t \geq 0$

$$\phi(0,y_0) = E\exp(-\lambda t)\phi(t,y_t) + E\int_0^t \exp(-\lambda s)f(y_s - \beta_s)\ ds \quad (3.23)$$

Since $\phi \in C_b^{1,2}([0,\infty) \times \mathbb{R}, \mathbb{R})$ as $t \to \infty$ we have

$$E\exp(-\lambda t)\phi(t,y_t) + E\int_0^t \exp(-\lambda s)f(y_s - \beta_s)\ ds$$

$$\to E\int_0^\infty \exp(-\lambda s)f(y_s - \beta_s)\ ds$$

which establishes $\phi(0, k_0 + v_0) = V(k_0)$. q.e.d.

Linking the value function of our monetary model control problem with a PDE conforms with practices in the established stochastic control literature. We make no attempt to present conditions that ensure a solution to (3.19) exists, merely observing that if one does exist then it is connected to our value function. Existence of PDE solutions connected to value functions is often a thorny issue in control theory. Sometimes researchers guess at a solution for the value function from the Hamilton-Jacobi-Bellman equation then seek conditions validating their guess c.f. Benth and Karleson (2005). This method is not used in analyzing (3.19) since it is complex enough to defy insights that would lead to a guess at a solution. Notice having nonrandom targets ensures (3.19) defines a PDE rather than a stochastic PDE, a type of equation for which existence of a solution would be even more thorny. Difficult PDE arising in control theory is one reason restrictions on cost functions are useful since they may allow us to identify the optimal policy without recourse to complex PDE. Constraints on random integrals could be used to obtain a fuller characterization of the value function in the presence of random targets. While this is the approach of Gagnon (2019) such restrictions are hard to verify in practice.

Discussing how our results compare to the established exchange rate impulse control literature is necessary because theorem 3.2 is a result

distinct from those in Cadenillas and Zapareto (1999, 2000), Jeanblanc-Picqué (1993) as well as Mundaca and Øksendal (1998), where ongoing intervention is the norm. Unlike previous researchers in stochastic impulse control of exchange rates we assume the target violation cost function f is bounded. Standard control theory assumes cost functions are bounded for mathematical convenience c.f. Yong and Zhou (1999), but assuming f is bounded has special significance. Bounded f reflects the belief that currency markets may be preoccupied with critical trading ranges. In this case, past some point increased deviations from targets cease to generate gigantic additional costs. For example, suppose maintaining credibility requires policymakers keep the exchange rate in a bounded interval $[a, c]$ where $\beta_t(\omega) \in (a, c)$ for all $(t, \omega) \in [0, \infty) \times \Omega$. Suppose the exchange rate residing in $[a, c]$ incurs no costs but moving it marginally beyond $[a, c]$ entails great costs. Larger deviations from $[a, c]$ may generate limited additional costs because high penalties follow from the exchange rate leaving $[a, c]$ in the first place. Assuming $f \leq M$ ensures $|f(z - l) - f(r - l)| \leq 2M$ for all $z, r, l \in \mathbb{R}$, so cost jumps are bounded, as required by this paradigm that investors focus on critical trading ranges.

On the other hand, if $\lim_{|z|\to\infty} f(z) = \infty$ then increasing deviations from exchange rate targets enough yields great jumps in costs because $\lim_{|z|\to\infty} |f(z - l) - f(r - l)| = \infty$ for any fixed $r, l \in \mathbb{R}$. Motivation for ongoing intervention actually comes from this condition. For example, in Harrison and Taksar (1983) target violation costs become arbitrarily large as deviations from targets become arbitrarily large. Target violation costs f satisfying $\lim_{|z|\to\infty} f(z) = \infty$ figure prominently in Cadenillas and Zapareto (1999, 2000); they could be built in Jeanblanc-Picqué (1993) and are permitted in Mundaca and Øksendal (1998). Cadenillas and Zapareto (1999, 2000) actually use quadratic target violation costs but linear intervention costs, suggesting target violation is more costly than intervention.

Lipschitz continuity of f in assumption 3.1 is also very important to optimality of zero intervention. It plays a pivotal role in the inequalities used to prove theorem 3.2. This is the first time Lipschitz continuity of the target violation cost function appears in impulse control of exchange rates. Quadratic target violation costs cannot be Lipschitz continuous because a differentiable Lipschitz continuous function necessarily has a bounded derivative. Furthermore, assuming $\frac{HR^*}{\lambda} < L$ suggests intervention costs dominate target violation costs, a situation distinct from that in Cadenillas

and Zapareto (1999, 2000). Differences in assumptions about cost functions certainly help create divergent results about equilibrium intervention but restricted intervention is also pivotal. Previous researchers ignored the view that central banks retain credibility by limiting interventions across time.

