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MARCOS RENAN VASCONCELOS MAGALHÃES

ESSAYS ON THE ROLE OF INFORMALITY, CORRUPTION AND SOCIAL NETWORKS IN BRAZIL

FORTALEZA
2023

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Tese apresentada ao Programa de Pós-Graduação em Economia - CAEN/UFC do Faculdade de Economia, Administração, Atuária e Contabilidade da Universidade Federal do Ceará, como requisito parcial à obtenção do título de doutor em Economia. Área de Concentração: Economia.

Orientador: Prof. Dr. Márcio Veras Corrêa.
Coorientador: Prof. Dr. Marcelo Aarestrup Arbex.

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“Àquele que puder ser sábio, não lhe perdoamos
que o não seja.”
“Se tens de servir a Deus com a tua inteligência,
para ti estudar é uma obrigação grave.”
São Josemaria Escrivá (Caminho, 332/336)

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“O que vale acima de tudo é o querer, um querer profundo: querer ser alguém; chegar a alguma coisa; ser desde já, pelo desejo, esse alguém qualificado por seu ideal.”
(SERTILLANGES, A.-D.; 1920, p. 25.)

RESUMO

Esta tese é composta de três ensaios sobre informalidade, corrupção e redes sociais e suas respectivas dinâmicas com os agregados macroeconômicos a partir de microfundamentos. No primeiro capítulo, estudamos um modelo de equilíbrio de escolha ocupacional de dois setores - os agentes podem ser empresários ou trabalhadores (formais ou informais). Um empresário informal enfrenta impostos determinados pela combinação da sua escolha de capital e da tolerância da sociedade relativamente à informalidade. Nosso modelo é consistente com muitas descobertas empíricas sobre o setor informal no Brasil, uma economia em desenvolvimento com um grande setor informal. Com uma versão calibrada do nosso modelo, mostramos que à medida que diminui a tolerância da sociedade à informalidade, o setor informal passa a empregar menos capital e trabalho e a informalidade diminui. Realizamos vários exercícios contrafactuais. A informalidade é substancialmente mais baixa em economias que são menos tolerantes às atividades informais, os empresários formais têm mais acesso aos mercados financeiros e a tributação da produção e do trabalho é mais baixa. Estendemos o modelo para considerar a tributação estocástica das atividades informais – uma tributação informal mais elevada (média), assim como sua maior variabilidade, reduzem a informalidade. No segundo capítulo, apresentamos um modelo em que o desvio de receitas fiscais por funcionários públicos impõe efeitos distorcivos no desempenho econômico através do seu efeito prejudicial no setor privado. A contribuição deste artigo, além das evidências empíricas apresentadas, é o estudo de uma economia mapeável na qual é possível avaliar as respostas dos agregados econômicos, via análises de estado estacionário e respostas dinâmicas a variações e choques de corrupção. O modelo é consistente com várias descobertas empíricas sobre a economia brasileira, como o nível de PIB perdido devido à corrupção e o número de burocratas corruptos. Com uma versão calibrada do nosso modelo para a economia brasileira, estudamos as implicações quantitativas das mudanças no nível de corrupção no desempenho econômico, comparando o estado estacionário e as trajetórias de transição das variáveis macroeconômicas. Globalmente, os nossos resultados mostram que as economias com maior controle da corrupção tendem a apresentar um melhor desempenho económico, com um nível mais elevado de produção, estoque de capital, consumo, investimento, arrecadação de impostos e salários. O último capítulo aperfeiçoa o modelo apresentado no segundo estudo, examinando a relação entre redes sociais e propagação da corrupção. Argumentamos que as redes sociais no mercado de trabalho podem facilitar a propagação da corrupção, proporcionando aos funcionários corruptos oportunidades de se encontrarem e conspirarem entre si. Neste intento,

desenvolvemos um modelo de redes sociais e propagação da corrupção em que os trabalhadores são dotados exogenamente de contatos sociais e se envolvem na busca de aperfeiçoar tais redes, de modo que estas possam afetar os seus resultados obtidos no mercado de trabalho. Assumimos que as "distribuições da lei de poder" (*power-law distributions*) governam a estrutura das redes sociais. Mostramos que um choque nas vagas corruptas aumenta inicialmente a taxa de aparecimento de oportunidades corruptas. As distorções induzidas pela corrupção têm um efeito adverso na produtividade da economia, levando à redução da demanda de capital. Tais consequências são particularmente visíveis em economias onde o número médio de contatos sociais é mais elevado. No que diz respeito ao choque de tecnologia, verifica-se um efeito positivo em todas as componentes da demanda agregada. No entanto, a influência na taxa de chegada de oportunidades corruptas varia a depender de como representamos o efeito na produção da economia. Em uma das abordagens, o efeito alinha-se com a noção de obstáculo (semelhante à hipótese da "areia nas rodas"), enquanto na outra, assemelha-se a uma facilitação (semelhante à hipótese da "graxa nas rodas"). As nossas descobertas sugerem que as redes sociais podem desempenhar um papel na facilitação da propagação da corrupção. As políticas devem ter como objetivo enfraquecer as redes do mercado de trabalho e aumentar a transparência dos processos de aquisição e contratação governamentais.
Palavras-chave: Setor informal; Normas sociais; Restrições de Crédito; Aplicação Limitada; Evasão fiscal; Crescimento; Corrupção; Redes sociais.
JEL: E6; E26; D73; E32; H26; O11; O17; O40; Z13.

ABSTRACT

This thesis is composed of three essays on informality, corruption and social networks and their respective dynamics with macroeconomic aggregates based on microfoundations. In the first chapter, we study an equilibrium two-sector occupational choice model - agents can be (formal or informal) entrepreneurs or workers. An informal entrepreneur faces taxation determined by the combination of her capital choice and society's tolerance of informality. Our model is consistent with many empirical findings regarding the informal sector in Brazil, a developing economy with a large informal sector. With a calibrated version of our model, we show that as society's tolerance of informality decreases, the informal sector employs less capital and labor, and informality decreases. We conduct several counterfactual exercises. Informality is substantially lower in economies that are less tolerant of informal activities, formal entrepreneurs have more access to financial markets, and taxation of output and labor is lower. We extend the model to consider stochastic taxation of informal activities - a higher (average) informal output taxation and its variability reduce informality. In the second chapter, we present a model in which the embezzlement of tax revenues by public officials imposes distortionary effects on economic performance through its dentrimental effect on the private sector. The contribution of this article, in addition to the empirical evidence presented, is the study of a tractable economy in which it is possible to evaluate the responses of economic aggregates, via steady state analyzes and dynamic responses to variations and corruption shocks. Our model is consistent with many empirical findings about the Brazilian economy, such as the level of GDP lost to corruption and the number of corrupt bureaucrats. With a calibrated version of our model for the Brazilian economy, we study the quantitative implications of changes in the level of corruption on economic performance by comparing steady state and transition paths of the variables. Overall, our results show that economies with higher corruption control tend to present a better economic performance, with a higher level of output, capital stock, consumption, investment, tax collection and wages. The last article improves the model presented in the second chapter, examining the relationship between social networks and the spread of corruption. We argue that social networks in labor market can facilitate corruption propagation by providing corrupt officials with opportunities to meet and collude with each other. We develop a model of social networks and corruption propagation in witch workers are endowed with peers exogenously and engage in network search to affect their labor market outcomes. We assume that power-law distributions govern the structure of social networks. We show that a shock on corrupt vacancies initially boosts the rate at which corrupt opportunities appear. Corruption-induced distortions have an adverse effect on the economy's productivity, leading to reduced demand for capital. These consequences are particularly noticeable in economies where the average number of peers is higher. Concerning the technology shock, there is a positive effect on all components of aggregate demand. Nonetheless, the influence on the arrival rate of corrupt opportunities varies depending on how we represent the effect on the economy's output. In one approach, the effect aligns with the notion of hindrance (akin to the "sand-in-the-wheels"hypothesis), while in another, it resembles a facilitation (akin to the "grease-in-the-wheels"hypothesis). Our findings suggest that social networks can play a role in facilitating corruption propagation. Policies should be aimed at weakening labor market networks and increasing the transparency of government procurement and contracting processes.

Keywords: Informal Sector; Social Norms; Credit Constraints; Limited Enforcement; Tax Evasion; Growth; Corruption; Social networks.
JEL: E6; E26; D73; E32; H26; O11; O17; O40; Z13.

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SUMMARY

1 TOLERANCE OF INFORMALITY AND OCCUPATIONAL CHOICES IN A LARGE INFORMAL SECTOR ECONOMY

1.1 Introduction

In this chapter, we study an equilibrium occupational choice model in which agents can choose to become an entrepreneur or a worker either in the formal or in the informal sector. Agents are heterogeneous in their wealth and in their ability to manage a firm. Formal and informal firms transform physical capital and labor into a single good using capital- and labor-intensive technologies, respectively. Formal and informal entrepreneurs can use their own resources to finance capital used in production. Only formal sector firms have access to the financial markets - an exogenous large number of financial intermediaries. Workers are paid the same competitive wage rate in both sectors and the economy's interest rate is determined endogenously. The government collects taxes on formal and informal outputs and on labor to finance informal sector monitoring costs. The main novelty of this paper is to study how endogenous taxation of informal output affects (formal vs. informal) allocations and the occupational choices of its agents (entrepreneurs vs. workers).

In our framework, an informal entrepreneur is subjected to a tax rate determined by the combination of her own choice of capital and society's tolerance of informality. The informal output tax in our model can be understood as a *catch-all* variable that accounts for the actual taxation of informal activities as well as various other factors at play in the economy related to the detection and punishment of such activities. There are two reasons for this approach. First, informal firms tend to operate with lower levels of capital to reduce their visibility and, thus, the chances of being detected by the tax authority. The more capital is used in production, the more visible informal entrepreneurs tend to be and the higher is the taxation of their output. Second, we acknowledge the fact that social norms may impose restrictions on the government's punishment of informal activities. For instance, the more tolerant of informality a society is - either in the form of production or consumption of goods produced in the informal sector - the lower the taxation (or punishment) of informal activities. Hence, our modeling approach and numerical exercises capture the effects of society's tolerance of informal activities, informal entrepreneurs' own perception of social norms, and informal taxation on production levels and occupational choices. The former is captured by an exogenous parameter calibrated to a large informal sector economy (Brazil), while the latter is expressed in the informal entrepreneur's optimal decision taking society's tolerance of informality as given.

The combination of these two features, i.e., an informal entrepreneur own choice of capital and society's tolerance of informality, affect the informal entrepreneur's maximization problem and, hence, the general equilibrium effects of policy changes. We consider two cases. First, the taxation of informal production is deterministic (our benchmark) and all informal firms are subject to the same tolerance of informality. Then, we extend the model to consider stochastic taxation of informal activities. That is, being caught by the tax authority managing an informal production technology is a stochastic event. All informal entrepreneurs are inspected and they have to pay a tax that depends on the size of the firm and on the (heterogeneous) tax auditors' tolerance of informal activities. In this environment, informal entrepreneurs face the same probability of being caught by either a more or a less tolerant tax auditor.

Our model is consistent with many empirical findings regarding the informal sector in Brazil. The size of the informal sector (% GDP) ranges between 32.6% - 41.7% in the period 1991-2015 (MEDINA; SCHNEIDER, 2018). Data from the 2003 *Brazilian Informal Urban Economy Survey (ECINF)* suggest that the informal sector is largely represented by very small firms with at most five employees. Moreover, formal firms employ 84% more workers, 385% more capital than the informal ones, and their productivity is higher (ULYSSEA, 2018). Using microdata from the 2008 *Brazilian National Household Sample Survey - PNAD*, a repeated cross section representative at the national level, we find that the fraction of individuals in the labor force who employ at least one worker is about 2% and self-employment accounts for 10% of the labor force (ANTUNES *et al.*, 2015a, Appendix - Brazil). According to this survey, the informal sector share in the total employment ranges between 32.5% - 43.6% (2002-2012). We follow Antunes *et al.* (2015b) and define formal entrepreneurs as those who manage a labor force with income higher than the minimum wage (R$415; 2008). Hence, in Brazil, the percent of entrepreneurs in the labor force is about 7.6%. With a calibrated version of our model, we explore the quantitative implications of policy changes for agents' occupational choices, input allocations and production in the formal and informal sectors.

We show that as society's tolerance of informality decreases, labor and output falls in the informal sector, i.e., informality decreases. Because taxation of informal activities is endogenously determined by how much capital informal entrepreneurs use, a less tolerant society imposes a higher taxation per unit of (informal) capital used. And, interestingly, as society becomes less tolerant to informality, the observed production increase in the formal sector occurs mainly through the extensive margin channel. On the other hand, the decrease in the informal sector production is due to less agents working fewer hours (both extensive and intensive margins). Regarding the distribution of occupational choices, we observed that changes in the tolerance parameter lead agents to move across occupations - informal entrepreneurs become workers - rather than across the formal-informal sector dimension.

Changes in labor income and formal output taxation have interesting effects on agents' occupational choices. While a reduction in the labor income tax leads informal entrepreneurs to change their occupation to become workers - as this now represents a higher payoff - a change in the taxation of the formal output increases the profitability of formal sector entrepreneurs. A lower tax on formal output not only attracts informal entrepreneurs to switch and become formal entrepreneurs (of less labor-intensive production technology) but also leads those already operating in the formal sector to expand their production by hiring more workers and employing more capital.

More accessibility to financial markets has two main effects. First, formal sector entrepreneurs have more access to credit in order to finance production. This leads to a drop in the informal sector production, which is more than compensated by an increase in the formal output. And, the overall effect of more access to additional funds leads to more production in the more efficient sector and, consequently, more output and consumption. Second, the equilibrium wage increases, making the worker occupation more attractive to some informal entrepreneurs. Through this channel, the size of the informal sector falls in both output and employment dimensions.

The results presented and discussed so far relied on the assumption of deterministic taxation of the informal output. We then extended our approach to consider stochastic taxation of informal production. We conduct numerical exercises in which informal entrepreneurs face uncertainty regarding the tax auditor's tolerance of informal activities, i.e., whether a more or less tolerant tax auditor will inspect their businesses. Overall, a higher (average) informal output taxation and its variability reduce informality. In particular, when society (tax auditor) is less tolerant of informal activities the share of informal entrepreneurs and informal production are smaller relative to the deterministic (benchmark) case. The sharpest contrast between the deterministic and the stochastic case is in the equilibrium interest rate, which is higher when informal entrepreneurs face a higher level of variability regarding the taxation of their output and they manage firms in a society that is less tolerant to their activities.

Related Literature. There is extensive literature in economics that studies both theoretically and empirically the causes (e.g., low level of human capital, poverty, institutions, social norms, taxation, government regulations, lack of access to finance) and consequences (e.g., poor provision of public goods, income inequality, low tax revenue) of informality, particularly in poor and developing countries. A non-exhaustive list of papers that focus on informality and topics of interest is: contract enforcement (QUINTIN, 2008), productivity (D'ERASMO; BOEDO, 2012), economic development (PORTA; SHLEIFER, 2014), unemployment benefits (BOSCH; ESTEBAN-PRETEL, 2015), search frictions in the labor market (CICCARONE *et al.*, 2016), growth (MAITI; BHATTACHARYYA, 2020), and tax collection Caro e Sacchi (2020). See Schneider e Enste (2000) for a review of the economic literature on informal activities and also Gerxhani (2003) and Ulyssea (2020).

This paper is more directly connected to four main strands of the literature. First, there are studies on individuals' occupational choice decision to become either an informal entrepreneur or an informal worker. In this literature, our article is closely related to Antunes e Cavalcanti (2007) and Amaral e Quintin (2006). Antunes e Cavalcanti (2007) solve numerically a general equilibrium model with credit constrained heterogeneous agents, occupational choices over formal and informal businesses, financial frictions and a government sector which imposes taxes and regulations on formal firms. They find that contract enforcement and regulation costs are equally important to account for the size of the informal sector in a developing country. Amaral e Quintin (2006) model the costs associated with informal sector production as resulting from financial frictions. Managers choose to enter the formal sector when the return to outside financing exceeds the additional tax cost they must bear. As a result, the most productive managers are self-selected into the formal sector, and operate with more capital. We contribute to this literature by considering endogenous taxation of informal entrepreneurs, based on their capital input decision and society's tolerance of informality.

Studies have shown that taxation, broadly speaking, is one of the main drivers of informality (CERDA; SARAVIA, 2013; LÓPEZ, 2017). On one hand, higher (lower) taxes can discourage (encourage) formal activities and push agents - workers and entrepreneurs - toward (away from) the informal sector. For instance, Saracoğlu (2008) shows that by reducing formal labor income taxation a country can successfully reduce employment in the informal sector - a result also observed in our analysis. On the other hand, auditing procedures, penalty and fines applied to those caught operating in the informal sector can potentially deter tax evasion and underground activities. Tied to this discussion is the notion of tax morale - the intrinsic or moral obligation to pay taxes, which points to the link between the quality of public policies and social values as a potentially key mechanism behind the low tax compliance rate and high informality observed in many economies (KOLM; LARSEN, 2002; BOERI; GARIBALDI, 2005; TORGLER; SCHNEIDER, 2009a; TRAXLER, 2010; VARVARIGOS, 2017).

As a matter of fact, informality and tax evasion can be approached from many perspectives: they can be viewed as a problem of public finance, law enforcement, labor supply or ethics, or a combination of all these (ANDREONI *et al.*, 1998). According to the traditional economic approach of tax compliance, e.g., Allingham e Sandmo (1972), taxes are paid or evaded strategically. The taxpayer determines how much tax to pay (evade) as if making a gambling decision in which the higher expected returns resulting from evasion are balanced against the risk associated with the possibility of being caught and penalized. However, many studies have noted that levels of informality and tax evasion are far different than a risk vs. return model would predict (SKINNER; SLEMROD, 1985; SLEMROD, 1992; TORGLER, 2007; ALM *et al.*, 2010). Researchers have noted that taxpayers exhibit a diverse range of beliefs and behaviors regarding the payment or evasion of taxes. Individuals do not always behave as the selfish, rational, self-interested individuals portrayed in the standard neoclassical paradigm, but rather are often motivated by many other factors (ALM *et al.*, 1992; ALM; TORGLER, 2011).