Gagnon (2019) also presents conditions where zero intervention is the optimal policy and freely floating exchange rates reign. However, Gagnon (2019) does not constrain interventions across time, makes no connection between the value function and a PDE and imposes different conditions on the target violation cost function f than those here. Consequently, the results presented here must be viewed as distinct. Also, SDE monetary dynamics in Gagnon (2019) allow b to depend on time and space which creates a more complex control problem than the one here. Our paper can be regarded as a variation of Gagnon (2019) that reinforces optimality of freely floating exchange rates. Broadening the conditions where freely floating exchange rates are optimal is important from the standpoint of economic theory, which often seeks to make very general qualitative statements.

CONCLUSION

Our theorems showing central banks refrain from exchange rate intervention provide a theoretical counterpart to econometric findings that currency intervention can be ineffective or damaging, phenomena that would lead policymakers away from discretionary changes designed to alter exchange rates. Casual observations of less aggressive currency intervention during the past decade when compared to the Plaza Accord era reinforce the relevance of our result. In essence our paper provides a control theoretic basis for the optimality of freely floating rates in the presence of empirical evidence that intervention has drawbacks. Much more research needs to be done with impulse control models in light of the vast empirical literature on the effects of central bank intervention. Variations in the dynamics of $(k_t, t \geq 0)$ may provide fertile ground for extensions of the results presented here.

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Chapter 9

AN RBC MODEL WITH CONVEX INVESTMENT ADJUSTMENT COSTS: LESSONS FOR BULGARIA (1999-2018)

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Abstract

We introduce investment adjustment costs into a real-business-cycle setup augmented with a detailed government sector. We calibrate the model to Bulgarian data for the period following the introduction of the currency board arrangement (1999-2018). We investigate the quantitative importance of investment frictions for the propagation of cyclical fluctuations in Bulgaria. The model with investment frictions performs poorly vis-a-vis data, and is "rejected" in favor of the standard (frictionless) model. We thus declare the transmission mechanism associated with the convex investment adjustment costs to be an unlikely driver of the observed business cycle fluctuations in Bulgaria over the period studied.

Keywords: business cycles, convex investment adjustment costs, Tobin's q, Bulgaria

JEL Classification Codes: E24, E32

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1. Introduction and Motivation

The benchmark real-business-cycle (RBC) model assumes that capital stock can be easily and costlessly increased from one period to another via investment. In addition, the standard framework postulates that each unit of newly-produced capital becomes immediately productive in the generation of aggregate output. In addition, in the standard model, when a technology shock affects overall productivity of the factors of production, households are assumed to face no computational costs, and are thus able to effortlessly re-optimize their saving and investment decisions at any given instant.

However, this is not how investment is undertaken in reality. Capital goods are objects such as factories and other structures, machines, tools, equipment, etc. Clearly those are not produced overnight, and usually require some time to be installed before they become productive. Therefore, as part of the investment process there are additional investment costs incurred, potentially substantive costs that are ignored in the benchmark RBC case. The presence of investment costs causes real rigidities in capital accumulation dynamics, as households now have to balance the cost of having capital stock that differs from its optimal level versus the cost of adjusting investment levels, and in turn, physical capital stock. As a result investment process becomes less volatile, and observed investment time series look smoother.

In the literature, several modelling approaches have been proposed to address the above-mentioned issue. The first approach introduces a cost to change the level of investment over time, while the second applied the same logic to the stock of capital. Both approaches are qualitatively equivalent. Capital adjustment costs have been considered in Hayashi (1982), Abel and Blanchard (1993), Shapiro (1986), and more recently in Jermann (1998), Edge (2000), Fernandez-de-Cordoba and Kehoe (2000), Boldrin et al. (2001), Canzoneri et al. (2005), among many others.

Following a long line in the literature, e.g., Smets and Wouters (2002), Burnside et al. (2004), Christiano et al. (2005), Chistoffel et al. (2008), among others, in this chapter we utilize the investment adjustment cost function. After all, investment adjustment costs are resource costs, and lead to loss of output and consumption at an aggregate level. More specifically, during the process of investment, some resources cannot be turned into productive capital and thus are irrecoverably lost. Those losses are likely

to be substantial for developing economies. We chose Bulgaria as a testing ground for this theory, as Bulgaria is one of the newest member states of the European Union (EU), but as a former transition economy is still developing, and thus its investment technology might exhibit inefficiencies of the type discussed due to the existence of certain transaction costs.

We thus proceed and incorporate an investment adjustment costs in an otherwise standard real-business-cycle (RBC) model with a detailed government sector. We calibrate the model for Bulgaria in the period 1999-2018, as Bulgaria provides a good testing case for the theory. We then proceed to quantitatively evaluate the effect of such frictions for business cycle fluctuations. To the best of our knowledge, this is the first thorough investigation of the phenomenon, using modern tools of macroeconomics and applying those to Bulgaria. Unfortunately, for reasonable degree of investment frictions, the model fit is quite poor, especially when compared to the benchmark case with no frictions. Therefore, investment frictions, at least by themselves are not able to characterize well the observed business cycle in Bulgaria.

The rest of the chapter is organized as follows: Section 2 describes the model framework and describes the decentralized competitive equilibrium system, Section 3 discusses the calibration procedure, and Section 4 presents the steady-state model solution. Sections 5 proceeds with the out-of-steady-state dynamics of model variables, and compared the simulated second moments of theoretical variables against their empirical counterparts. Section 6 concludes the chapter.

2. Model Description

There is a representative households which derives utility out of consumption and leisure. The time available to households can be spent in productive use or as leisure. The government taxes consumption spending, levies a common proportional ("flat") tax on labor and capital income, in order to finance wasteful purchases of government consumption goods, and government transfers. On the production side, there is a representative firm, which hires labor and capital to produce a homogenous final good, which could be used for consumption, investment, or government purchases.

2.1. Households

There is a representative household, which maximizes its expected utility function

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ \ln c_t + \gamma \ln(1 - h_t) \Big\} \tag{2.1}$$

whereE_0 denotes household's expectations as of period 0, c_t denotes household's private consumption in period t, h_t are hours worked in period t, $0 < \beta < 1$ is the discount factor, $0 < \gamma < 1$ is the relative weight that the household attaches to leisure.

The household starts with an initial stock of physical capital $k_0 > 0$, and has to decide how much to add to it in the form of new investment. The law of motion for physical capital will feature convex (quadratic) investment adjustment costs as in Christiano et al. (2005) and is as follows:

$$k_{t+1} = (1 - \delta)k_t + \left[1 - \frac{\phi}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t \tag{2.2}$$

and $0 < \delta < 1$ is the depreciation rate. For $\phi = 0$, the model collapses to the setup without investment frictions. Note that investment and capital accumulation decisions can be equivalently considered from the firm's point of view, as discussed in Tobin (1969). In this paper we perform it from the household's point of view, as they are assumed to be the owners of capital. In addition, from the neoclassical perspective, firms are just production sets, or "technologies," and are thus unable to make their own decisions.

Next, the real interest rate is r_t, hence the before-tax capital income of the household in period t equals $r_t k_t$. In addition to capital income, the household can generate labor income. Hours supplied to the representative firm are rewarded at the hourly wage rate of w_t, so pre-tax labor income equals $w_t h_t$. Lastly, the household owns the firm in the economy and has a legal claim on all the firm's profit, π_t.

Next, the household's problem can be now simplified to

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ \ln c_t + \gamma \ln(1 - h_t) \Big\} \tag{2.3}$$

s.t.

$$(1+\tau^c)c_t + i_t = (1-\tau^y)[r_t k_t + \pi_t + w_t h_t] + g_t^t \tag{2.4}$$

$$k_{t+1} = (1-\delta)k_t + \left[1 - \frac{\phi}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t \tag{2.5}$$

where where τ^c is the tax on consumption, τ^y is the proportional income tax rate on labor and capital income ($0 < \tau^c, \tau^y < 1$), τ_t^k is the progressivwe rate applied to capital income, and g_t^t denotes government transfers. The household takes the tax rates $\{\tau^c, \tau^y\}_{t=0}^{\infty}$, government spending categories, $\{g_t^c, g_t^t\}_{t=0}^{\infty}$, profit $\{\pi_t\}_{t=0}^{\infty}$, the realized technology process $\{A_t\}_{t=0}^{\infty}$, prices $\{w_t, r_t\}_{t=0}^{\infty}$, and chooses $\{c_t, h_t, k_{t+1}\}_{t=0}^{\infty}$ to maximize its utility subject to the budget constraint.