In this paper we assume that factors associated with informal activities and on how a society views informality can be translated into a punishment of (tax on) informal activities. An individual's tax behavior can then be seen as the outcome of the interaction of objective, external factors (e.g., the tax system as an imposed system) and subjective, person-bound factors such as personality and taxpayers interdependence with others (GROENLAND; VELDHOVEN, 1983). Individuals are rarely in isolation as all are members of social groups, societies and cultures. Consequently, tax behavior is not a function purely of individual choice: individuals might look to others in order to decide what is acceptable, reasonable, and expected within the social context in which the action is made (CULLIS; LEWIS, 1997; PICKHARDT; PRINZ, 2014). It is in this context that we model and study society's tolerance of informality and its economic implications.

In particular, there is growing evidence that, among other factors, individuals are influenced by the social context in which decisions are made. As Alm (2019) points out, much individual behavior can be broadly viewed as a "psychological contract" between individuals (and also between individuals and government). Central to this contract is the broad notion of a social norm - a pattern of behavior that is judged in a similar way by others and that is sustained in part by social approval or disapproval (ACEMOGLU; JACKSON, 2017). While informality might be tolerated and, to some degree, accepted in some societies, in others, informal activities are perceived as immoral, even illegal.[1]

Third, several papers study the relationship between informality and financial development (ANTUNES; CAVALCANTI, 2007). Antunes *et al.* (2008b) show that differences across countries in intermediation costs and enforcement generate differences in occupational choice, firm size, credit, output and income inequality. Blackburn *et al.* (2012) study the relationship between the informal sector and financial development in a model of tax evasion and bank intermediation. The key implication of their analysis is that the marginal net benefit of income disclosure increases with the level of financial development. Guo e Hung (2020) find a positive correlation between financial development and the ratio of tax revenue over GDP; a result similar to ours.

Financial markets interact with informality with important aggregate consequences. Franjo *et al.* (2020) build a model of occupational choice with progressive income taxation and informal production in which informal entrepreneurs have no access to credit and face an endogenous probability of detection by fiscal authorities. The authors evaluate the impact of removing financial frictions using their model calibrated to the Brazilian economy and find that removing financial frictions lead the size of the informal economy to shrink and to positive gains regarding the economy's (official) GDP, productivity and tax revenues. As the authors noted, accounting for the informal sector is crucial for understanding the relationship between financial and economic development. Erosa *et al.* (2021) also calibrate a model to Brazilian microdata and find that the effects of informality on capital accumulation and resource allocation critically depend on financial frictions. Moreover, the effects caused by the interaction between informality and financial frictions vary substantially depending on the relative importance of the two margins of informality. In the presence of financial frictions, the elimination of informality significantly reduces the mass of entrepreneurs, increases aggregate capital and the economy's productivity.

Finally, there are several papers that study the Brazilian economy and features of

[1] A growing literature has considered other potential explanations for individuals' tax compliance behavior (PICKHARDT; PRINZ, 2014). Factors that might affect an individual's decision to pay or evade taxes and, hence, engage in informal activities, include ethics (e.g., Alm e Torgler (2011)), institutional quality (e.g., Torgler e Schneider (2009b), Alm *et al.* (2012)) and social interactions (e.g., Myles e Naylor (1996), Kirchler (2007), Fortin *et al.* (2007), Coricelli *et al.* (2010), Dulleck *et al.* (2016)).

its informal sector. In Ulyssea (2018) informal firms coexist with formal firms, which may hire informal workers. Through counterfactual exercises, the author shows that there is substantial heterogeneity in policy effects among groups (switchers, always formal, and always informal firms) and within groups. Paula e Scheinkman (2011) test implications of a simple equilibrium model of informality using *ECINF* data and verify that formal activities are positively correlated with firms' size and informal firms employ a lower capital-labor ratio. Using a nationally representative Brazilian panel data that covers both formal and informal workers, Gomes *et al.* (2020) study labor earnings dynamics and document that informality in Brazil is associated with more volatile earnings, while formal sector workers are subject to significant downside risk. See also Monteiro e Assuncao (2012), Paula e Scheinkman (2010) and Engbom *et al.* (2021).

Besides this introduction, this paper is organized in three additional sections. Section 1.2 presents the model. In Section 1.3, we present the results for a calibrated version of the model and conduct counterfactual analyses. Section 1.4 concludes.

1.2 The Economy

The economy is populated by one-period lived agents in discrete time. Every period, a cohort of measure one is born and the economy goes on forever. Agents are heterogeneous with respect to their endowments and their ability to manage a firm. Agent's wealth is inherited from her previous generation but her entrepreneurial ability is not. Agents are endowed with one unit of time and they can choose to become an entrepreneur or a worker.

If an agent decides to become an entrepreneur she produces a single final good managing either a formal or an informal production technology - i.e., formal and informal firms combine labor and capital to produce the same good with different technologies. Firms in both sectors face different taxation and credit constraints. Only formal sector firms have access to the financial markets, which is represented by an exogenous large number of financial intermediaries. These intermediaries rent agents' wealth and lend it at an endogenously determined interest rate. The final good can be either consumed, invested or left as bequests for the next generation. Its price is normalized to one. The decision to become an entrepreneur and the firm's size depend on an agent's ability to manage a firm, her inherited wealth, her access to financial markets and output taxation. Instead of managing a firm, agents can work in formal or informal firms, which pay the same competitive wage rate. A worker does not value leisure and, hence, she inelastically supplies labor.

The government taxes workers and formal firms. Due to its limited and costly monitoring capacity, the government taxes informal firms only partially. Entrepreneurs caught operating in the informal sector are subject to a tax rate that depends on the size of its (informal) capital stock, as well as on society's tolerance of informal activities. The government tax revenue finances transfers to agents and monitoring costs. We assume, without loss of generality, that society's tolerance of informality is common knowledge and capital fully depreciates.

1.2.1 Preferences and Technologies

The timing of the model is as follows. At the beginning of period t, the agents inherit wealth b_t from their parents, which follows from endogenously determined wealth distribution G_t. Next, agents choose their occupations (entrepreneur or worker) and the sector of activity (formal or informal). Production takes place. Based on the occupational choice payoffs, all agents then make optimal consumption and wealth decisions. The government taxes workers and formal entrepreneurs. It also monitors and taxes informal sector entrepreneurs. At the end of period t, agents die and they are replaced by their heirs. These steps are repeated from $t+1$ on.

In our economy, agents value their current consumption c_t and the amount of wealth b_{t+1} they leave for their offspring (BANERJEE; NEWMAN, 1993). The agent's preferences are represented by the following utility function

$$u(c_t, b_{t+1}) = c_t^{\eta} b_{t+1}^{1-\eta}, \tag{1.1}$$

where $\eta \in (0,1)$ represents the weight of current consumption on the agent's instantaneous utility.

If an agent decides to become an entrepreneur, she combines labor (l) and capital (k), along with her entrepreneurial ability x to produce the same good either in the formal ($i = F$) or in the informal ($i = I$) sector, according to the following production technology

$$y_i = x A_i k_i^{\alpha_i} l_i^{\beta_i}, \tag{1.2}$$

where α_i, $\beta_i \in (0,1)$ and k_i, l_i and A_i are the capital and labor inputs and the productivity in sector $i = F, I$, respectively. We normalize $A_F = 1$ and, in line with the literature, we assume that productivity is lower in the informal sector ($A_I < 1$). Production technologies exhibit decreasing returns to scale, i.e., $\alpha_i + \beta_i < 1$.[2] We further assume that $\alpha_I < \alpha_F$, which implies that production in the informal firms is more labor intensive.

2 Basu e Fernald (1997) find that a typical industry appears to have significantly decreasing returns to scale.

1.2.2 Workers' and Entrepreneurs' Problems

We now consider the problem faced by workers and entrepreneurs. In a given period t, an agent has to decide whether to become a worker or an entrepreneur. An agent with inherited wealth b_t that decides to become a worker inelastically supplies labor to a firm in the formal or in the informal sector, taking the wage rate w_t as given. Hence, the worker's payoff $\Pi_w(b_t; w_t, r_t)$ is given by

$$\Pi_w(b_t; w_t, r_t) = (1 - \tau_w)w_t + (1 + r_t)b_t + T_t, \tag{1.3}$$

where τ_w is the tax rate on labor income, r_t is the rate of return on households' savings, w_t is the wage rate and T_t is a lump-sum government transfer. The wage rate and the lump-sum transfers are the same regardless whether the agent works in the formal or in the informal sector.

Instead of supplying labor services, an agent can choose to become an entrepreneur and manage either a formal or an informal firm. One interpretation for this choice is the decision by entrepreneurs whether or not to legally declare their establishment (AMARAL; QUINTIN, 2006). An entrepreneur's goal is to maximize profit by producing and selling the final good according to the sector-specific production function, equation (1.2), subject to labor and capital costs and output taxation. Thus, the profit maximization problem of an entrepreneur (e) managing a firm $i = F, I$ is as follows:

$$\pi_{e,i}(b_t, x_t; w_t, r_t) = \max_{k_i, l_i \geq 0} \ \{(1 - \tau_i)\, y_i - w_t l_i - (1 + r_t)k_i : \quad 0 \leq k_i \leq \lambda_i b\}. \tag{1.4}$$

And, the entrepreneur's payoff Π_e is given by

$$\Pi_e(b_t, x_t; w_t, r_t) = \pi_{e,i}(b_t, x_t; w_t, r_t) + (1 + r_t)b_t + T_t, \tag{1.5}$$

which also takes into account the return on the entrepreneur's own financial resources $(1 + r_t)b_t$ and government transfers T_t. Two features of a firm's profit maximization problem, equation (1.4), deserve particular attention, namely, the credit (collateral) constraint, i.e. $0 \leq k_i \leq \lambda_i b$, and the output taxation τ_i.

In our model, credit markets are assumed to be imperfect and all borrowing and lending decisions are made through financial intermediaries. The amount of capital k_i used in production combines the entrepreneur's own capital and capital borrowed from financial intermediaries. A capital constrained formal entrepreneur can obtain additional funds but due to the imperfect enforceability of contracts (EVANS; JOVANOVIC, 1989), the access to additional units of capital is determined by the entrepreneur's own wealth through a collateral constraint $0 \leq k \leq \lambda_F b$, where $\lambda_F \geq 1$. The parameter λ_F informs the entrepreneur's accessibility to financial markets, which can be interpreted, for instance, as the economy's degree of financial development (BUERA *et al.*, 2015). If $\lambda_F = \infty$, the credit market is perfect and there are no barriers to indebtedness. On the other hand, when $\lambda_F = 1$ the firm's capital is financed by the entrepreneur's own resources. This latter condition represents the case of informal entrepreneurs in our economy. In line with most of the literature that studies financial frictions and informal activities, we assume that informal entrepreneurs do not have access to the financial markets (i.e., $\lambda_I = 1$).

We assume that the government levies taxes τ_i on the firm's output (HSIEH; KLENOW, 2009; RESTUCCIA; ROGERSON, 2008). Formal entrepreneurs are subject to an exogenously given output tax rate τ_F. Tax collection in the formal sector is straightforward as production can be direct and costlessly observed by the tax authority. On the other hand, the government can only tax informal production imperfectly. Taxation of informal output is endogenously determined by the amount of capital k_I used in production along with a parameter that reflects the government's ability to tax informal entrepreneurs. Hence, an informal entrepreneur faces the following tax rate:[3]

$$\tau_I = 1 - e^{-k_I \zeta}, \tag{1.6}$$

where the parameter $\zeta \geq 0$ is assumed to be a proxy for the fact that social norms impose restrictions on the government's ability to tax informal activities (see Sandmo (2005) and citing literature). In other words, ζ captures the combination of a society's intolerance of informality as well as the informal entrepreneur's perception of how informal activities are tolerated by society and how informal entrepreneurs are taxed (punished). For instance, in one extreme case of an economy where informal activities are fully accepted (tolerated), $\zeta = 0$ implies that $\tau_I = 0$ and the informal sector production is not taxed. The more tolerant a society is the lower ζ, which renders a lower τ_I and higher net informal profits. On the other hand, a higher value of ζ represents a society that is less tolerant to informality and, thus, it imposes a harsher punishment on informal entrepreneurs.[4] Hence, the role of τ_I in our model is to capture the joint effect

[3] The government could potentially discourage informal activities if it had access to either higher detection probabilities or very harsh penalties. However, detection probabilities are typically low because of social norms that limit "cruel and unusual punishments". We take into account such limitations in our parameter ζ. Also, note that we could easily adapt our benchmark model to consider the monitoring intensity as an stochastic variable instead of a deterministic one, as assumed here. We consider this possibility in Section 3.3.

[4] In our model, the informal output tax, τ_I can be understood as a *catch-all* variable that accounts for the actual

of society's tolerance of informal production (social norms) and how informal entrepreneurs themselves perceive the punishment imposed by the government. These are reflected on the informal entrepreneurs (endogenous) choice of capital. The combination of these two features affect the informal entrepreneur's maximization problem and the general equilibrium effects of policy changes.

A formal entrepreneur's profit maximization problem, equation (1.4), imply the following optimal capital demand functions:

$$k_F = \begin{cases} \left[x(1-\tau_F) \left(\frac{\alpha_F}{1+r} \right)^{1-\beta_F} \left(\frac{\beta_F}{w} \right)^{\beta_F} \right]^{\frac{1}{1-\alpha_F-\beta_F}}, & \text{if } k_F \leq b, \quad (1.7) \\ \lambda_F b, & \text{otherwise}, \quad (1.8) \end{cases}$$

and the optimal labor demand functions:

$$l_F = \begin{cases} \left[x(1-\tau_F) \left(\frac{\alpha_F}{1+r} \right)^{\alpha_F} \left(\frac{\beta_F}{w} \right)^{1-\alpha_F} \right]^{\frac{1}{1-\alpha_F-\beta_F}}, & \text{if } k_F \leq b, \quad (1.9) \\ \left[x(1-\tau_F)(\lambda_F b)^{\alpha_F} \left(\frac{\beta_F}{w} \right) \right]^{\frac{1}{1-\beta_F}}, & \text{otherwise.} \quad (1.10) \end{cases}$$

Notice that equations (1.7)-(1.10) highlight the fact that we have two types of formal entrepreneurs - those constrained by their own resources but with access to the financial markets and those unconstrained. Taxation of formal output (τ_F) and the formal entrepreneur's accessibility to financial markets, measured by the collateral constraint parameter $\lambda_F \geq 1$, affect the firm's optimal capital and labor allocations, and, thus, the optimal formal firm's profit. The optimal capital and labor demand decisions of unconstrained entrepreneurs are represented by equations (1.7) and (1.9), respectively. In other words, entrepreneurs with optimal capital demand $k_F \leq b$ constitute the mass of self-financed formal entrepreneurs. On the other hand, if the optimal capital demand of an entrepreneur is greater than her own resources b (i.e., $b < k_F \leq \lambda_F b$) she will finance production with additional resources through the financial markets.[5] The optimal capital and labor demand decisions of constrained entrepreneurs that have access to financial markets are represented by equations (1.8) and (1.10), respectively.

taxation of informal activities as well as various other factors at play in the economy related to the detection and punishment of such activities. For instance, we can also interpret the "punishment" of informal activities not just necessarily tied to taxation of informal output. There is large evidence that informal activities are associated or subject to corruption, weak rule of law and business institutions in general. By operating low scale firms, informal entrepreneurs might avoid engaging in side deals with tax inspectors and cumbersome bureaucracy, but even so be subject to overall costs - e.g., transportation - that lead to production losses.

[5] It is straightforward to show that entrepreneurs that obtain additional funds from financial intermediaries invest all their capital endowments in their firms, see Antunes *et al.* (2008a).

Informal entrepreneurs are constrained by their own resources when making their optimal capital and labor choices ($k_I \leq b$; $\lambda_I = 1$). Taking into account the taxation of the informal output, equation (1.6), they maximize profits, equation (1.4), which implies the following optimal demand functions for informal capital and labor, respectively:

$$k_I = \begin{cases} \left[xA_I \left(\frac{(1-\tau_I)\beta_I}{w} \right)^{\beta_I} \left(\frac{(1-\tau_I)\alpha_I - \tau_I \varepsilon}{1+r} \right)^{1-\beta_I} \right]^{\frac{1}{1-\alpha_I-\beta_I}}, & \text{if } k_I \leq b, \quad (1.11) \\ b, & \text{otherwise}, \quad (1.12) \end{cases}$$

$$l_I = \begin{cases} \left[xA_I \left(\frac{(1-\tau_I)\beta_I}{w} \right)^{1-\alpha_I} \left(\frac{(1-\tau_I)\alpha_I - \tau_I \varepsilon}{1+r} \right)^{\alpha_I} \right]^{\frac{1}{1-\alpha_I-\beta_I}}, & \text{if } k_I \leq b, \quad (1.13) \\ \left[xA_I (1-\tau_I) b^{\alpha_I} \left(\frac{\beta_I}{w} \right) \right]^{\frac{1}{1-\beta_I}}, & \text{otherwise}. \quad (1.14) \end{cases}$$

where $\varepsilon = (\partial \tau_I / \partial k_I)(k_I / \tau_I)$ is the elasticity of the informal tax with respect to the informal capital. Unconstrained (constrained) informal entrepreneurs optimal capital and labor demand decisions are represented by equations (1.11) and (1.13) (equations (1.12) and (1.14)), respectively. Notice that, facing a higher taxation of informal output, unconstrained informal firms reduce the optimal amount of capital input in production, equation (1.11), consequently lowering their optimal labor demand, equation (1.13).

1.2.3 Agent's Optimal Occupational Choice

In the previous section, we presented the optimal payoffs of workers and (formal, informal) entrepreneurs, equations (1.3) and (1.5), respectively. Taking prices, income taxation, and formal and informal output taxation as given, an agent with an entrepreneurial ability x and wealth b_t decides her occupational choice. That is, she must decide whether to become a worker or an entrepreneur and, in the latter case, whether to manage a formal or an informal production technology.

The agent's optimal occupational choice is the one that generates the highest payoff, i.e., the solution of the following maximization problem

$$\Pi(b,x;w,r) = \max\left\{\Pi_w(b;w), \Pi_e(b,x;w,r)\right\}, \tag{1.15}$$

where $\Pi_w(b;w)$ and $\Pi_e(b,x;w,r)$ are given by equations (1.3) and (1.5), respectively.

Given the entrepreneurial ability and wealth distributions, the solution of the agent's problem, equation (1.15), allow us to characterize the mass of entrepreneurs $\mathbb{E}(w,r)$ and workers

$\mathbb{W}(w,r)$ in the economy, respectively,

$$\mathbb{E}(w,r) = \{(b,x) \in \mathcal{O} : \max\{\Pi_F(b,x;w,r), \Pi_I(b,x;w,r)\} \geqslant \Pi_w(b;w)\}, \tag{1.16}$$

$$\mathbb{W}(w,r) = \{(b,x) \in \mathcal{O} : \Pi_w(b;w) > \max\{\Pi_F(b,x;w,r), \Pi_I(b,x;w,r)\}\}, \tag{1.17}$$

where $\mathcal{O} = [0,\infty) \times [x_L, x_H]$ and $\mathbb{E}(w,r) + \mathbb{W}(w,r) = 1$. The mass of formal and informal entrepreneurs are defined as follows, respectively

$$\mathbb{E}_F(w,r) = \{(b,x) \in \mathcal{O} : \{\Pi_F(b,x;w,r) \geqslant \Pi_I(b,x;w,r)\}\} \cap \mathbb{E}(w,r), \tag{1.18}$$

$$\mathbb{E}_I(w,r) = \{(b,x) \in \mathcal{O} : \{\Pi_I(b,x;w,r) > \Pi_F(b,x;w,r)\}\} \cap \mathbb{E}(w,r), \tag{1.19}$$

where $\mathbb{E}(w,r)$ is defined in equation (1.16) and $\mathbb{E}_F(w,r) \cup \mathbb{E}_F(w,r) = \mathbb{E}(w,r)$.

1.2.4 Agent's Utility Maximization Problem

Given the agent's optimal occupational choice, she chooses current consumption c_t and the amount of wealth b_{t+1} she will leave for her offspring. Recall that, although entrepreneurial ability is drawn every period from the same distribution, the wealth distribution evolves over time. Thus, there is a link between generations that occurs through an agent's optimal wealth decision, e.g., parents decide to accumulate and transfer wealth to their children, which may affect their occupational choices.

The agent's optimization problem is to maximize utility, equation (1.1), subject to the following budget constraint:

$$c_t + b_{t+1} \leq \Pi(b,x;w,r), \tag{1.20}$$

where $\Pi(b,x;w,r)$ is given by equation (1.15). The solution of the agent's utility maximization problem implies that the optimal current consumption c_t and next period wealth b_{t+1} are $c_t = \eta\Pi(\cdot)$ and $b_{t+1} = (1-\eta)\Pi(\cdot)$, respectively.

1.2.5 Wealth Distribution

In order to characterize the wealth distribution law of motion, we assume that G_0 and G_t are the initial and time t distributions of wealth, respectively. Let $b \in Z = [b_L, b_h] \subset \Re_+$ represent the time t individual's wealth inherited from a previous generation. We assume that $\mathscr{Z}$ is a σ-algebra in Z and G is a probability measure defined on the measurable space $(Z, \mathscr{Z})$. Note that G characterizes the cross-sectional distribution of wealth among individuals. That is, for any

$V \subset Z$, with $V \in \mathscr{Z}$, $G(V)$ describes the mass of individuals with wealth defined in Z. Thus, for any $(b,V) \in (Z,\mathscr{Z})$, a non-stationary transition probability function P_t is defined as follows:

$$P_t(b,V) = Pr[b_{t+1} \in V|b_t]. \tag{1.21}$$

In other words, for $V \in \mathscr{Z}$ and $b \in Z$, the function $P_t(b,V)$ defines the probability that the wealth of the individual's heir will be in the set V in the period $t+1$, given that her wealth (state) in period t is b. Then, the law of motion of the wealth distribution is given by:

$$G_{t+1} = \int P_t(b,V)G_t(db). \tag{1.22}$$

1.2.6 The Government and the Economy's Resource Constraint

The government finances transfers T to entrepreneurs and workers and a (*per* informal firm) monitoring cost M through formal and informal output taxation ($\mathbb{T}_i, i = F, I$) and labor income tax on workers ($\mathbb{T}_w$). The government budget constraint is as follows

$$\mathbb{T}_F + \mathbb{T}_I + \mathbb{T}_w = \iint\limits_{\mathbb{X}_{EW}} TF(dx)G_t(db) + \iint\limits_{\mathbb{X}_{E_I}} MF(dx)G_t(db), \tag{1.23}$$

where $\mathbb{X}_{EW} = (x,b) \in \mathbb{E}(w_t,r_t) \cup \mathbb{W}(w_t,r_t)$, $\mathbb{X}_{E_I} = (x,b) \in \mathbb{E}_I(w_t,r_t)$,

$$\mathbb{T}_i = \iint\limits_{\mathbb{X}_{E_i}} \tau_i y_i F(dx)G_t(db), \quad \mathbb{T}_w = \iint\limits_{\mathbb{X}_W} \tau_w w F(dx)G_t(db),$$

$\mathbb{X}_{E_i} = (x,b) \in \mathbb{E}_i(w_t,r_t)$, for $i = F, I$, and $\mathbb{X}_W = (x,b) \in \mathbb{W}(w_t,r_t)$.

The economy's resource constraint is

$$\begin{aligned} \iint\limits_{\mathbb{X}_E} yF(dx)G_t(db) = & \iint\limits_{\mathbb{X}_{EW}} cF(dx)G_t(db) + \iint\limits_{\mathbb{X}_{EW}} hF(dx)G_t(db) \\ & + \iint\limits_{\mathbb{X}_{EW}} TF(dx)G_t(db) + \iint\limits_{\mathbb{X}_{E_I}} MF(dx)G_t(db) \end{aligned} \tag{1.24}$$

where, abusing notation, $y = y_F + y_I$ and $h \equiv b_{t+1}$. The total amount of resources in this economy, left-hand side of equation (1.24), is equal to the sum of current consumption, next period wealth, government transfers to entrepreneurs and workers and informal sector monitoring cost, right-hand side of equation (1.24).

1.2.7 The Stationary Equilibrium

We are now ready to present our definition of a stationary equilibrium for our economy.

Definition 1 *A stationary competitive equilibrium is characterized by*

- *a policy set* $\Upsilon = \{\tau_F, \tau_I, \tau_w, T, M\}$ *that includes a tax on the formal output, a tax on the informal output which is a function of society's tolerance of informal production* (ζ)*, a tax on the worker's income, transfers to workers and entrepreneurs* (T) *and per firm monitoring costs* (M)*, respectively,*
- *a price system* $Q = \{w, r\}$ *of wages and interest rate,*
- *agents' allocations* $X = \{c, b\}$*, i.e., current consumption and wealth,*
- *the degree of financial markets accessibility* (λ)*, and*
- *a distribution of entrepreneurial ability and an invariant wealth distribution* $G(b)$*,*

such that, at the steady-state:

1. *the resulting optimal allocations satisfy the agents' optimal occupational choice described in equations* (1.3), (1.4), (1.5), (1.6), *and* (1.15)*,*
2. *the optimal allocations maximize the individuals' utility, equation* (1.1)*, subject to a budget constraint, equation* (1.20)*,*
3. *the wealth and entrepreneurial ability distributions are constant over time,*
4. *the government budget constraint and the economy's resource constraint, equations* (1.23) *and* (1.24)*, respectively, are satisfied, and*
5. *the wage rate and the economy's interest rate satisfy the following market clearing conditions, respectively:*

$$\iint_{\mathbb{X}_W} F(dx)G(db) = \iint_{\mathbb{X}_E} lF(dx)G(db). \tag{1.25}$$

$$\iint_{\mathbb{X}_E} kF(dx)G(db) = \iint_{\mathbb{X}_{EW}} bF(dx)G(db). \tag{1.26}$$

where $l = l_F + l_I$ *and* $k = k_F + k_I$*,* $\mathbb{X}_{EW} = (x,b) \in \mathbb{E}(w_t, r_t) \cup \mathbb{W}(w_t, r_t)$*,* $\mathbb{X}_E = (x,b) \in \mathbb{E}_i(w_t, r_t)$*, and* $\mathbb{X}_W = (x,b) \in \mathbb{W}(w_t, r_t)$*.*

It can be shown that the steady-state equilibrium is unique and the economy converges to this equilibrium from any initial condition. See Antunes *et al.* (2008a) for details on the characterization of equilibrium.

1.3 Economic Implications of the Model

In this section we describe the quantitative implications of a calibrated version of our model. We calibrate the model to match important characteristics of the formal and the informal sectors, as well as aggregate features of the Brazilian economy. Then, we simulate the benchmark steady state equilibrium and conduct several counterfactual exercises. In particular, we study how changes in society's tolerance of informality, taxation and access to the financial markets affect individuals' occupational choices and the aggregate behavior of the economy.[6]

1.3.1 Calibration and Parameterization

To carry out our numerical exercises, first we calibrate seven parameters of the model so that the stationary equilibrium is consistent with target moments describing the empirical distributions of informal output and employment, the economy total credit (%GDP), aggregate consumption (%GDP), total tax collection (%GDP), and the share of formal entrepreneurs in the labor force, as well as other relevant data moments. These seven parameters are the informal sector labor share (β_I), society's tolerance of informal activities (ζ), the weight of consumption in the utility function (η), the parameters associated to the accessibility to financial markets parameter (λ_F) and the informal sector productivity (A_I), and the entrepreneurial ability distribution parameters (χ). We normalize the formal sector productivity parameter $A_F = 1$. We also choose values for the labor income tax (τ_w), the formal output tax (τ_F), formal sector capital (α_F) and labor (β_F) income shares based on information that is exogenous to the model and consistent with empirical studies in the literature, in particular, those related to the Brazilian economy. The calibrated values of the model parameters are summarized in Table 1.1 and each of these parameters is discussed in turn below.

Following Antunes e Cavalcanti (2007) and in line with Gollin (2002), we set α_F and β_F such that about 55% of formal income is paid to labor, 35% is the remuneration of capital, and 10% are profits. Hence, as our benchmark, we set the capital and labor shares in the formal sector to $\alpha_F = 0.35$ and $\beta_F = 0.55$, respectively. Recall that production in the informal sector is also assumed to exhibit decreasing returns to scale, i.e., $\alpha_I + \beta_I < 1$. Consistent with the assumption that $\alpha_F > \alpha_I$ and that profits are equivalent to ten percent of informal income, we

6 We assume zero lump sum transfers in our numerical exercises. The government budget constraint, equation (23), is adjusted accordingly.

fix $\alpha_I = 0.30$ as our benchmark value.[7] According to the *Brazilian National Household Sample Survey* (*PNAD*), informal workers represent 32.5 - 43.6% of the employed labor force in the period 2002-2012. We set the informal sector labor share in our model $\beta_I = 0.60$ to match the share of informal workers in the total employment in Brazil in the year 2008, which according to the *PNAD* is estimated to be 38.1%. Notice that an informal labor share greater than the one observed in the formal sector is consistent with evidence put forward by, for instance, Loayza (1996) - in developing economies, informal firms tend to be labor intensive since capital is scarcer than labor.

The inefficiency of informal sector production is well documented in the literature (PORTA; SHLEIFER, 2014). Ulyssea (2018) shows that the informal sector productivity in Brazil is approximately 20% lower than its formal counterpart. Hence, given the normalized formal sector productivity parameter ($A_F = 1$) we set the informal sector parameter to $A_I = 0.8$ in our benchmark calibration. We set the utility function curvature parameter $\eta = 0.85$ so that the steady state equilibrium consumption to GDP ratio in our model is consistent with data from the Penn World Table (PWT) - in the period 1960-2017, aggregate private consumption corresponds to 73% of the Brazilian GDP.[8]

Brazil has a very complex production and labor income tax code and characterizing it is beyond the scope of this paper. We follow Fernández-Rodríguez e Martínez-Arias (2014) and set the formal output tax rate $\tau_F = 0.34$, i.e., formal output is taxed at a 34% rate. In the tax code, labor income is taxed at rates that range from zero to 27.5% (Ministry of Economy of Brazil). In our benchmark calibration, we set $\tau_w = 0.275$.[9] In the period 1991-2015, the size of the informal sector in Brazil is estimated to range from 32.6 - 41.7 percent of the Brazilian GDP according to Medina e Schneider (2018). The society's tolerance of informal activities parameter ζ is set to 4.7 (i.e., $\zeta = 4.7$), such that the size of the informal sector to the GDP in our benchmark stationary equilibrium matches its estimated value of 35%.

The parameter that represents the entrepreneur's accessibility to financial markets (λ_F) is chosen so that our model matches the observed credit to GDP ratio of 0.372 in Brazil (Central Bank of Brazil). Hence, we set $\lambda_F = 1.8$ in our benchmark calibration, which is in line other papers that have used similar borrowing constraints (e.g., Buera *et al.* (2011), Buera *et al.* (2013), Franjo *et al.* (2020), Erosa *et al.* (2021)).

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7 Main results are robust to reasonable variations around this benchmark calibration (available upon request).

8 We use the 2011 real consumption to real GDP ratio at constant national prices (2011 US$ millions).

9 These values are also consistent with the estimated tax burden in the Brazilian economy. See Prado (2011) and Pereira e Júnior (2011) for more on this.

Table 1.1 – Benchmark parameter calibration

Parameter	Description	Source	Value
Preferences			
η	Utility function curvature	(5)	0.850
Technology			
α_F	Formal sector - Capital share	(1)	0.350
β_F	Formal sector - Labor share	(1)	0.550
α_I	Informal sector - Capital share	(6)	0.300
β_I	Informal sector - Labor share	(5)	0.600
A_F	Formal sector - Productivity	(6)	1.000
A_I	Informal sector - Productivity	(2)	0.800
Financial Market			
λ_F	Financial markets accessibility	(5)	1.800
Tax Policies			
τ_F	Tax rate on output	(3)	0.340
τ_w	Tax rate on labor income	(4)	0.275
ζ	Tolerance of informal sector	(5)	4.700
Talent Distribution			
χ	Talent (upper bound)	(5)	2.000

Sources: 1. Gollin (2002); 2. Ulyssea (2018); 3. Fernández-Rodríguez e Martínez-Arias (2014); 4. Ministry of Economy of Brazil; 5. Jointly calibrated; 6. Normalized.

The entrepreneurial ability (x) is assumed to be uniformly distributed and independent of b, i.e., $x \sim U(0, \chi)$ and $x \perp b$ (see, for instance, Stiglitz (1969), Benhabib *et al.* (2011)). Regarding the individual's wealth distribution, first recall Antunes e Cavalcanti (2007)'s Proposition 3, p.212, which states that *for any initial bequest distribution G_0 and stationary government policies and institutions, the bequest distribution converges to G.* Hence, starting from any given distribution G_0, we simulated an economy with 100,000 individuals characterized by random pairs of ability and wealth (x_0, b_0). Next, using the optimal bequest policy derived in Section 2.4 and the exogenous distribution of ability, we obtain a new vector, (x_1, b_1). We then repeat this procedure to the point where the wealth distribution law of motion in two consecutive periods ($G_{\upsilon+1}$ and G_υ, for a large υ) is invariant.[10] At this point, we have found our invariant wealth distribution. Finally, we then check whether this equilibrium outcome is

10 Formally, we must assume that the bequest distribution is continuous on its support, $r \in I = [-1, \bar{r}]$, for $\bar{r} < \infty$, and there is free disposal of bequest to guarantee that there is a unique invariant distribution G. Please refer to Antunes *et al.* (2008a) for more details.

Table 1.2 – Key statistics: Data and benchmark Economy

	Brazilian economy	Benchmark model
Occupational Choice (%)		
Workers	68.0	76.0
Entrepreneurs	32.0	24.0
Informal sector		
Share total output (%)	35.1	36.7
Share total employment (%)	38.1	38.0
Standard deviation (labor)	0.73	0.85
Share of Total Output (%)		
Total tax collection	34.1	34.2
Total consumption	73.0	73.3
Total credit	37.1	38.0
Formal and informal ratios		
Average employment ratio (l_F/l_I)	1.84	1.63
Average capital ratio (k_F/k_I)	4.85	4.55

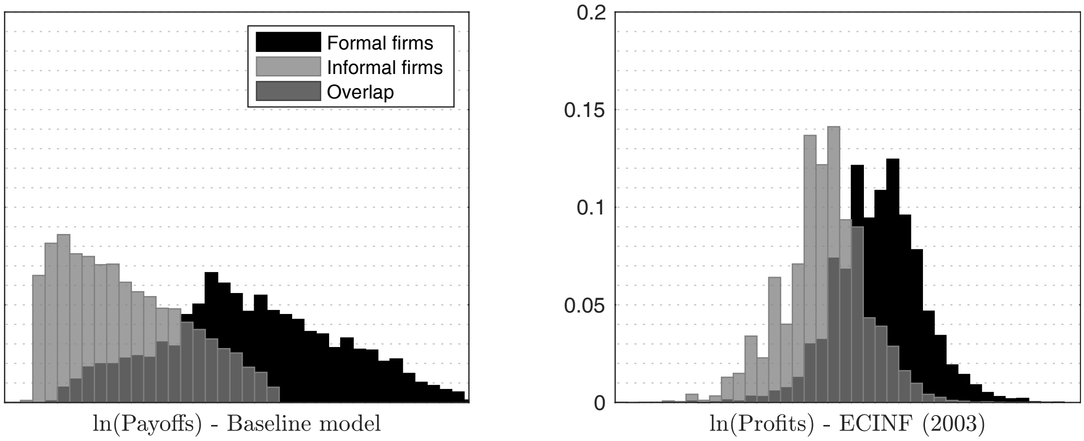
Sources: Ministry of Economy of Brazil, Brazilian Central Bank, ECINF, Brazilian households survey (PNAD), Penn World Table 9.1, Medina e Schneider (2018) and Ulyssea (2018).

compatible with the steady-state profits an agent would receive if she were to become a formal or an informal entrepreneur. For different values of χ, we repeat this procedure such that the optimal steady-state equilibrium is satisfied and the model parameters match the empirical mass of formal entrepreneurs, which in Brazil is roughly 7.6%. Therefore, our strategy was to adjust the parameter χ so that the simulated economy resembles key features of the Brazilian economy. In our benchmark calibration, the upper bound of the ability distribution is set to $\chi = 2.00$. The invariant (standard Pareto) wealth distribution is characterized by the following scale and tail index parameters $\sigma_{model} = 0.1609$ and $\kappa_{model} = 0.2375$, respectively.[11] Figure A.1 in the Appendix shows that our model stationary wealth distribution is very similar to the Brazilian empirical wealth (*PNAD*) distribution.