The first-order optimality conditions as as follows:

$$c_t \quad : \quad \frac{1}{c_t} = \lambda_t(1+\tau^c) \tag{2.6}$$

$$h_t \quad : \quad \frac{\gamma}{1-h_t} = \lambda_t(1-\tau^y)w_t \tag{2.7}$$

$$i_t \quad : \quad \lambda_t = \mu_t\left[1 - \frac{\phi}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 - \phi\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right] + \beta E_t \mu_{t+1}\phi\left(\frac{i_{t+1}}{i_t} - 1\right)\left(\frac{i_{t+1}}{i_t}\right)^2 \tag{2.8}$$

$$k_{t+1} \quad : \quad \mu_t = \beta E_t[\lambda_{t+1}(1-\tau^y)r_{t+1} + (1-\delta)\mu_{t+1}] \tag{2.9}$$

$$TVC \quad : \quad \lim_{t\to\infty} \beta^t \lambda_t k_{t+1} = 0 \tag{2.10}$$

where λ_t is the Lagrangean multiplier (or the "shadow price of wealth") attached to household's budget constraint in period t, and μ_t is the multiplier attached to the law of motion for capital (or the "shadow price of capital"). Note that now the optimal capital stock decision and investmetn are separated due to the presence of investment adjustment costs: more specifically, investment now becomes a "state-", or pre-determined variable in the dynamic system.

The interpretation of the first-order conditions above is as follows: the first one states that for each household, the marginal utility of consumption equals the marginal utility of wealth, corrected for the consumption tax rate. The second equation states that when choosing labor supply optimally, at the margin, each hour spent by the household working for the firm should balance the benefit from doing so in terms of additional income generates, and the cost measured in terms of lower utility of leisure. The third equation balances the cost and benefits of an extra uniot of investment. The

forth equation is the so-called "Euler condition," which describes how the household chooses to allocate physical capital over time. Alternatively, it can be interpreted as an "asset pricing" equation, stating that the current price of an installed unit of capital depends on its expected future value, taking into account the physical depreciation rate and the expected after-tax rate of return to capital. The last condition is called the "transversality condition" (TVC): it states that at the end of the horizon, the value of physical capital should be zero.

Let us now define $q_t = \mu_t/\lambda_t$. This corresponds to the q-ratio discussed in Tobin (1969) and later in Hayashi (1982). More specifically, this corresponds to the $average\ q$ (observable, proxied by financial data), while Hayashi (1982) derived that under certain conditions the average equals to the $marginal\ q$ (which is unobservable, but the relevant concept for the theory). By definition, the q-ratio is the fraction of the market value of the firm's assets relative to the replacement cost of the installed capital. This is exactly what the two Lagrange multipliers capture in the model.In finance, the q-theory is used to inform investment decision and is based on the analysis of the q-ratio. The FOCs for capital and investment now become

$$q_t = \beta E_t \frac{c_t}{c_{t+1}}[(1-\tau^y)r_{t+1} + (1-\delta)q_{t+1}] \tag{2.11}$$

$$1 = q_t\left[1 - \frac{\phi}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 - \phi\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right] + \beta E_t \frac{c_t}{c_{t+1}} q_{t+1}\phi\left(\frac{i_{t+1}}{i_t} - 1\right)\left(\frac{i_{t+1}}{i_t}\right)^2 \tag{2.12}$$

where we made use of the fact that $\lambda_t = 1/[(1+\tau^c)c_t]$. We have done this transformation in order to study the evolution of the q-ratio over the business cycle, which potentially provides an additional margin of comparison between the theory and data.

2.2. Firm Problem

There is a representative firm in the economy, which produces a homogeneous product. The price of output is normalized to unity. The production technology is Cobb-Douglas and uses (rents) both physical capital, k_t, and labor hours, h_t, to maximize static profit

$$\Pi_t = A_t k_t^{\alpha} h_t^{1-\alpha} - r_t k_t - w_t h_t, \tag{2.13}$$

where A_t denotes the level of technology in period t. Since the firm rents the capital from households, the problem of the firm is a sequence of static profit maximizing problems. In equilibrium, there are no profits, and each input is priced according to its marginal product, *i.e.*,

$$k_t \quad : \quad \alpha \frac{y_t}{k_t} = r_t, \tag{2.14}$$

$$h_t \quad : \quad (1-\alpha) \frac{y_t}{h_t} = w_t. \tag{2.15}$$

In equilibrium, given that the inputs of production are paid their marginal products, $\pi_t = 0, \forall t$.