Table 1.2 presents our key target statistics for the Brazilian economy as well as those resulting from our calibrated model in a stationary equilibrium. Notice that our model matches the Brazilian economy fairly well along several dimensions. In particular, the model fits well

[11] The shape parameter is closely related to the general shape of the distribution graph. A small value of the shape parameter, for instance, means a thicker tail of the Pareto distribution. The scale parameter is associated to the statistical dispersion of the distribution - e.g., the lower the scale parameter, the more concentrated the distribution is.

Figure 1.1 – Payoffs Distribution (baseline model) × Profits Distribution (ECINF)



Notes: Left panel - simulations based on the model. Right panel - ECINF informal firms' profits. The data is normalized (log) to allow for comparisons. The sum of the bars height is less than or equal to 1. That is, the figures display the relative frequencies.

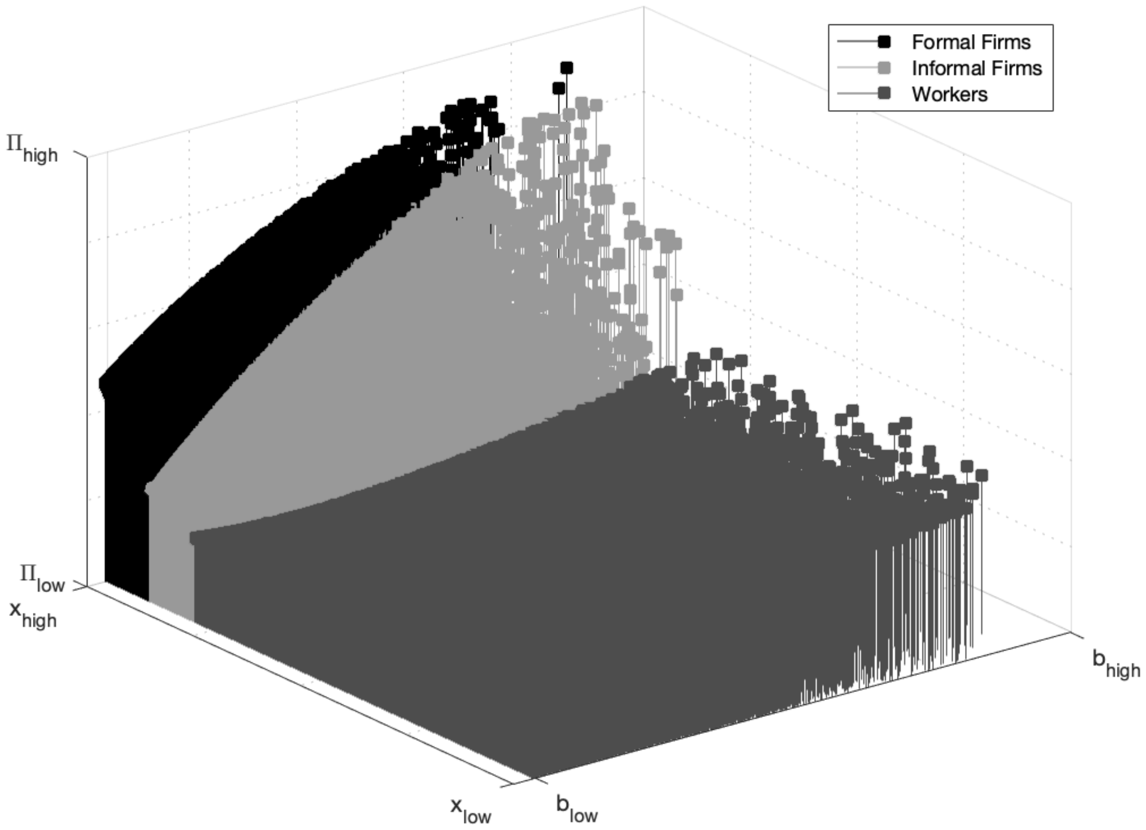
the statistics related to the informal sector: output, employment, formal and informal (average) capital (k_F/k_I) and labor (l_F/l_I) ratios.[12] In addition, our calibrated model is also consistent with two additional features observed in the data: the participation of formal entrepreneurs in the labor force (*PNAD*) and the standard deviation of the informal employment (*ECINF*). In our benchmark equilibrium, we find that the proportion of entrepreneurs is about 24% of the population - 6.9% (17.1%) are formal (informal) entrepreneurs. It is worth to point out that this result is similar to found in Erosa *et al.* (2021).

Figure 1.1 illustrates the payoff and profit distributions according to our calibrated model and data from the Brazilian Informal Urban Economy Survey (*ECINF*), respectively. An important stylized fact of large informal sector economies is displayed in this figure, i.e., formal and informal sector firms might have the same payoff (profit). In Figure 1.1 this is highlighted by the overlap of formal and informal entrepreneurs' payoffs (model) and profits (*ECINF* data). The fact that informal entrepreneurship is an occupation that can generate payoffs similar to the one observed by formal entrepreneurs can be attributed to three main factors: society's high tolerance of informal activities, high (formal) tax burden and labor intensive (informal) production technology. In addition, we observe fewer firms with large payoffs and profits - there is a large concentration of informal firms at low levels of capital and the mass of informal workers is smaller than its formal counterpart.

The equilibrium entrepreneurial ability distribution, the wealth distribution and the payoff distribution are plotted in Figure 1.2. We divide the state space (b,x) into the set of

[12] To capture the latter, we use formal and informal firms' data from the ECINF. Capital inputs were proxied by the variable total value of facilities and equipment.

Figure 1.2 – Distribution of Agents Regarding Ability, Wealth and Income



workers, formal and informal entrepreneurs, $\mathbb{W}(w,r)$, $\mathbb{E}_F(w,r)$ and $\mathbb{E}_I(w,r)$, respectively. Notice that if an agent's entrepreneurial ability is low, her optimal occupational choice is to become a worker (the dark gray shaded area). Workers get paid the equilibrium wage regardless the sector they are employed at and we observe workers across the whole wealth distribution. Entrepreneurs are more concentrated at high levels of entrepreneurial ability, even for low levels of wealth. Accessibility to financial markets also play a role in determining whether a formal entrepreneur has access to additional funds to finance production. While informal entrepreneurs do not have access to the financial markets, by operating in the informal sector they avoid formalization costs, which in our model is represented by the formal output taxation.

1.3.2 Implications of the Model and Quantitative Exercises

In this section, we conduct several quantitative exercises to evaluate the impact on economic outcomes of key parameter changes. In particular, we focus on how the formal and informal sector production and employment, tax collection, wage and interest rate are affected by a variety of parameter and policy changes, i.e., the society's tolerance of informality

(ζ), the taxation of labor and formal output, τ_w and τ_F, respectively, and the entrepreneur's accessibility to the financial markets (λ_F). Results are presented in Tables 1.3 - 1.7. To allow for comparisons, columns marked with an asterisk ($*$) in each table show the results for our benchmark parameterization. We then vary one parameter at a time while keeping all other parameters constant at their benchmark levels.

Tolerance of Informality. As society's tolerance of informality decreases, i.e., ζ increases, the informal sector labor and output fall and informality decreases (Table 1.3). The case of $\zeta = 6.0$ is illustrative. When a society is less tolerant to informality, a harsher punishment is imposed on informal entrepreneurs. Because the taxation of informal activities τ_I is endogenously determined by how much capital is used by informal entrepreneurs, a larger ζ imposes a higher taxation per unit of (informal) capital used in production - e.g., the average tax rate increases from 6.05% ($\zeta^* = 4.7$) to 6.51% ($\zeta^* = 6.0$). In this case ($\zeta = 6.0$), informal entrepreneurs reduce the amount of labor use in production more strongly than they reduce capital use. Production in the formal (informal) sector increases (decreases) by about five (twelve) percent. The observed increase in formal sector production occurs through two channels: intensive margin - formal entrepreneurs benefit from a lower equilibrium wage that more than compensates for the increase in the interest rate[13] - and extensive margin - some informal entrepreneurs become formal. The decrease in the informal sector production is due to fewer agents working less hours (both extensive and intensive margins). Thus, the increase in the government's tax revenue is mainly due to the higher production in the formal sector, which more then compensates the drop in the revenue collected from the informal sector.

Regarding the distribution of occupational choices, we observe that changes in the tolerance parameter lead agents to shift between the two entrepreneurial options rather than at the entrepreneur-worker dimension. For instance, the less tolerant a society is the larger the drop in the share of informal firms - e.g., from 17.14 in the benchmark case ($\zeta = 4.7$) to 15.04 ($\zeta = 8.0$); Table 1.3. This drop is accommodated by the reallocation of agents from informal to formal entrepreneurship and also to paid work: the former accounts for four-fifths of the variation. The shares of formal entrepreneurs and workers range from 6.85 and 76.01 ($\zeta = 4.7$) to 8.51 and 76.45 ($\zeta = 8.0$), respectively. Note that most of the action is across entrepreneurial choices. When ζ changes, which can be attributed to the fact that changes in society's tolerance

[13] The equilibrium interest rate in the baseline calibration ($\zeta^* = 4.7$) is 1.80% and it increases to 1.86% when $\zeta^* = 6.0$ (Table III).

Table 1.3 – Tolerance of Informality (ζ)

	$\zeta = 0$	$\zeta = 3.0$	$\zeta^* = 4.7$	$\zeta = 6.0$	$\zeta = 8.0$	$\zeta \to \infty$
Occupational Choice (%)						
Workers	79.88	75.87	76.01	76.14	76.45	84.2
Formal entrepreneurs	0	5.74	6.85	7.61	8.51	15.8
Informal entrepreneurs	18.11	18.39	17.14	16.25	15.04	0
% of total output						
Formal sector size	0	55.51	63.25	67.51	72.04	100
Informal sector size	100	44.59	36.74	32.49	27.96	0
% of total capital						
Formal capital	0	85.86	90.09	91.99	93.79	100
Informal capital	100	14.14	9.91	8.01	6.21	0
% of total labor						
Formal labor	0	53.94	62.01	66.41	71.14	100
Informal labor	100	46.06	37.99	33.59	28.66	0
Tax collection (% of total output)						
Workers	11.29	10.59	10.49	10.47	10.44	10.3
Formal entrepreneus	0	18.84	21.51	22.95	24.49	34
Informal entrepreneus	0	2.32	2.22	2.11	2.01	0
Informal tax rate (average, in %)	0	5.2	6.05	6.51	7.18	0
Interest rate (in %)	1.39	1.71	1.8	1.86	1.91	2.32
% Variation (relative to benchmark)						
Total output	28.11	1.86	0	-1.13	-2.09	-4.28
Formal output	-100	-10.76	0	5.53	11.53	51.34
Informal output	248.63	23.59	0	-12.6	-25.51	-100
Consumption	24.51	1.47	0	-0.61	1.24	-0.37
Tax Collection	-50.75	-5.49	0	2.69	5.7	23.92
Wage income[1]	31.22	2.99	0	-1.49	-3.15	-15.18

Notes: *benchmark model (Brazil); (1) Gross wage income.

of informality are either exacerbated ($\uparrow \zeta$) or attenuated ($\downarrow \zeta$), the net efficiency gap between formal and informal production, i.e., $(1-\tau_i)y_i$, also changes.

By means of counterfactual exercises, we can associate the values of the tolerance parameter to the estimated size of the informal sector in other countries. For instance, according to Medina e Schneider (2018) the sizes of the informal sector in Ecuador and Turkey are about 32.04% and 28.14% of the GDP, respectively. Based on the results presented in Table 1.3, the estimated values for these two countries would be associated to $\zeta = 6.0$ (Ecuador) and $\zeta = 8.0$ (Turkey).[14] In particular, we notice the impact of society's lower tolerance of informal

[14] We can match the sizes of the informal sector in Italy (23.51%), Canada (12.02%) and United States (7.76%) (MEDINA; SCHNEIDER, 2018) if we set $\zeta = 11, 25$ and 39, respectively.

activities (higher ζ) in the composition of the economy production sector. Although aggregate production declines, mainly due to the sharp drop in the informal sector production, the average entrepreneurial ability of those managing firms in the economy increases. In other words, we observe more high ability agents in the entrepreneur occupation (formal, informal) in less tolerant societies. Finally, compared to our benchmark value ($\zeta = 4.7$), all these results highlight that the size of the informal sector can be associated with how a society perceives and tolerates informal activities. As $\zeta \to \infty$, i.e. an intolerant society, the size of the informal sector converges to zero.

Labor Income and Formal Output Taxation. Compared to our benchmark case, the immediate effect of a lower tax on labor income τ_w is an increase in the worker (net and gross) wage income, making this occupation more attractive in both sectors. So from the agent's point of view, a reduction of taxes on wages has an important effect regarding an occupational choice rearrangement: we observe that informal entrepreneurs change their occupation to become workers, as this now represents a higher payoff. Consider, for instance, a lower labor income tax relative to our (Brazil) benchmark. For instance, let $\tau_w = 0.22$, similar to the wage taxation in countries like Israel and Switzerland (OECD, 2020b). Relative to the benchmark, lower wage taxation leads to a larger share of workers in the population, fewer informal entrepreneurs and about the same share of formal entrepreneurs in the economy. Entrepreneurs move from the informal sector to wage employment, a sector that now has slightly higher payoff on average.

The fact that some informal entrepreneurs change occupation and become workers leads to (i) a lower demand for capital in the informal sector and (ii) a higher supply of this factor by workers. As a result, the interest rate falls by approximately 0.3 percentage point. A lower interest rate benefits entrepreneurs in the formal sector - a sector that is relatively more productive and less labor intensive. In other words, the marginal benefit of a lower labor income taxation is higher in the formal sector, which leads formal entrepreneurs to hire more capital and to produce more output. As a matter of fact, the observed increase in the formal output is due to changes in the intensive margin only. That is, formal entrepreneurs can scale their production up as capital becomes cheaper. Although the tax base increases and the size of the informal sector falls, the net government revenue change is negative and tax collection decreases.

Table 1.5 presents the effects on key variables of changes in the taxation of formal output τ_F. As expected, decreases in the formal output tax rate τ_F increase the profitability of formal sector entrepreneurs. A lower tax on output leads to two distinct changes. First, it becomes more attractive to informal entrepreneurs to become formal entrepreneurs, moving

Table 1.4 – Labor Income Tax (τ_w)

	$\tau_w = 0.22$	$\tau_w = 0.25$	$\tau_w^* = 0.275$	$\tau_w = 0.30$	$\tau_w = 0.33$
Occupational Choice (%)					
Workers	77.28	76.69	76.01	75.3	74.54
Formal entrepreneus	6.8	6.82	6.85	6.86	6.87
Informal entrepreneus	15.92	16.49	17.14	17.84	18.59
% of total output					
Formal sector size	63.77	63.53	63.25	62.88	62.57
Informal sector size	36.23	36.47	36.74	37.12	37.43
Tax collection (% of total output)					
Workers	7.63	9.06	10.49	11.95	13.36
Formal entrepreneus	21.68	21.6	21.51	21.38	21.27
Informal entrepreneus	2.27	2.25	2.22	2.29	2.17
Interest rate (in %)	1.77	1.79	1.8	1.81	1.82
% Variation (relative to benchmark)					
Total output	0.47	0.28	0	-0.57	-0.82
Formal output	1.29	0.72	0	-1.16	-1.88
Inormal output	-0.93	-0.47	0	0.45	1.02
Consumption	3.99	2.00	0	-2.03	-4.02
Tax Collection	-7.27	-3.55	0	3.24	6.7
Wage income[1]	1.17	0.58	0	-0.64	-1.23

Notes: *benchmark model (Brazil); (1) Gross wage income. The labor income taxes were chosen for counterfactual purposes to resemble tax rates in the following countries: Israel ($\tau_w = 0.22$), Korea ($\tau_w = 0.25$), United Kingdom ($\tau_w = 0.30$) and Iceland ($\tau_w = 0.33$); Tax wedge of a single worker without children earning a nation's average wage (OECD, 2020b).

to a less labor-intensive production technology. And, second, it leads entrepreneurs already operating in the formal sector to expand their production levels, i.e., to hire more workers and to use more capital. Let $\tau_F = 0.28$ - a taxation similar to the one observed in countries like Sweden, Norway or Italy.[15] Relative to our benchmark value $\tau_F = 0.34$, a decrease in the formal output taxation of six percentage points ($\tau_F = 0.28$) causes a substantial decrease in the share of informal entrepreneurs in the labor force - it drops from 17.14 in the benchmark case ($\tau_F = 0.34$) to 14.43 when $\tau_F = 0.28$. This tax reduction (from $\tau_F = 0.34$ to $\tau_F = 0.28$) also leads to an increase in the share of formal entrepreneurs in the economy (from 6.85 to 7.38, respectively).

Comparing the effect of changes in these two tax instruments (τ_w, τ_F) on the government tax revenue, we observe that while reductions of τ_w lead to a drop in the government tax

[15] Taxation trends in the European Union. See also Global Revenue Statistics Database, OECD.Stat and OECD (2020a).

Table 1.5 – Formal Output Tax (τ_F)

	$\tau_F = 0.28$	$\tau_F = 0.31$	$\tau_F = 0.34^*$	$\tau_F = 0.37$	$\tau_F = 0.40$
Occupational Choice (%)					
Workers	78.19	77.12	76.01	74.83	73.77
Formal entrepreneus	7.38	7.11	6.85	6.72	6.54
Informal entrepreneus	14.43	15.77	17.14	18.45	19.69
% of total output					
Formal sector size	70.4	66.87	63.25	59.49	55
Informal sector size	29.6	33.13	36.74	40.51	45
Tax collection (% of total output)					
Workers	10.46	10.5	10.49	10.51	10.51
Formal entrepreneus	19.71	20.73	21.51	22.01	22
Informal entrepreneus	1.8	2.01	2.22	2.45	2.81
Interest rate (in %)	2.13	1.96	1.8	1.66	1.51
% Variation (relative to benchmark)					
Total output	6.82	3.19	0	-3.28	-5.88
Formal output	18.89	9.09	0	-9.02	-18.15
Inormal output	-13.94	-6.97	0	6.61	15.24
Consumption	7.7	3.67	0	-3.55	-6.97
Tax Collection	2.54	0.23	0	-1.14	-2.87
Wage income[1]	3.53	1.76	0	-1.54	-2.88

Notes: *benchmark model (Brazil); (1) Gross wage income. The formal output tax rates (τ_F) were chosen for counterfactual purposes to resemble the tax revenue as share of GDP in the following countries: Sweden ($\tau_F = 0.28$), Italy ($\tau_F = 0.31$), United States ($\tau_F = 0.39$), and Japan ($\tau_F = 0.42$); (Source: Taxation trends in the European Union.)

revenues (Table 1.4), tax revenue actually increases by reducing taxation of the formal output (τ_F) (Table 1.5). This result might suggest that, regarding the taxation of output produced in the formal sector, the Brazilian economy is on the "wrong side" of the Laffer curve.[16]

Accessibility to the Financial Markets. In our benchmark equilibrium ($\lambda = 1.8$, Table 1.6), the credit-to-GDP ratio is about 38%, matching the observed credit-to-GDP ratio of 0.372 in Brazil (Central Bank of Brazil). There are three times more informal than formal entrepreneurs and workers account for three quarters of the occupational choice in the economy. We also observe that 99% (55%) of formal (informal) entrepreneurs are credit constrained in the benchmark equilibrium. Production in the formal sector accounts for two thirds of the GDP

[16] The "wrong side" of the Laffer Curve denotes a situation in which the tax rate is greater than the one that would maximize total tax revenue (Trabandt e Uhlig (2011)). A reduction in the current tax rate would, hence, increase the tax revenue.

and taxes collected from formal entrepreneurs are equivalent to 21% of the economy's GDP (benchmark equilibrium).

Table 1.6 – Entrepreneur's Accessibility to Financial Markets (λ_F)

	$\lambda_F = 1$	$\lambda_F^* = 1.8$	$\lambda_F \to \infty$
Credit (% of total output)	(0.0)	(38.00)	(73.19)
Occupational Choice (%)			
Workers	76.64	76.01	80.35
Formal entrepreneus	6.91	6.85	9.31
Informal entrepreneus	16.45	17.14	10.34
Constrained Entrepreneurs (%)			
Formal	100.00	99.05	0.0
Informal	60.34	55.02	20.34
% of total output			
Formal sector size	59.00	63.25	74.22
Informal sector size	41.00	36.74	25.78
Tax collection (% of total output)			
Workers	10.46	10.49	10.37
Formal entrepreneurs	20.06	21.51	25.23
Informal entrepreneurs	2.72	2.22	2.04
Interest rate (in %)	1.23	1.8	2.56
% Variation (relative to benchmark)			
Total output	-3.32	0.0	8.17
Formal Output	-9.82	0.0	26.93
Informal Output	7.86	0.0	-24.11
Consumption	-4.13	0.0	9.00
Tax Collection	-6.09	0.0	19.00
Wage income[1]	-0.91	0.0	5.18

Notes: *benchmark model (Brazil); (1) Gross wage income; In our numerical exercise we assume $\lambda = 10,000$ as the perfect-credit economy.

To better understand the role credit markets for formal and informal entrepreneurs and key economic variables in our model economy, we conduct two extreme exercises regarding the entrepreneur's accessibility to financial markets.[17] First, we assume $\lambda = 1$, which resembles a no-credit economy. In this case, formal production falls and informal output increases. In this extreme case, the lack of access to financial markets leads to lower output, consumption and tax

[17] Using the World Bank Global Financial Inclusion Database and compared to the benchmark (Brazil), higher accessibility to financial markets can be associated to countries, such as Chile, Poland, and France. On the other hand, lower accessibility to financial markets are features of countries like Argentina, Peru, Paraguay, and other developing countries.

collection. On the other hand, a higher accessibility to financial markets by formal entrepreneurs has two main effects when compared to our benchmark case $\lambda_F = 1.8$ (Table 1.6). First, formal sector entrepreneurs have more access to credit in order to finance their production. This implies a drop in the informal sector production, which is more than compensated by the formal output production increase (scale production up). The overall effect of more access to additional funds is a higher production in the more efficient sector and, consequently, more output and consumption. Second, the (gross) equilibrium wage (w) increases, making the worker occupation more attractive to some informal entrepreneurs. In fact, while a higher λ_F makes it easier for formal entrepreneurs to access additional funds to finance their production, it also increases, in equilibrium, the returns for those that choose to be workers. Intuitively, higher access to credit in the formal sector increases the demand for labor and the equilibrium wage level. Through this channel the size of the informal sector falls in both the output and the employment dimensions. Higher wages and higher formal output combined increase the government tax base. Hence, the government's labor income and output tax revenues increase (LOPEZ-MARTIN, 2019; FRANJO *et al.*, 2020). In a perfect-credit economy ($\lambda \to \infty$) the fraction of informal entrepreneurs and the percentage of informal firms are smaller relative to our benchmark case ($\lambda = 1.8$). In fact, as $\lambda \to \infty$ informal production falls by 24%, a result in line with Franjo *et al.* (2020). As the economy converges to the extreme case of full accessibility to financial markets, the share of formal constrained entrepreneurs converges to zero, output and consumption increases. We also observe that the equilibrium interest rate increases when λ increases.

1.3.3 Stochastic taxation of informal output

We have assumed so far in our theoretical model (Section 1.2) and in our numerical exercises (Sections 3.1, 3.2) that the taxation of informal production is deterministic. In the quantitative exercises presented and discussed in Subsection 3.2, informal entrepreneurs face the same tolerance parameter ζ and the informal output tax is $\tau_I = 1 - e^{-k_I \zeta}$.

The main goal of this section is twofold. First, we want to understand the potential effects of stochastic informal taxation (*vis-á-vis* a deterministic τ_I) on the economy's equilibrium outcomes. And, second, we investigate how a higher expected tax on informal entrepreneurs might affect their optimal decisions as well as key variables of the model. Hence, we extend the model to consider stochastic taxation of informal activities. That is, being caught by the tax authority managing an informal production technology is a stochastic event. All informal entrepreneurs are inspected and they are forced to pay a tax that depends on the size of the firm (as before) and on a tax auditor's (heterogeneous) tolerance of informal activities. In this environment, informal entrepreneurs face the same probability of being caught by either a more (low ζ) or a less tolerant (high ζ) tax auditor. In other words, while some tax auditors are more tolerant and consequently will impose a lower tax on informal entrepreneurs, others are stricter (less tolerant) and will impose higher tax rates on informal entrepreneurs. Therefore, the payoff of an informal entrepreneur now depends not only on her entrepreneurial ability and wealth but also on a probability of being inspected and on the tolerance level of a tax auditor.[18]

Assume that society's tolerance of informality (ζ), interpreted now as the tax auditor tolerance of informality, follows a distribution $\Gamma(\zeta)$ with support in the interval $[\zeta_L, \zeta_H]$, where ζ_L and ζ_H represent the lower- and upper-level of tolerance, i.e., tax auditors that are more and less tolerant of informal activities, respectively. Hence, an informal entrepreneur faces the following (expected) informal tax rate

$$\tau_I = \int_{\zeta_L}^{\zeta_H} (1 - e^{-k_I \zeta}) d\Gamma(\zeta), \tag{1.27}$$

and her (stationary) expected profit is given by $\int_{\zeta_L}^{\zeta_H} \pi_{e,I}(b, x; w, r, \zeta) d\Gamma(\zeta)$.

Recall that, in our benchmark equilibrium, the society's tolerance of informal activities parameter ζ is set to 4.7, i.e., $\zeta^* = 4.7$. We then conduct two numerical experiments. In a first experiment we assume that the expected value of ζ is such that the expected informal tax rate is equal to the one an informal entrepreneur faces in the deterministic case (Section 1.2). Hence, we assume that ζ is drawn from a uniform distribution $\mathscr{U}(0, 9.4)$. Next, we conduct a second experiment where the tolerance of informality parameter is drawn from an alternative uniform distribution $\mathscr{U}(0.5, 9.9)$, i.e., informal entrepreneurs face a higher expected informal tax rate. Notice that, in both cases, informal entrepreneurs face uncertainty regarding the tax auditor's tolerance of informal activities, i.e., whether a more or less tolerant tax auditor will inspect their businesses. Moreover, these two uniform distributions of the tolerance parameter imply that the expected informal output tax ranges between 0-22% in the first case and 0.15%-23%, in the second one. Thus, while in the first numerical experiment informal entrepreneurs might not be taxed at all (i.e., an informal tax equals to zero), in the second case, tax auditors are (on average)

[18] We acknowledge that there are other ways to model stochastic taxation or punishment of informal activities. With the proposed extension we change the model only parsimoniously while keeping its main features. The level of tolerance of tax auditors can be, for instance, associated with the size of the informal firm, the kind of output produced, levels of corruption and side payments that are not modelled directly in our work.

Table 1.7 – Stochastic Tolerance of Informality

	$\zeta^{*}=4.7$	$\zeta^{**}\sim\mathscr{U}(0,9.4)$	$\zeta^{***}\sim\mathscr{U}(0.5,9.9)$
Occupational Choice (%)			
Workers	76.01	76.09	76.21
Formal entrepreneurs	6.85	6.89	7.19
Informal entrepreneurs	17.14	17.02	16.60
% of total output			
Formal sector size	63.25	63.36	69.98
Informal sector size	36.74	36.64	30.02
% of total capital			
Formal capital	90.09	90.13	92.98
Informal capital	9.91	9.87	7.02
% of total labor			
Formal labor	62.01	62.10	68.97
Informal labor	37.99	37.90	31.03
Tax collection (% of total output)			
Workers	10.49	10.50	10.45
Formal entrepreneurs	21.51	21.54	23.79
Informal entrepreneurs	2.22	2.20	2.06
Informal tax rate (average, in %)	6.05	6.01	6.87
Interest rate (in %)	1.8	1.78	1.86
% Variation (relative to benchmark)			
Total output	0.0	-0.05	-1.68
Formal Output	0.0	0.12	8.77
Informal Output	0.0	-0.34	-19.67
Consumption	0.0	0.01	-0.99
Tax Collection	0.0	0.03	4.31
Wage income[1]	0.0	0.04	-2.37

Notes: *benchmark model, **1st and ***2nd experiment; (1) Gross wage income.

less tolerant of informal activities. In other words, there is roughly the same variability of τ_I among informal firms in both cases, with a higher mean for the second uniform distribution.[19]

Table 1.7 presents our results. To allow for comparisons, the results for our benchmark deterministic taxation of informal output (Table 1.3, Subsection 3.2) are also presented in Table 1.7. Overall, the variability of τ_I and a higher (average) informal output taxation reduces informality. In particular, when society (tax auditors) is less tolerant of informal activities the share of informal entrepreneurs and informal production are smaller relative to the benchmark case $\zeta^{*}=4.7$. On the other hand, formal output is higher and the government tax revenue

[19] We also assume that the entrepreneurs' (x,b) profiles and the auditors' tolerance levels (ζ) are not correlated.

increases.

The sharpest contrast between these two exercises is the equilibrium interest rate. In the case where tax auditors are (on average) as tolerant of informal activities as in the deterministic case, i.e., $\zeta \sim \mathscr{U}(0, 9.4)$, but informal entrepreneurs face stochastic taxation (punishment), the equilibrium interest rate is lower than in the benchmark (deterministic) case. As entrepreneurs leave the informal sector to become workers, this occupational reallocation reduces the demand for capital and pushes the economy interest rate to a lower level (a reduction of 0.2 percentage point). In the second experiment, i.e., $\zeta \sim \mathscr{U}(0.5, 9.9)$, for a higher level of the expected informal tax rate the reduction in total output ($y_F + y_I$), as well as the share of entrepreneurs in the labor force, are more pronounced. And, while we observe no variation in the equilibrium wage rate in the first case, i.e., $\zeta \sim \mathscr{U}(0, 9.4)$, it falls substantially in the second case. The fall in production (both intensive and extensive margins), along with a lower equilibrium wage, leads to a higher equilibrium interest rate when informal entrepreneurs face a higher expected taxation of informal output and they manage firms in a society that is less tolerant to their activities.

1.4 Conclusion

In this paper we show that endogenous taxation of informal output has important implications for the allocation and production of output in both formal and informal sectors of an economy, as well as for the agents' occupational choices (entrepreneurs vs. workers). We develop a framework where an entrepreneur that manages an informal firm is subjected to a tax rate that is determined by the combination of her capital choice and society's tolerance of informality. The latter is the main novelty of the paper. In our theoretical model and quantitative exercises, we study the joint effects of how a society tolerates informal production (social norms) and how informal entrepreneurs themselves perceive the punishment imposed by the government. The combination of these two features affects the informal entrepreneur's maximization problem and the general equilibrium effects of policy changes. Our model is consistent with many empirical findings regarding the informal sector in Brazil, a developing economy with a large informal sector. With a calibrated version of our model, we show that as society's tolerance of informality decreases, the informal sector employs less capital and labor, produces less output and informality decreases. Because the taxation of informal activities is endogenously determined by how much capital informal entrepreneurs use, a less tolerant society imposes a higher taxation per unit of (informal) capital used. We also observe that changes in society's tolerance of informality lead agents to shift between the two entrepreneurial options rather than at the entrepreneur-worker dimension. Overall, our results show that informality is substantially lower (while output, consumption and tax collection are higher) in economies that are less tolerant of informal activities, formal entrepreneurs have more access to financial markets and taxation of output and labor is lower. We also extend the model to consider stochastic taxation of informal activities and we show that uncertainty regarding informal output taxation reduces informality.

2 THE ROLE OF CORRUPTION IN A SIMPLE GROWTH MODEL

2.1 Introduction

In this chapter, we present a growth model that evaluates the effect of bureaucratic corruption on economic performance from the point of view of public finances. Corruption is modeled as the misappropriation of public funds that leads to a loss of available resources for the government to finance its expenditures. Firms are exogenously subject to a penalty related to the number of corrupt bureaucrats in the economy that is endogenously determined by the model, so as to represent the detrimental effect on the private sector in line with the "sand the wheels hypothesis"[1]. Households are formed by individuals in the private and public sectors and the latter, despite earning extra income due to the embezzlement of tax collections that would formerly be used to provide public goods, impose distortionary effects on economic growth. The main novelty of this article is the study of a tractable economy, in which it is possible to evaluate the responses of economic aggregates, via steady-state analyzes and dynamic responses to variations and shocks of corruption.

The model results are consistent with the empirical evidence presented for a group of countries and a case study for the Brazilian economy. The predictions of the analysis are also consistent with several empirical observations - that is, a negative correlation between tax revenues and corruption (GHURA, 1998; TANZI; DAVOODI, 2000; IMAM; JACOBS, 2014), a negative correlation between investment and corruption (CAMPOS *et al.*, 1999; LE; RISHI, 2006), a negative correlation between capital stock and corruption (ASILIS; JUAN-RAMON, 1994; LAMBSDORFF, 2003), a negative correlation between wages and corruption (SOSA, 2004; CORNELL; SUNDELL, 2020), and a negative correlation between growth and corruption (MAURO, 1995; KEEFER; KNACK, 1997; GYIMAH-BREMPONG, 2002).

Our model is consistent with many empirical findings regarding Brazilian economy. According to Federation of Industries of the State of São Paulo (2010), the fraction of product lost due to corrupt activities in Brazil is of the order of 1.38% of GDP. Data for 2010 from Office of the Comptroller General (CGU) and the Annual List of Social Information (RAIS) suggest that about 4.88% of public workers in Ministries in Brazil are involved with corruption. Among the corrupt activities, it is considered: improper use of resources by public agents; irregular

[1] There are two views on the impact of corruption on the economy. It can act like grease on the wheels, simplifying a bureaucratic economy already full of unnecessary regulations, or like sand on the wheels, hampering its performance. For more on this see Cooray e Schneider (2018) and references therein.

granting of benefits granted by them; acceptance of bribes or commissions and irregularities in certain careers in state-owned companies. With a calibrated version of our model for the Brazilian economy, we explore the quantitative implications of changes in the level of corruption on economic performance via steady-state comparison and transition paths of the variables.