2.3. Government

In the model setup, the government is levying taxes on labor and capital income, as well as consumption, in order to finance spending on wasteful government purchases, and government transfers. The government budget constraint is as follows:

$$g_t^c + g_t^t = \tau^c c_t + \tau^y [w_t h_t + r_t k_t + \pi_t] \tag{2.16}$$

Income tax rate and government consumption-to-output ratio would be chosen to match the average share in data, and consumption taxation is progressive. Finally, government transfers would be determined residually in each period so that the government budget is always balanced.

2.4. Dynamic Competitive Equilibrium (DCE)

For a given process followed by technology $\{A_t\}_{t=0}^{\infty}$ tax schedules $\{\tau^c, \tau^y\}_{t=0}^{\infty}$, and initial capital stock $\{k_0\}$, the decentralized dynamic competitive equilibrium is a list of sequences $\{c_t, i_t, k_t, h_t\}_{t=0}^{\infty}$ for the household, a sequence of government purchases and transfers $\{g_t^c, g_t^t\}_{t=0}^{\infty}$, and input prices $\{w_t, r_t\}_{t=0}^{\infty}$ such that (i) the household maximizes its utility function subject to its budget constraint; (ii) the representative firm maximizes profit; (iii) government budget is balanced in each period; (iv) all markets clear.

3. DATA AND MODEL CALIBRATION

To characterize business cycle fluctuations in Bulgaria, we will focus on the period following the introduction of the currency board (1999-2018). Quarterly data on output, consumption and investment was collected from National Statistical Institute (2019), while the real interest rate is taken from Bulgarian National Bank Statistical Database (2019). The calibration strategy described in this section follows a long-established tradition in modern macroeconomics: first, as in Vasilev (2016), the discount factor, $\beta = 0.982$, is set to match the steady-state capital-to-output ratio in Bulgaria, $k/y = 13.964$, in the steady-state Euler equation. The labor share parameter, $1 - \alpha = 0.571$, is obtained as in Vasilev (2017d), and equals the average value of labor income in aggregate output over the period 1999-2016. This value is slightly higher as compared to other studies on developed economies, due to the overaccumulation of physical capital, which was part of the ideology of the totalitarian regime, which was in place until 1989. Next, the average labor and capital income tax rate was set to $\tau^y = 0.1$. This is the average effective tax rate on income between 1999-2007, when Bulgaria used progressive income taxation, and equal to the proportional income tax rate introduced as of 2008. Similarly, the average tax rate on consumption is set to its value over the period, $\tau^c = 0.2$. Following Torres (2013), we set the scale parameter of the investment adjustment cost equal to $\phi = 6$. Note that this parameter represents strength, or "the intensity" of the investment adjustment cost channel. As pointed in Torres (2013), this is very close to Smets and Wouters (2003), who estimate a parameter of 5.9 for an adjustment cost function similar to the one used in this paper, while Christoffel *et al.* (2008) obtain a value of 5.8.

Next, the relative weight attached to the utility out of leisure in the household's utility function, γ, is calibrated to match that in steady-state consumers would supply one-third of their time endowment to working. This is in line with the estimates for Bulgaria (Vasilev 2017a) as well over the period studied. Next, the depreciation rate of physical capital in Bulgaria, $\delta = 0.013$, was taken from Vasilev (2016). It was estimated as the average quarterly depreciation rate over the period 1999-2014. Finally, the process followed by TFP process is estimated from the detrended series by running an AR(1) regression and saving the residuals. Table 1 below summarizes the values of all model parameters used in the paper.

Table 1. Model parameters

Parameter	Value	Description	Method
β	0.982	Discount factor	Calibrated
α	0.429	Capital Share	Data average
$1-\alpha$	0.571	Labor Share	Calibrated
γ	0.873	Relative weight attached to leisure	Calibrated
δ	0.013	Depreciation rate on physical capital	Data average
τ^y	0.100	Average tax rate on income	Data average
τ^c	0.200	VAT/consumption tax rate	Data average
ϕ	6.000	Scale parameter, investment adjustment cost	Set
ρ_a	0.701	AR(1) persistence coefficient, TFP process	Estimated
σ_a	0.044	st. error, TFP process	Estimated

4. STEADY-STATE

Once the values of model parameters were obtained, the steady-state equilibrium system solved, the "big ratios" can be compared to their averages in Bulgarian data. The results are reported in Table 2. The steady-state level of output was normalized to unity (hence the level of technology A differs from one, which is usually the normalization done in other studies), which greatly simplified the computations. Next, the model matches consumption-to-output and government purchases ratios by construction; The investment ratios are also closely approximated, despite the closed-economy assumption and the absence of foreign trade sector. The shares of income are also identical to those in data, which is an artifact of the assumptions imposed on functional form of the aggregate production function. The after-tax return, where $\bar{r} = (1-\tau^y)r - \delta$ is also relatively well-captured by the model. Lastly, given the absence of debt, and the fact that transfers were chosen residually to balance the government budget constraint, the result along this dimension is understandably not so close to the average ratio in data.

5. OUT OF STEADY-STATE MODEL DYNAMICS

Since the model does not have an analytical solution for the equilibrium behavior of variables outside their steady-state values, we need to solve the

Table 2. Data averages and long-run solution

Variable	Description	Data	Model
y	Steady-state output	N/A	1.000
c/y	Consumption-to-output ratio	0.648	0.674
i/y	Investment-to-output ratio	0.201	0.175
k/y	Capital-to-output ratio	13.96	13.96
g^c/y	Government consumption-to-output ratio	0.151	0.151
wh/y	Labor income-to-output ratio	0.571	0.571
rk/y	Capital income-to-output ratio	0.429	0.429
h	Share of time spent working	0.333	0.333
$\bar{r}$	After-tax net return on capital	0.014	0.016

model numerically. This is done by log-linearizing the original equilibrium (non-linear) system of equations around the steady-state. This transformation produces a first-order system of stochastic difference equations. First, we study the dynamic behavior of model variables to an isolated shock to the total factor productivity process, and then we fully simulate the model to compare how the second moments of the model perform when compared against their empirical counterparts.

5.1. Impulse Response Analysis

This subsection documents the impulse responses of model variables to a 1% surprise innovation to technology. The impulse response functions (IRFs) are presented in Fig. 1. As a result of the one-time unexpected positive shock to total factor productivity, output increases upon impact. This expands the availability of resources in the economy, so used of output - consumption, investment, and government consumption also increase contemporaneously. With investment adjustment cost the impulse response of investment is now hump-shaped, due to the different mechanism of adjustment. Investment volatility is now lower due to the presence of quadratic investment costs, so investment will not change too much from one period to the next. Note that investment will goes up by less, and capital will accumulate more slowly when ϕ takes a larger value. Because investment jumps up by less compared to the frictionless case, consumption now responds more. In turn, the intra-temporal optimality between consumption

and leisure causes a smaller response of hours worked. The novel result in this framework is that the new variable, the q-ratio, responds positively to the technology shock. The larger the value of ϕ, the larger the response in q. Upon impact of the shock, the q-ratio jumps above its steady-state value (which equals unity by defintion). In other words, in good times it is profitable to invest, as then the increase in the firm's market value is larger than the cost of investment, or equivalently, the cost of new capital. At the same time, the increase in productivity increases the after-tax return on the two factors of production, labor and capital. The representative households then respond to the incentives contained in prices and start accumulating capital. In turn, the increase in capital input feeds back in output through the production function and that further adds to the positive effect of the technology shock.