We show that as the number of corrupt bureaucrats increases, revenue falls proportionally and there is a gradual increase in the distortion in the economy, decreasing productivity, so that investment falls, causing the capital stock to reduce and, despite the slight increase in the hours worked, the product plummets. Such impacts caused by corruption imply a lower salary level and, due to the lower demand for capital, there is also a slight reduction on the interest rate. Considering all the effects listed, the level of consumption in the economy is reduced, even with the illicit diversion of tax collection.

Such results deal with a static version of the model. We then extend our approach to consider corruption as a time-varying process. In this case, we model corruption as a first-order autoregressive process such as Němec *et al.* (2021) and study how shocks of 100 basis points in this variable affect the performance of the economy for different values of persistence. The results basically follow the previous ones based on the steady state analyses, however it is possible to evaluate the transition path of each model variable. The results reveal that when the corruption shock is more persistent, the capital stock, consumption and real wages decrease in greater magnitude and have hump-shaped responses, unlike the other variables.

Related Literature: Does corruption throw sand into or grease the wheels of economic growth and development? The "grease the wheels" hypothesis supported by Kato e Sato (2015) posits that corruption can foster economic activity under conditions of weak governance structures and ineffective policy. So corruption could exhibit a positive impact on economic growth. Proponents of so-called "efficient corruption"often claim that bribery can allow companies to get their activities done more quickly in an economy characterized by bureaucratic delays and rigid laws (LEFF, 1964; HUNTINGTON, 2006). A corruption-based system via bribery for better allocation of licenses and government contracts may lead to an outcome where the most efficient firms will be able to pay the highest bribes (LUI, 1985). Nevertheless, these arguments typically assume that corrupt actions merely avoid the distortions. Frequently, both distortions and corruption stem from a shared set of underlying factors. In brief, corrupt officials might not bypass distortions; instead, they deliberately create extended administrative delays to entice larger bribe amounts.

Aidt (2009) suggests evidence for the "grease the wheel" hypothesis is very weak, and that there is a very strong negative correlation between wealth per capita and corruption, and that the effect of corruption on GDP per capita will lead to unsustainable development. Cooray e Schneider (2018) argue that corruption can be costly for economic activity, advocating in favor of the "sand the wheels" hypothesis.

In most theories that link corruption to slower economic growth, corrupt action by itself does not impose a greater social cost. Rather, the primary social losses from corruption come from supporting inefficient firms and allocating talent, technology, and capital away from their most socially productive uses (MURPHY *et al.*, 1991; MURPHY *et al.*, 1993). When the expectation of potential profits of companies is reduced due to corruption, entrepreneurs choose not to open companies or to expand less quickly (ANTUNES; CAVALCANTI, 2003). Entrepreneurs may also end up choosing to transfer part or all of their savings to the informal sector which is a sector that demands less physical capital and labor, in addition to operating with a production function with lower productivity, which results in a lower aggregate output in the economy (ARBEX *et al.*, 2022). Furthermore, if entrepreneurs internalize the likely dealing of bribes in the future, they have incentives to adopt inefficient "fly-by-night" production technologies with a high degree of reversibility, which allows them to react more flexibly to events and demands from corrupt officials and more credibly threaten to shut down operations (CHOI; THUM, 2004; SVENSSON, 2003).

In line with the "sand the wheels" hypothesis, Mauro (1995) uses data from a sample of developed and developing countries to investigate the effects of corruption on economic growth. Using a single equation model and employing Ordinary Least Squares (OLS) and Instrumental Variables (IV) estimation techniques, he finds that corruption has a significant negative impact on economic growth. Most of the impact on growth, according to him, comes from the decrease in investment in physical capital.

Pellegrini e Gerlagh (2004), in the same vein as Mauro (1995), analyze the direct and indirect channels of the effect of corruption on economic growth and suggest that corruption imposes distortionary effects on the later through its detrimental effects on the private sector, the quality of institutions, and the policy makers. In countries with good institutions, where social, political, and legal rules provide for protected property rights, fair contracts enforcement, and reliance on a free market mechanism that guide the economy, capital investments are advantageous to individuals as well as create a positive impact on the economic activity as a whole (CARSON; PRADO, 2016).

In addition to the discussion between the two hypotheses mentioned above, there is extensive literature in economics that studies both theoretically and empirically the causes (e.g., institutions, government regulations, taxation) and consequences (e.g., poor provision of public goods, inflation, low tax revenue, low economic growth) of corruption. A non-exhaustive list of papers that focus on corruption and topics of interest is: growth (MURPHY *et al.*, 1991; MAURO, 1995; PELLEGRINI; GERLAGH, 2004; FAROOQ *et al.*, 2013; BAÇÃO *et al.*, 2019), human capital (MO, 2001), development (LEFF, 1964; ANTUNES; CAVALCANTI, 2003; BLACKBURN *et al.*, 2006; BARDHAN, 2017), property rights (ACEMOGLU; VERDIER, 1998), inequality (GUPTA *et al.*, 2002; DUSHA, 2019), poverty (SILVA *et al.*, 2022), taxation (AGHION *et al.*, 2016), tax collection (TANZI; DAVOODI, 2000; GHOSH; NEANIDIS, 2017), public capital (CHAKRABORTY; DABLA-NORRIS, 2011), fiscal transparency (ELLIS; FENDER, 2006), shadow economy (DREHER; SCHNEIDER, 2010; BERDIEV; SAUNORIS, 2018; NĚMEC *et al.*, 2021), inflation (BLACKBURN *et al.*, 2008; BLACKBURN; POWELL, 2011; ALI; SASSI, 2016) and environmental degradation (KRISHNAN *et al.*, 2013; SEKRAFI; SGHAIER, 2018; HASEEB; AZAM, 2021; USMAN *et al.*, 2022). See Jain (2001) for a review of the economic literature on corruption and also Aidt (2003).

This paper is more directly connected to three main strands of the literature. The first is the branch dedicated to studying aspects of economic growth in the midst of business environments surrounded by corruption. These studies confirm the hypothesis that corruption has a growth-deteriorating effect. In this literature, our paper is related to Blackburn *et al.* (2006) and Blackburn e Powell (2011). The model of Blackburn *et al.* (2006) incorporates the features that government intervention requires public officials to gather information and administer policies, and that at least some of these officials are corruptible in the sense of being willing to misrepresent information at the right price. Specifically, their analysis is based on a simple neoclassical growth model, in which public agents (bureaucrats) are given the responsibility to collect taxes from individuals (households) on behalf of the political elite (the government). Bureaucrats have the opportunity to engage in corrupt practices that are difficult for the government to monitor. A two-way causality is understood to arise from the mutual interaction between bureaucratic decision making and aggregate economic activity. These authors find that there is a significant negative relationship between the level of economic development and the level of corruption in the economy. Blackburn e Powell (2011), on the other hand, study an economy populated by private and public workers, in which publics are divided between honest and corrupt. The same portion of tax collection is transferred to public workers to offer public goods to the rest of the economy. However, the corrupt ones divert such amount, leaving the government with the option of using inflationary tax to finance the supply of public goods. In summary, corruption impedes real economic growth by forcing the government to rely more on inflationary finance which reduces capital accumulation through the tax that it imposes on investment. Our approach is closer to the way such articles model corruption, although we do not investigate questions about causality or the inflation-corruption channel. We contribute to this literature by providing a tractable framework for analyzing both the steady state and adjustment paths of a dynamic economy in which macroeconomic aggregates (level of output, capital stock, hours worked, and so on) depend on the level of corruption and the deep parameters of the economy.

Most studies have dealt with corruption from a steady state perspective and not as a dynamic process in the economy. Blackburn *et al.* (2006) and Aghion *et al.* (2016) are some examples of these works. Other studies, in turn, have worked on corruption as an economic process endowed with some persistence, working with time series or theoretical models. Bação *et al.* (2019), in turn, investigate the impact of corruption on economic growth in Portugal over the period 1980-2018, making use of a VAR (unrestricted and structural) model inspired by the standard Cobb-Douglas aggregate production function which includes the capital stock, hours worked, total factor productivity and the corruption perceptions index (CPI) of Transparency International. Based on impulse response functions, the estimation results of a structural VAR model with economically plausible long-term constraints indicate modest gains with the reduction of corruption. However, the magnitude of the estimated effect of corruption on economic growth in the unrestricted VAR model is large (and positive), but statistically not significantly different from zero. Farooq *et al.* (2013), for instance, examines the link for Pakistan with data for the period 1987-2009. The results found using the cointegration and VECM approaches indicate that there is a long-term relationship between the variables, with corruption, proxied by the Transparency International CPI, hampering growth. On the other hand, Němec *et al.* (2021) assess the economic impacts of corruption on the size of the informal sector, sources of economic growth and the tax burden in the Czech Republic and generalizes the effects of corruption and its consequences for other post-communist EU member states. Using an extended DSGE model, they confirm the that an increase in perceived corruption supports the informal sector's growth. In their work, they model corruption as a first-order autoregressive process and run alternative simulations for different corruption shock persistences: 0 (no persistence); 0.5 (medium persistence); and 0.9 (high persistence). As a matter of fact, the perception of corruption can be approached from a dynamic perspective. In this paper we assume that the factors associated with corruption and the way it dialogues with economic agents can be translated into extra illegal income for corrupt individuals and social loss from supporting inefficient companies with a lower technological level. It is possible to generate impulse response functions from the model and investigate the impact of corruption on a wider range of macroeconomic variables and their transition path.

Finally, there are several works that study the Brazilian economy and the various facets of corruption present in this country. Corruption in the Brazilian public sector is a notably well-known issue. While worldwide research on the causes of corruption discuss the culture of professionals or companies that can allow corruption to happen (AMEYAW *et al.*, 2017; ZHANG *et al.*, 2017), in Brazil the causes are related to the financing of political campaigns and obtaining subsidized credit from national public banks (ARMIJO; RHODES, 2017; CHAMON *et al.*, 2019). Carson e Prado (2014) provides an overview of the status, sources, and forms of corruption in Brazil. According to them, while the country outperforms many of its regional and developmental peers on various corruption-related indicators, corruption continues to plague many areas of public life, most notably in regional and state governments, political parties, parliament, and public procurement at all levels of government. They also highlight how systemic failures and deficiencies undermine the performance of accountability mechanisms, particularly at the punishment level. Our contribution to this literature lies in calibrating the model for the Brazilian economy, thus establishing a feasible amount of the share of corrupt public workers based on the deep parameters of the Brazilian economy and also in performing counterfactual analysis for variations in the level of corruption.

Besides this introduction, this paper is organized in four additional sections. Section 2.2 shows some evidence of corruption and its persistence among countries with a focus on Brazilian economy. Section 2.3 presents the model. In Section 2.4 we present the results for a calibrated version of the model and conduct counterfactual analyses. Section 2.5 concludes.

2.2 Empirical Evidence

In this section, we review the empirical evidence on corruption that motivates the theoretical model. The discussion is divided into two parts: 1) international evidence of the relationship between corruption and macroeconomic variables among countries and 2) a time series analysis for Brazil, a country involved in several corruption scandals in recent years (CARSON; PRADO, 2014).

2.2.1 Corruption and Macroeconomics

There are several institutions responsible for developing corruption indicators through which countries can be ranked. The rankings prepared by these institutions offer models of success and failure in global terms and, not infrequently, serve as a parameter for decision-making by governments, financial institutions and private agents.

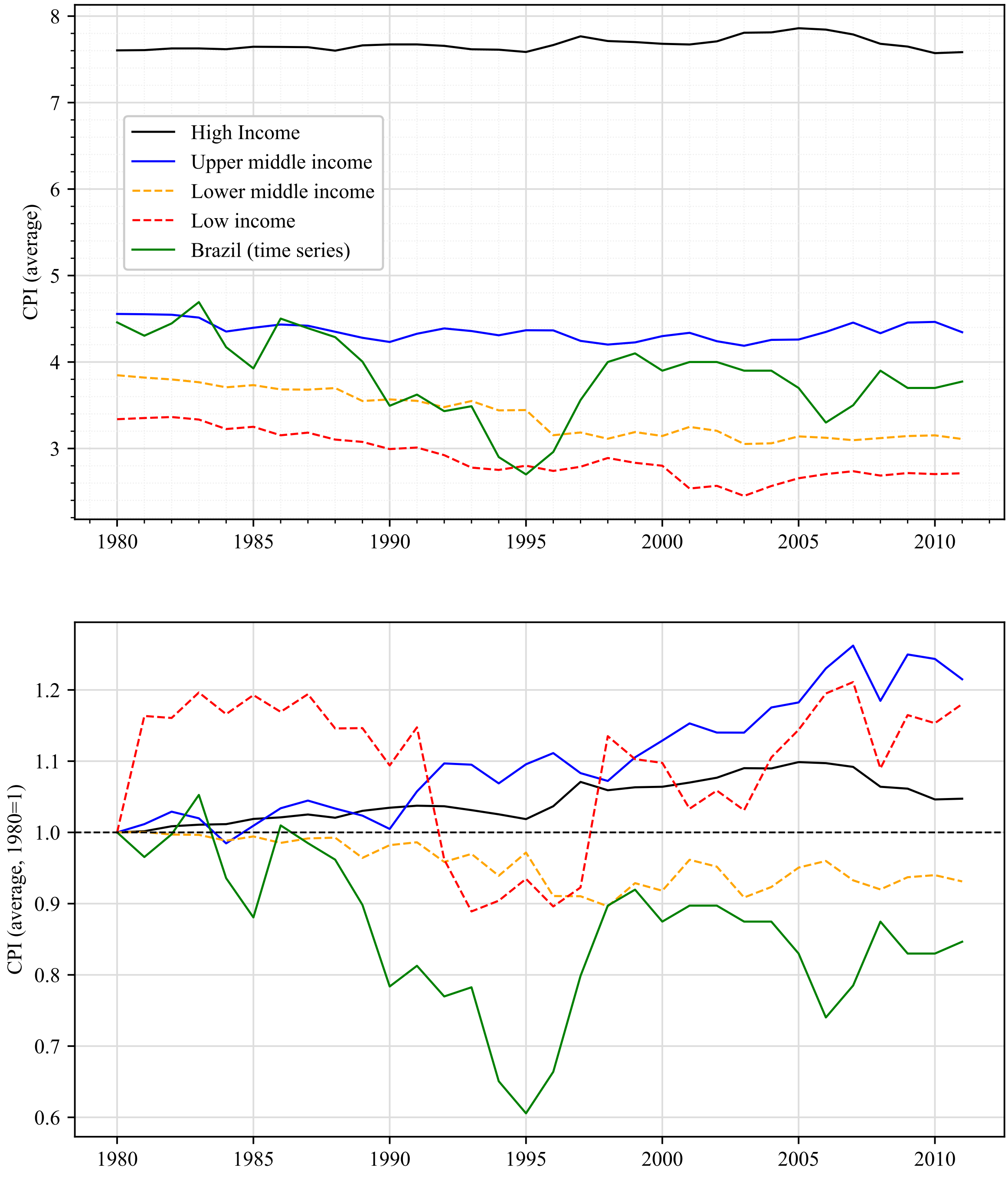
On a strictly economic level, the impact of indices prepared by economic risk rating agencies, such as Standard & Poor's, Moody's and Fitch, on the ability of countries to obtain international investments in more or less favorable conditions is remarkable (COOLEY; SNYDER, 2015). This model has expanded to other fields of activity: particularly notable examples are the corruption perception index (CPI) ranking prepared by Transparency International (BUKOVANSKY, 2015). The CPI belongs to the category of composite indices, which are compiled by a combination of several corruption indicators, thus including more information and eliminating possible unilateral deviations of the results obtained.

The corruption perception index of Transparency International shows that corruption is higher in emerging countries (MONTEIRO *et al.*, 2022). The scale of this index goes from 0, the highest level of corruption, to 10, the lowest level.[2] The Figure 2.1 raises the idea that corruption is intrinsically linked to income, so that low-income countries are characterized by higher levels of corruption, while, on the opposite side, high-income countries tend to have less or greater control of corruption. Many countries of the world seem to have become trapped in a vicious circle of widespread poverty and wholesale misgovernance, concern over which has been growing visibly among international organisations (BLACKBURN *et al.*, 2006). The incidence of corruption is quite diverse across countries and diversity appears to be quite persistent. Furthermore, it is notable that the perception of corruption across countries has slight changes over time, so that the variable may be endowed with some persistence.

Richer countries tend to have more developed institutions and systems of governance, including stronger legal frameworks and more effective enforcement mechanisms. These

[2] It is important to note that the CPI is a perception-based index and not a measure of actual corruption levels. It is based on surveys and assessments from experts and business people who are familiar with corruption in a particular country. However, a high CPI score can indicate that a country has effective anti-corruption measures in place and is perceived as a trustworthy and transparent place to do business.

Figure 2.1 – Corruption Perception Index across countries (1980-2011)



Sources: Castellacci e Natera (2011) and Penn World Table (PWT) 10.01.

institutions and systems can help to deter corrupt behavior and ensure that corrupt actors are held accountable for their actions. In contrast, low income countries may have weaker institutions and systems of governance, which can create opportunities for corruption to thrive. In such contexts, corrupt actors may be able to exploit their positions of power or influence to extract rents or engage in other illicit activities without fear of retribution.

This index is available from 1995 to 2022. However, the historical series of indicators for the countries underwent a methodological change in 2012, so that after that year the indices are no longer comparable to the previous ones. To get around this problem and gain more degrees of freedom, we used the series provided in the CANA dataset (CASTELLACCI; NATERA, 2011), which extends the CPI series to the period 1980-1994.[3] Figure 1 therefore presents the indicators of the original base with the extension carried out by the aforementioned authors, covering the period from 1980 to 2011. To get an idea of the disposition of the countries in the ranking, the five that presented the highest (lowest) averages in the period were Denmark, New Zealand, Finland, Iceland and Singapore, all with CPI above 9 (Angola, Nigeria, Paraguay, Nigeria , Cameroon and Uzbekistan, all with CPI below 2), in that order.[4] This dataset has been used in several previous empirical studies, such as Aidt (2009), Farooq *et al.* (2013), Ali e Sassi (2016), Němec *et al.* (2021), Afonso e Rodrigues (2022), Litina e Varvarigos (2023), among others.