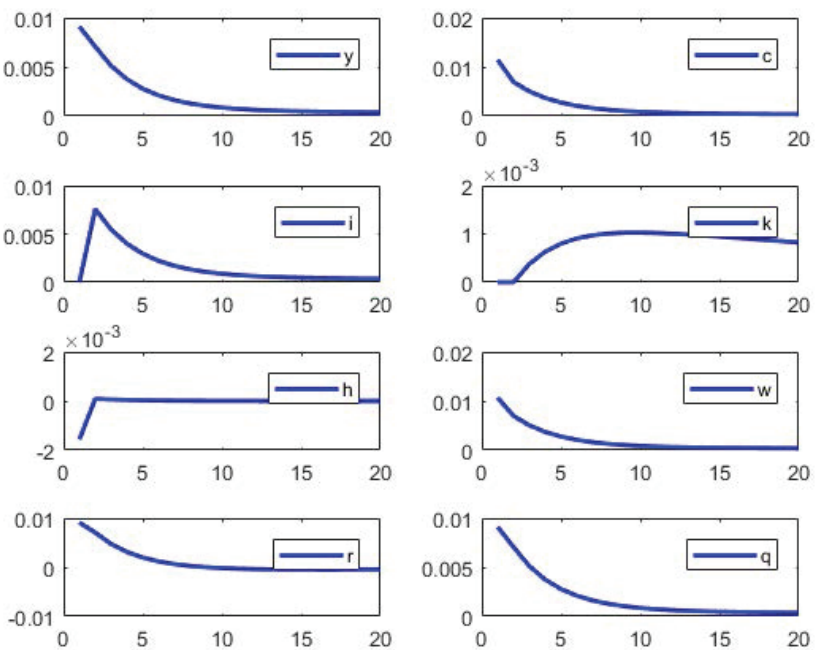

Figure 1. Impulse Responses to a 1% surprise innovation in technology.

Over time, as capital is being accumulated, its after-tax marginal product starts to decrease, which lowers the households' incentives to save and

invest. As a result, physical capital stock eventually returns to its steady-state, and exhibits a hump-shaped dynamics over its transition path. The rest of the model variables return to their old steady-states in a monotone fashion as the effect of the one-time surprise innovation in technology dies out.

5.2. Simulation and Moment-Matching

As in Vasilev (2017b), we will now simulate the model 10,000 times for the length of the data horizon. Both empirical and model simulated data is detrended using the Hodrick-Prescott (1980) filter. Table 3 on the next page summarizes the second moments of data (relative volatilities to output, and contemporaneous correlations with output) versus the same moments computed from the model-simulated data at quarterly frequency.The "Inv. Costs Model" is the case with investment adjustment costs, while the "Benchmark RBC" is the frictionless setup. In addition, to minimize the sample error, the simulated moments are averaged out over the computer-generated draws. The adjustment cost model provides a poor fit relative to the benchmark case. Consumption volatility is too high, even exceeding that of output. At the same time, investment volatility is too low, and less than that of output. Those two effects are in stark contrasts with the stylized fact that consumption generally varies less than output, while investment is more volatile than output in Bulgaria.

With respect to the labor market variables, the variability of employment predicted by the adjustment cost model is way too lower than that in data, while the variability of wages in the model exceeds significantly that in data. Next, in terms of contemporaneous correlations, the model systematically over-predicts the pro-cyclicality of the main aggregate variables - consumption, investment, and government consumption. This, however, is a common limitation of this class of models. Along the labor market dimension, the contemporaneous correlation of employment with output is strongly countercyclical, which comes at odds with data. With respect to wages, the model predicts strong cyclicality, while wages in data are acyclical. This shortcoming is well-known in the literature and an artifact of the wage being equal to the labor productivity in the model. Still, in terms of matching the second moments in data, the model with investment adjustment costs provides a poor fit, especially when compared to the al-

Table 3. Business cycle moments

	Data	Inv. Costs Model	Benchmark RBC
σ_c/σ_y	0.55	1.05	0.82
σ_i/σ_y	1.77	0.80	2.35
σ_g/σ_y	1.21	1.00	1.00
σ_h/σ_y	0.63	0.04	0.28
σ_w/σ_y	0.83	1.04	0.86
$\sigma_{y/h}/\sigma_y$	0.86	1.04	0.86
$corr(c,y)$	0.85	0.99	0.90
$corr(i,y)$	0.61	0.98	0.83
$corr(g,y)$	0.31	1.00	1.00
$corr(h,y)$	0.49	-0.84	0.59
$corr(w,y)$	-0.01	0.99	0.96

ternative, a benchmark model with no frictions.

In the next subsection, as in Vasilev (2016), we investigate the dynamic correlation between labor market variables at different leads and lags, thus evaluating how well the model matches the phase dynamics among variables. In addition, the autocorrelation functions (ACFs) of empirical data, obtained from an unrestricted VAR(1) are put under scrutiny and compared and contrasted to the simulated counterparts generated from the model.

5.3. Auto- and Cross-Correlation

This subsection discusses the auto-(ACFs) and cross-correlation functions (CCFs) of the major model variables. The coefficients empirical ACFs and CCFs at different leads and lags are presented in Table 4 below against the averaged simulated AFCs and CCFs. As in Canova (2007), such a comparison is used as a goodness-of-fit measure for RBC models.

As seen from Table 4 above, the model compares relatively well vis-a-vis data. Empirical ACFs for output and investment are slightly outside the confidence band predicted by the model, while the ACFs for total factor productivity and household consumption are well-approximated by the model. The persistence of labor market variables are also relatively well-described by the model dynamics. Overall, the model with investment

Table 4. Autocorrelations for Bulgarian data and the model economy

		k			
Method	**Statistic**	**0**	**1**	**2**	**3**
Data	$corr(u_t, u_{t-k})$	1.000	0.765	0.552	0.553
Model	$corr(u_t, u_{t-k})$	1.000	0.946	0.882	0.810
	(s.e.)	(0.000)	(0.032)	(0.062)	(0.089)
Data	$corr(n_t, n_{t-k})$	1.000	0.484	0.009	0.352
Model	$corr(n_t, n_{t-k})$	1.000	0.946	0.882	0.810
	(s.e.)	(0.000)	(0.032)	(0.062)	(0.089)
Data	$corr(y_t, y_{t-k})$	1.000	0.810	0.663	0.479
Model	$corr(y_t, y_{t-k})$	1.000	0.955	0.901	0.839
	(s.e.)	(0.000)	(0.027)	(0.053)	(0.077)
Data	$corr(a_t, a_{t-k})$	1.000	0.702	0.449	0.277
Model	$corr(a_t, a_{t-k})$	1.000	0.954	0.898	0.834
	(s.e.)	(0.000)	(0.028)	(0.054)	(0.079)
Data	$corr(c_t, c_{t-k})$	1.000	0.971	0.952	0.913
Model	$corr(c_t, c_{t-k})$	1.000	0.954	0.900	0.838
	(s.e.)	(0.000)	(0.027)	(0.053)	(0.077)
Data	$corr(i_t, i_{t-k})$	1.000	0.810	0.722	0.594
Model	$corr(i_t, i_{t-k})$	1.000	0.955	0.902	0.841
	(s.e.)	(0.000)	(0.027)	(0.052)	(0.076)
Data	$corr(w_t, w_{t-k})$	1.000	0.760	0.783	0.554
Model	$corr(w_t, w_{t-k})$	1.000	0.955	0.900	0.838
	(s.e.)	(0.000)	(0.027)	(0.053)	(0.077)

adjustment costs generates too much persistence in output and both employment and unemployment, and is subject to the criticism in Nelson and Plosser (1992), Cogley and Nason (1995) and Rotemberg and Woodford (1996b), who argue that the RBC class of models do not have a strong internal propagation mechanism besides the strong persistence in the TFP process. In those models, e.g., Vasilev (2009), and in the current one, labor market is modelled in the Walrasian market-clearing spirit, and output and unemployment persistence is low.

Next, as seen from Table 5 on the next page, over the business cycle,

Table 5. Dynamic correlations for Bulgarian data and the model economy

		k						
Method	**Statistic**	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**
Data	$corr(h_t, (y/h)_{t-k})$	-0.342	-0.363	-0.187	-0.144	0.475	0.470	0.346
Model	$corr(h_t, (y/h)_{t-k})$	-0.010	-0.010	-0.010	-0.850	-0.166	-0.104	-0.060
	(s.e.)	(0.324)	(0.280)	(0.228)	(0.131)	(0.221)	(0.262)	(0.297)
Data	$corr(h_t, w_{t-k})$	0.355	0.452	0.447	0.328	-0.040	-0.390	-0.57
Model	$corr(h_t, w_{t-k})$	-0.010	-0.010	-0.010	-0.850	-0.166	-0.104	-0.060
	(s.e.)	(0.324)	(0.280)	(0.228)	(0.131)	(0.221)	(0.262)	(0.297)

in data labor productivity leads employment. The model, however, cannot account for this fact. As in the standard RBC model a technology shock can be regarded as a factor shifting the labor demand curve, while holding the labor supply curve constant. Therefore, the effect between employment and labor productivity is only a contemporaneous one.

CONCLUSION

We introduce quadratic investment adjustment costs into an otherwise standard real-business-cycle setup augmented with a detailed government sector. We calibrate the model to Bulgarian data for the period following the introduction of the currency board arrangement (1999-2018). We investigate the quantitative effect, resulting from the presence of investment frictions on cyclical fluctuations in Bulgaria. The model performs poorly vis-a-vis data, and is rejected in favor of the standard ("frictionless") model. We thus declare the transmission mechanism associated with the convex investment adjustment costs to be an unlikely candidate to rationalize the observed business cycle fluctuations in Bulgaria over the period studied. This comes at a stark contrast with the rest of the business cycle literature, which attributes a promising role for such costs to explain investment dynamics and other business cycle facts.

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