By analyzing the CPI for low-income countries, low middle-income countries, upper middle-income countries, high-income countries, and Brazil, it’s can be observed trends and patterns within each group (first panel of Figure 2.1).[5]

When comparing low-income countries, low middle-income countries, upper middle-income countries, high-income countries, and Brazil, it becomes apparent that low-income countries generally have a higher perceived level of corruption compared to countries with higher incomes. This is likely due to limited resources for effective governance, weak institutional frameworks, and the difficulties associated with combating corruption in challenging economic and social conditions.

Moving on to low middle-income countries, there is a slight improvement in the CPI compared to low-income countries. This suggests that as countries progress economically, they tend to invest more in anti-corruption measures, strengthen governance institutions, and enhance transparency and accountability mechanisms. However, corruption remains a significant challenge within this group.

Upper middle-income countries, on the other hand, exhibit a higher CPI compared to the previous two groups. This indicates that as countries experience further economic growth

[3] It should be noted that, if the analysis is performed for the CPI data after methodological changes (2012-2022), the results regarding the differentiation of country groups by income vs corruption are maintained.

[4] To differentiate countries by income levels, we follow the World Bank’s Analytical Rankings for 2011, the last year before the methodological change in Transparency International’s corruption index. The classification takes into account thresholds of GNI per capita in US$.

[5] The set of countries totals 100. The country groups have been separated into quartiles for GDP per capita, so that each group contains 25 countries. This classification can be consulted in the Appendix, in the Table. A.1.

and development, they can make significant progress in reducing corruption. These countries often have stronger legal and regulatory frameworks, improved governance practices, and more robust institutions, resulting in a relatively lower perceived level of corruption.

High-income countries consistently demonstrate the lowest perceived levels of corruption, as reflected in their high CPI scores. These countries typically have well-established democratic systems, strong adherence to the rule of law, effective anti-corruption measures, and transparent governance structures. However, it's important to note that even in high-income countries, corruption can still exist, albeit at relatively lower levels.

As for Brazil, its CPI fluctuates over the years but generally falls within the range of upper middle-income countries. The Brazilian score suggests that corruption remains a concern: this highlights the ongoing need for efforts to address corruption, strengthen institutions, and promote transparency and accountability within the country.

Regarding the normalization of the CPI for the year 1980 (second panel of Figure 2.1), it allows us to observe changes in the CPI over time in comparison to the initial year. Looking at the groups individually, low-income countries exhibit high variability in the CPI. While the average normalized indicator for the group remained below 1 between 1992 and 1997, it increased after 1998, indicating a relative improvement in its evolution with higher variance. Conversely, the group of low middle-income countries experienced the most significant deterioration in the normalized indicator, remaining below unity for most years, although it stabilized somewhat from 1994 onwards.

In contrast, upper middle-income countries showed a more substantial improvement in the normalized CPI compared to other groups. The values consistently increased, suggesting that these countries have been relatively successful in combating corruption. For high-income countries, since they already held top positions in the CPI ranking, the marginal improvement in the indicator, while present, fell short of what was observed for the upper middle-income group.

Analyzing the normalized CPI for Brazil, we see a fluctuating pattern in the perceived level of corruption over the years. The early 1980s and mid-2000s exhibit relatively stable perceptions, while the mid-1980s to early 1990s indicate a decline in corruption perceptions. Despite some recovery in the late 1990s and early 2000s, the normalized CPI for Brazil remains relatively low, suggesting ongoing challenges in effectively combating corruption and improving transparency and governance. It's worth noting that Brazil's performance was worse compared to the other groups of countries.

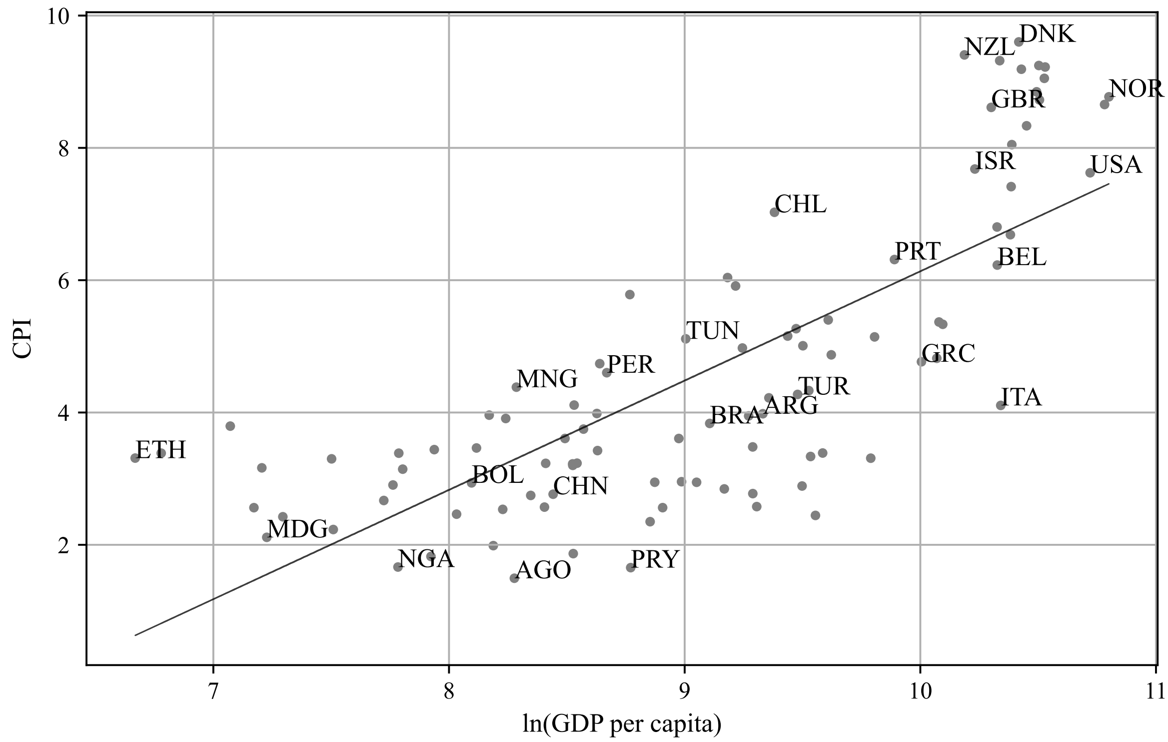
Table 2.1 – CPI quartiles and macroeconomic variables across countries (averages of 1980-2011)

Quartiles	CPI	ln(Hours worked)	ln(GDP_{pc})	ln(K_{pc})	TFP	Share in output				
						C	I	G	X	M
Q1	2.39	7.60	8.36	9.58	0.45	0.61	0.20	0.20	0.13	-0.13
Q2	3.35	7.61	8.80	9.89	0.65	0.71	0.17	0.19	0.12	-0.18
Q3	4.63	7.56	9.63	10.97	0.73	0.61	0.21	0.21	0.23	-0.29
Q4	7.94	7.50	10.50	11.86	0.90	0.56	0.27	0.17	0.43	-0.44

Sources: Castellacci e Natera (2011) and Penn World Table (PWT) 10.01.

Notes: Hours worked are the annual average in each country. GDP_{pc} and K_{pc} are GDP and Capital Stock per capita in each country in current PPP (2017 US$). The TFP is also measured in current PPP and the United States is taken as a reference (USA=1).

Figure 2.2 – Relation between ln(GDP per capita) and CPI across countries (averages of 1980-2011)



Sources: Castellacci e Natera (2011) and Penn World Table (PWT) 10.01.

Table 2.1 presents data for a total of 100 countries, using the CPI from the CANA dataset combined with some macroeconomic variables available from Penn World Table 10.01. The countries were separated by the quartiles of the average CPI in the period from 1980 to 2011 and for each group of countries the averages of several variables of interest were calculated, from real variables in level to the share of the economic aggregates in the output. As one goes from the first to the last quartile, it is mainly noted that TFP and GDP and Capital Stock per capita increase. This indicates that greater control of corruption is associated with technology, wealth and a more capital-intensive economy. On the other hand, it can be seen that the average number of hours worked seems to decrease, in the same comparison, but with a much lower magnitude. Finally, regarding the participation of economic aggregates in output, it is noted that higher levels of investment and trade openness (X-M) and lower levels of consumption and government spending are correlated with less corrupt economies. Regarding the share of consumption, this result is expected, since more corrupt countries tend to be hand-to-mouth economies, as they are poorer. As pointed out by Gupta *et al.* (2002), there is evidence that high and increasing corruption increases income inequality and poverty by reducing economic growth.

As high as the level of corruption is in low-income countries, it becomes much less significant in high-income countries. Table 2.1 shows that estimates of the magnitude of corruption decline with GDP per capita. Figure 2.2 illustrates this point more clearly by showing a strong positive correlation between GDP per capita and the level of corruption control that is measured by the CPI.[6] Very similar results are obtained with the other indicators in Table 2.1. As an economy develops, corruption shrinks.

2.2.2 A case study for the Brazilian Economy

As previously mentioned, there are authors that regard corruption as a driver of economic growth (the greasing the wheel hypothesis). On the other hand, there are those who argue that corruption creates inefficiencies rather than corrects them, which in turn hampers growth (the sanding the wheel hypothesis). The sign of the relationship between corruption and economic growth is thus an empirical issue as aforementioned.

In this section, we investigate the impact of corruption on economic growth in Brazil over the period 1980-2011. The empirical approach makes use of a VAR model inspired by the standard Cobb-Douglas aggregate production function as in Bação *et al.* (2019). The VAR models (unrestricted and structural) includes the capital stock, hours worked, total factor productivity and the corruption perceptions index (CPI) of Transparency International.

The standard approach to the study of growth makes use of a Cobb-Douglas aggregate production function in which output (Y) depends on total factor productivity (A), the capital stock (K) and the labour input (L). α is the capital share and it is set at 0.33. Additionally, we include in the production function the term that measures the level of corruption in the economy

[6] For the analysis, the averages from 1980 to 2011 were used, however the results are maintained for any year of this interval taken separately.

(ϑ), the corruption perception index.

$$Y_t = \vartheta_t A_t K_t^{\alpha} L_t^{1-\alpha} \tag{2.1}$$

Taking logs and first-differencing we would get

$$g_t^Y = g_t^{\vartheta} + g_t^A + \alpha g_t^K + (1-\alpha) g_t^L, \tag{2.2}$$

where the g's are the logarithmic growth rates of the variables in superscript. We then use two models (VAR and SVAR) where we include the growth rates of total factor productivity, capital stock, hours worked and output, along with a variable related to corruption. We set the capital share at one-third as usual. The VAR model is based on the Cholesky decomposition, which imposes a recursive structure on the shocks that move the variables. The main reason for using the second model is to give robustness to the analyses by imposing long-term constraints on the VAR model, and thus moving to a more complex structural VAR (SVAR) model.

It is important here to highlight which variables will be used for the analyses. The corruption level (η) is the previously explained CPI itself. All other variables are taken from Penn World Table 10.01. The TFP level is given at current PPPs (USA=1). The labor factor is given by the average annual hours worked by employed people. Finally, the economy's capital stock and output are given by the capital stock and GDP at current PPPs (2017 US$) per worker.

Consider the following autoregressive vector (VAR) in its reduced form:

$$\begin{aligned} Z_t &= C(\mathcal{L})Z_t + \varepsilon_t, \\ E(\varepsilon_t \varepsilon_t') &= \Omega, \\ E(\varepsilon_t \varepsilon_{t+s}') &= 0, \forall s \neq 0 \end{aligned} \tag{2.3}$$

Z_t is to represent the vector of macroeconomic variables, C is a polynomial function of order p, and $\mathcal{L}$ is the lag operator.

Consider a matrix B such that it is the contemporaneous relationships between the variables and $B\varepsilon_t = u_t$. Multiplying equation (2.3) by B such that:

$$BZ_t = BC(\mathcal{L})Z_t + u_t \tag{2.4}$$

Equation (2.4) is the structural VAR representation (SVAR) (HAMILTON, 2020). Structural shocks in this kind of model can be identified by restricting, via matrix B, contemporaneous relationships between the variables.[7] Previous studies, economic theory and typical facts

[7] For more on this topic, see Rocha *et al.* (2022a) and Rocha *et al.* (2022b).

should be used to determine these restrictions.

$$BZ_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & a_{23} & 0 & 0 \\ a_{31} & 0 & 1 & 0 & 0 \\ a_{41} & a_{42} & 0 & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \begin{bmatrix} A_t \\ \vartheta_t \\ K \\ L \\ Y_t \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ \alpha \\ 1-\alpha \\ 1 \end{bmatrix}' \tag{2.5}$$

The previous expression allows identifying structural shocks in a SVAR model, which in turn are nothing more than some restrictions in contemporary relationships.[8] To support the discussion of contemporary relationships, which are illustrated by equation (2.5), it can be observed that TFP is affected by their own shocks, although their shocks affect all other variables. Corruption is affected by productivity and capital stock shocks, while its own shock affects the hours worked and the output in the economy. The capital stock is affected only by productivity shocks, but its own shocks also affects the output, in addition to the level of corruption. The Brazilian GDP is affected by all other variables.[9]

As far as the models estimations are concerned, they follow the conventional routine: unit root (hence, all variables that comprise the model are I(1)), ADF, PP, KPSS and cointegration tests were used. In the models cointegration can be found. Both models are then estimated in log-differences to make the series stationary. Committed to information criteria proposed by Schwartz (SC) and Hannan-Quinn (HQ), in the present paper a lag length of two was chosen. In addition, the models are well specified, that is, they do not undergo autocorrelation with the respective residuals.

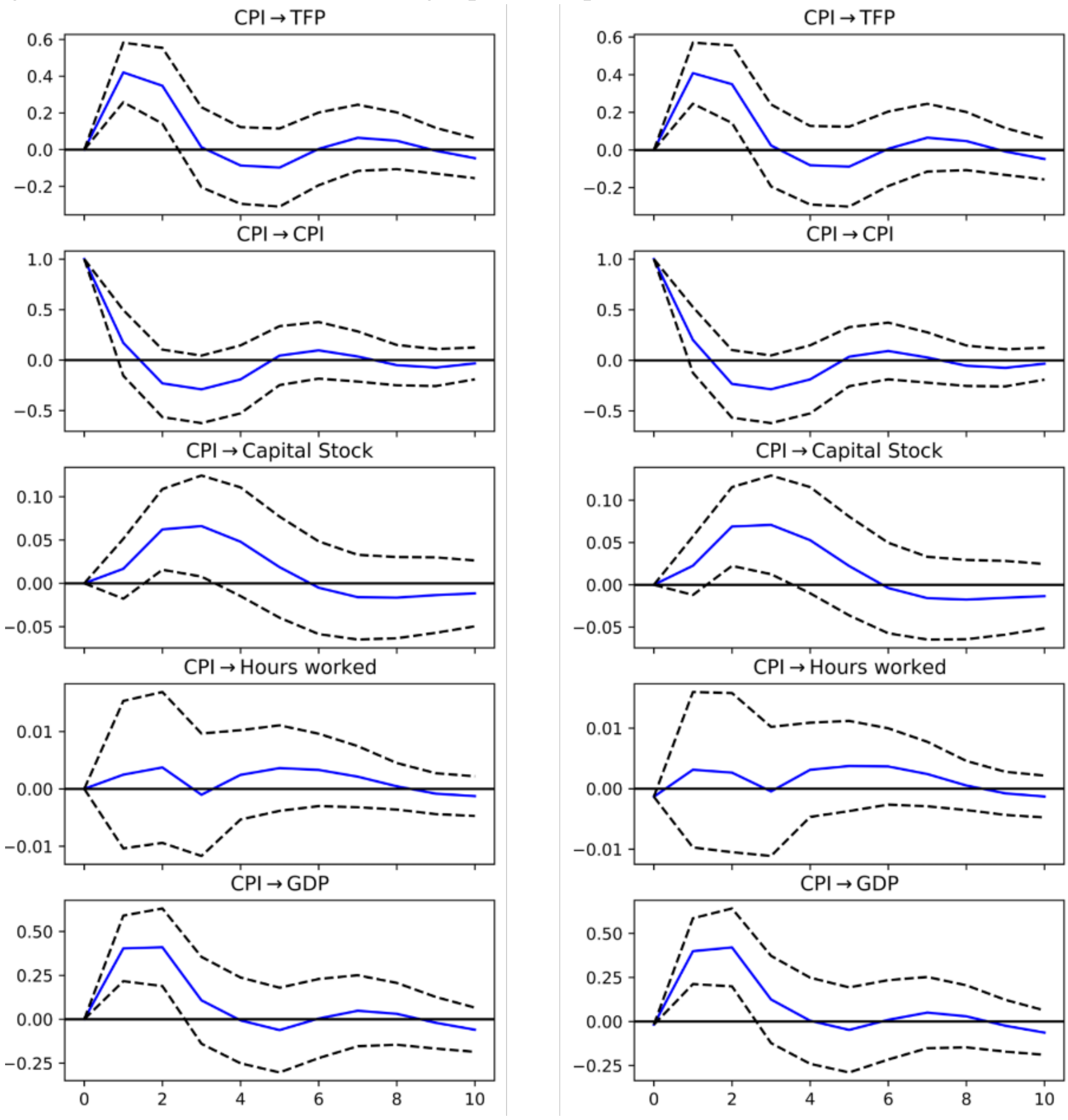
Figure 2.3 reports the results of both models: on the left, the VAR model and, on the right, the SVAR. They show how domestic variables react to a CPI shock. To better visualize their dynamic behavior, the results of both models were placed side by side. In short, the results are quite similar.

Regarding all model variables, Figure 2.3 highlights the positive shocks of CPI: the TFP increases and stays above its baseline for about two years and, as a consequence,

8 The VAR model follows the same ordering of the variables.

9 It is important to highlight that, since the interrelationships between corruption and the other variables are not well established in the literature, other specifications were tested to identify the matrix of contemporary relationships and the results did not change substantially. Two other specifications, for example, that were tested and produced similar results were: $\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & 0 & 1 & 0 & 0 \\ a_{41} & a_{42} & 0 & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix}$, $\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & a_{23} & 0 & 0 \\ a_{31} & 0 & 1 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix}$ and $\begin{bmatrix} 1 & a_{12} & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ a_{31} & 0 & 1 & 0 & 0 \\ a_{41} & a_{42} & 0 & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix}$.

Figure 2.3 – VAR (left) and SVAR (right panel) responses to innovation of ± 1 standard error



stimulates the demand for investments, since capital becomes more productive, encouraging capital accumulation. Thus, the capital stock stays above its baseline for a relatively longer period of time, around five years. Since there is a higher demand for capital and, given its complementarity with the labor input, there is a positive impact on hours worked, remaining the first two years above its baseline, with a slight decrease in the third year and, again, experiencing a positive impact from the fourth to the seventh year. All these facts together reverberate in a positive trajectory in the economy's output that remains above its baseline in the first three years. This fact sheds light on Brazilian authorities to keep the level of corruption low and under control.

It is worth mentioning that the SVAR model used to empirically analyze corruption and its dynamic interaction with macroeconomic variables is considered quite robust in terms of changes in the identification matrix of contemporary relationships. The reason is that the impulse response functions generated for all variables exhibit almost the same shape, in addition to also approaching the unrestricted VAR results.

2.3 A Simple Growth Model of Corruption

We consider an economy with representative firms and families, government and no external sector. We also assume the existence of a continuous measure of individuals indexed by $i \in [0,1]$. The employed population is divided intos a fraction $\upsilon \in (0,1)$ of individuals who work in the private sector, that is, in firms generating output, while $1-\upsilon$ individuals perform the activity of bureaucrats, working for the government in public administration. Each individual chooses how many hours to work, h_t. A proportion $\eta \in (0,1)$ of bureaucrats engage in corruption, diverting public resources that would otherwise be used to finance public expenditures and provide public goods. Firms, in turn, hire labor from households, rent capital and sell products to all economic agents in perfectly competitive markets. In agreement with Azzimonti *et al.* (2009), we assume that lump sum rates are not available to the government and consider a more realistic case, in which the only fiscal instruments are distortionary taxes.

2.3.1 Production

Entrepreneurs are exogenously subject to a penalty related to the number of corrupt bureaucrats in the economy that will be endogenously determined by the model, in order to reduce technology productivity. Thus, the following penalty rate applies to the production function managed by the entrepreneur:

$$\tau^{\eta} = f(\eta), \tag{2.6}$$

where the parameter $\eta \in [0,1]$, proportion of bureaucrats who engage in corruption, appears as a proxy to capture the inefficiency caused by corrupt activities. We assume that $f(\eta)' > 0$ and $f(\eta)'' < 0$. In an ideal case of an economy where corruption does not exist, $\eta = 0$ implies that the production is not penalized, i.e., $f(0) = 0$. On the other hand, in an economy populated with public workers who are always involved in corruption, $f(1) = \kappa$, where κ is the upper bound of the inefficiency caused by corruption. So $f(\eta) \in [0,\kappa]$.

Let A_t be a productivity factor which evolves according to $A_{t+1} = (1+\gamma)A_t$. Let K_t

be the capital stock, and H_t be the total hours employed in the production of good Y_t. The capital share is represented by α. The technology is given by

$$Y_t = (1-\tau^{\eta})K_t^{\alpha}(A_tH_t)^{1-\alpha}, \tag{2.7}$$

and capital evolves according to

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{2.8}$$

where I_t is investment at t and δ is the depreciation rate. Notice that the production function (2.7) imposes purely labor-augmenting (Harrod-neutral) technological change.[10]

2.3.2 Government

There is a government which finances its expenditures through tax on consumption, τ^c, labor income, τ^h, and capital income, τ^k. The government is also seen as a provider of public goods and services that contribute to the well-being of the economy. The real value of government spending on these items is the residual value after bureaucrats' salaries are paid and is given by χ_t.

According to Blackburn *et al.* (2008), the government incurs expenses related to the salaries of bureaucrats, which are determined in such a way that any bureaucrat (whether corrupt or not) could work in a firm and earn equal remuneration to workers in the private sector. Any bureaucrat who is willing to accept a salary less than this remuneration must be expecting compensation for some kind of negligence and is therefore immediately identified as corrupt. As in other studies (ACEMOGLU; VERDIER, 1998; BLACKBURN *et al.*, 2006; BLACKBURN; FORGUES-PUCCIO, 2007), it is assumed that the bureaucrat who is discovered to be corrupt is subject to the maximum penalty of having all his income confiscated (i.e., he is exonerated).

Consequently, the honest bureaucrat would never reveal himself in the way described above. Thus, the government can minimize its labor costs, while ensuring a greater participation of bureaucrats in government activities, by setting salaries of all bureaucrats equal to the salary paid by companies to households: in the case of a lower salary in the sector public, bureaucrats could engage in corruption. Denoting the real value of wages by w_t, it follows that government expenditure on wages is given by $(1-\upsilon)w_t$.

Blackburn e Powell (2011) assume that government spending is financed via taxes on firm output. In contrast, we consider that government expenditures are financed by taxes

[10] Only purely labor-augmenting technological change is consistent with balanced growth. (ACEMOGLU, 2009)

collected from households once they own the firms, $\tau^c N_t c_t + \tau^h w_t N_t h_t + \tau^k r_t K_t$, where N_t is the total number of employed individuals in the economy.

By constructing the model, it is taken into account that the responsibility for collecting taxes lies with the bureaucrats, each one having jurisdiction over the same number of firms and families. Therefore, the total tax revenue allocated individually is given by

$$\psi_t = \frac{\tau^c N_t c_t + \tau^h w_t N_t h_t + \tau^k r_t K_t}{1-\upsilon} \tag{2.9}$$

Each bureaucrat is allocated the same amount of taxes with the intention of providing public goods for society. Noncorrupt bureaucrats, $(1-\upsilon)(1-\eta)$, are faithful to this service, however corrupt bureaucrats, $\eta(1-\upsilon)$, pocket the amount allocated to them. In this way, it follows that the resources available for government activities are $(1-\eta)\left(\tau^c N_t c_t + \tau^h w_t N_t h_t + \tau^k r_t K_t\right)$. Suppose that in every period the government balances its budget, such that

$$G_t := (1-\eta)\left(\tau^c N_t c_t + \tau^h w_t N_t h_t + \tau^k r_t K_t\right) - (1-\upsilon) w_t = \chi_t \tag{2.10}$$

Note that, since the government's budget constraint links fiscal policies, a higher level of corruption can have a strong impact on the conduct of these policies. For example, Tanzi e Davoodi (2000), Friedman *et al.* (2000) and Ghura (1998) provide evidence that corruption leads to lower levels of tax revenue, making fiscal policy management more difficult.

2.3.3 Household

There is a continuum of identical households with measure one. Each household has N_t members, which grows at rate ζ. The representative household owns the initial capital stock, K_0, and each household member has a unit of productive time in each period. Let h_t and l_t be hours worked and leisure by each household member, respectively, such that $h_t + l_t = 1$. Preferences of the representative household is given by the following utility function:

$$U = \sum_{t=0}^{\infty} \beta^t N_t \left[\ln(c_t) + \theta \ln(1-h_t) + \ln(\chi_t)\right], \tag{2.11}$$

where θ is the weight of leisure in utility. The budget constraint of the households is given by:

$$(1+\tau^c) N_t c_t + K_{t+1} = \eta(1-\upsilon)\psi_t + \left(1-\tau^h\right) w_t N_t h_t - \left(1-\delta+\left(1-\tau^k\right) r_t\right) K_t \tag{2.12}$$

The meaning of $\eta(1-\upsilon)\psi_t$ − given that ψ_t is the tax revenue allocated to each bureaucrat in each period, η is the portion of those who engage in corruption, and $(1-\upsilon)$

represents the share of individuals who works for the government – is to aggregate all the amount diverted by corruption that enters as income in the intertemporal consumption restriction of families with corrupt bureaucrats. To these, adding the rest of the households in the economy, we arrive at (2.12). It should be noted that no tax is levied on the term $\eta(1-\upsilon)\psi$, given that such resources come from illicit sources.

Substituting (2.9) in (2.12), see that:

$$(1+\tau^c-\eta\tau^c)N_tc_t+K_{t+1}=\left(1-\tau^h+\eta\tau^h\right)w_tN_th_t+\left[1-\delta+\left(1-\tau^k+\eta\tau^k\right)r_t\right]K_t \tag{2.13}$$

From the budget constraint modified by the inclusion of resources from corruption, it is noted that the taxes paid by families to the government are mitigated in the order of corrupt public officials present in each one of them.

2.3.4 Firm and Household Problems

A firm's goal is to maximize profit by producing and selling the final good according to the production function, equation (2.7), subject to labor and capital costs and output penalty rate, equation (2.6). Thus, the profit maximization problem of the representative firm is as follows:

$$\Pi_t\left(K_t,H_t;\eta\right)=\max_{K_t,L_t\geq 0}\left\{(1-\tau^\eta)K_t^\alpha\left(A_tH_t\right)^{1-\alpha}-w_tH_t-r_tK_t\right\} \tag{2.14}$$

where r_t is the rental rate on capital and w_t is the wage rate. The firm's profit maximization problem, equation (2.14), imply the following optimal capital and labor demand functions, isolated for the respective prices, i.e., the marginal products of capital and labor equal their marginal costs:

$$r_t=\alpha(1-\tau^\eta)K_t^{\alpha-1}(A_tH_t)^{1-\alpha} \tag{2.15}$$

$$w_t=(1-\alpha)(1-\tau^\eta)K_t^\alpha(A_tH_t)^{-\alpha} \tag{2.16}$$

The representative household's problem is to choose $\{c_t,h_t,K_{t+1}\}_{t=0}^\infty$ to maximize (2.11) subject to (2.13) and $c_t,h_t,K_{t+1}\geq 0$, given K_0, η and $\{w_t,r_t\}_{t=0}^\infty$. The Lagrangian associated with the household's problem is

$$\begin{aligned}\mathscr{L}=&\sum_{t=0}^\infty\beta^t\left\{N_t\left[\ln\left(c_t\right)+\theta\ln\left(1-h_t\right)+\ln\left(\chi_t\right)\right]\right\}+\sum_{t=0}^\infty\beta^t\lambda_t\left\{\left(1-\tau^h+\eta\tau^h\right)w_tN_th_t\right.\\&\left.+\left[1-\delta+\left(1-\tau^k+\eta\tau^k\right)r_t\right]K_t-K_{t+1}-(1+\tau^c-\eta\tau^c)N_tc_t\right\}\end{aligned} \tag{2.17}$$

The first order conditions are given by:

$$c_{t+1} = \beta \left[1 - \delta + \left(1 - \tau^k + \eta \tau^k\right) r_{t+1}\right] c_t \tag{2.18}$$

$$\frac{\theta c_t}{1 - h_t} = \frac{w_t \left(1 - \tau^h + \eta \tau^h\right)}{1 + \tau^c - \eta \tau^c} \tag{2.19}$$

The equations (2.18) and (2.18) together with (2.15) and (2.16) deliver, respectively, the Euler's equation and the intratemporal marginal rate of substitution between consumption and leisure:

$$c_{t+1} = \beta \left[1 - \delta + \left(1 - \tau^k + \eta \tau^k\right) \alpha \left(1 - \tau^\eta\right) K_{t+1}^{\alpha - 1} \left(A_{t+1} H_{t+1}\right)^{1-\alpha}\right] c_t \tag{2.20}$$

$$\frac{\theta c_t}{1 - h_t} = \frac{(1 - \alpha)\left(1 - \tau^\eta\right) K_t^\alpha A_t^{1-\alpha} H_t^{-\alpha} \left(1 - \tau^h + \eta \tau^h\right)}{1 + \tau^c - \eta \tau^c} \tag{2.21}$$

Likewise, imputing the marginal costs of capital and labor to the household budget constraint plus the income from corruption, that is, (2.15) and (2.16) in (2.13), we have:

$$\begin{aligned}(1 + \tau^c - \eta \tau^c) N_t c_t + K_{t+1} = & \left(1 - \tau^h + \eta \tau^h\right) (1 - \alpha)(1 - \tau^\eta) K_t^\alpha (A_t H_t)^{-\alpha} N_t h_t \\ & + \left[1 - \delta + \left(1 - \tau^k + \eta \tau^k\right) \alpha (1 - \tau^\eta) K_t^{\alpha - 1} (A_t H_t)^{1-\alpha}\right] K_t\end{aligned} \tag{2.22}$$

2.3.5 Equilibrium

We are now ready to present our definition of a stationary equilibrium for our economy.

Definition 2 *The competitive equilibrium of this economy is a sequence of*

- *a policy set $\Upsilon = \{\tau^c, \tau^h, \tau^k, \tau^\eta, \chi_t\}$ that includes a tax on the consumption, a tax on the hours worked, a tax on the capital return, a tax on the output which is a function of the amount of corrupt bureaucrats in the economy (η) and the provision of public goods (χ_t), respectively;*
- *a price system $Q = \{w_t, r_t\}$ of wages and interest rate; and*
- *the allocation $X = \left\{Y_t, C_t, K_t, H_t, G_t, \{c_t^i, h_t^i\}_{i \in [0,1]}\right\}_{t \geq 0}$*

such that, given the initial conditions and restrictions imposed by the problem, at the steady-state:

1. *the resulting optimal allocations satisfy*
   - *(i) the household's maximization problem described in equations (2.20), (2.21) and (2.22) and*
   - *(ii) the firm's maximization problem described in equations (2.7), (2.8), (2.15) and (2.16); and*

2. *the government budget constraint, equation (2.10);*
3. *the equilibrium of the labor and goods market at any time, respectively, as follows:*

$$N_t h_t = H_t \tag{2.23}$$

$$N_t c_t + K_{t+1} + G_t = (1-\tau^{\eta}) K_t^{\alpha} (A_t H_t)^{1-\alpha} + (1-\delta) K_t \tag{2.24}$$

2.3.5.1 Growth and transformation of model variables

According to Acemoglu (2009), if the neoclassical growth model has (i) labor-augmenting technological progress growing at the rate μ; (ii) CRRA preferences; and (iii) production function $Y : \mathbb{R}_+^3 \to \mathbb{R}_+$ twice continuously differentiable in K and L, satisfying diminishing marginal products, constant returns to scale and Inada conditions; then there exists a unique BGP with normalized capital to effective labor ratio and output per capita and consumption per capita grow at the same rate μ.

So we will find the BGP equilibrium for the variables c, K, h, w, r, Y and G. Denote by x_μ the growth of the variable μ in the BGP. Using market clearing conditions and equation (2.20):

$$x_c = \frac{c_{t+1}}{c_t} = \beta\left(1-\delta+\left(1-\tau^k+\eta\tau^k\right)\alpha(1-\tau^{\eta}) K_{t+1}^{\alpha-1} (A_{t+1}N_{t+1}h_{t+1})^{1-\alpha}\right) \tag{2.25}$$

Dividing the above expression by itself in the t period and using the fact that $x_A = A_{t+1}/A_t = 1+\gamma$ and $x_N = N_{t+1}/N_t = 1+\zeta$:

$$x_K = \frac{K_{t+1}}{K_t} = (1+\gamma)(1+\zeta)\frac{h_{t+1}}{h_t} \tag{2.26}$$

As the log utility function meet the Inada Conditions, thus $x_h = h_{t+1}/h_t = 1$, otherwise the household problem would not be solved. So:

$$x_K = \frac{K_{t+1}}{K_t} = (1+\gamma)(1+\zeta) \tag{2.27}$$

By equation (2.21) evaluated at $t+1$ and divided by itself in the previous period:

$$x_c = \frac{c_{t+1}}{c_t} = (1+\gamma) \tag{2.28}$$

Repeating the same steps for the production function, interest rate, wage rate, and assuming that government spending grows at the same rate as output:

$$x_Y = \frac{Y_{t+1}}{Y_t} = (1+\gamma)(1+\zeta) \tag{2.29}$$

$$x_G = \frac{G_{t+1}}{G_t} = (1+\gamma)(1+\zeta) \tag{2.30}$$

$$x_r = \frac{r_{t+1}}{r_t} = 1 \tag{2.31}$$

$$x_w = \frac{w_{t+1}}{w_t} = (1+\gamma) \tag{2.32}$$

Realize that if capital, output, and government spending were normalized to labor ratio, the variables would grow at the same rate as technological progress $(1+\gamma)$.

Since "effective"or efficiency units of labor are given by $A(t)N(t)$, and Y exhibits constant returns to scale in its two arguments, we now define $\tilde{k}_t$ ($\tilde{y}_t$, $\tilde{g}_t$) as the effective capital (output, government spending)-labor ratio, i.e., capital divided by efficiency units of labor,

$$\tilde{k}_t = \frac{K_t}{A_t N_t}, \quad \tilde{y}_t = \frac{Y_t}{A_t N_t}, \quad \tilde{g}_t = \frac{G_t}{A_t N_t} \tag{2.33}$$

The same strategy above is used for the output and government spending. On the other hand, for consumption, hours worked, interest rate and wages, consider the following transformations:

$$\tilde{c}_t = \frac{c_t}{A_t}, \quad \tilde{h}_t = h_t, \quad \tilde{r}_t = r_t, \quad \tilde{w}_t = \frac{w_t}{A_t} \tag{2.34}$$

Replacing the transformed variables in equation (2.20) and using market clearing conditions, see that:

$$(1+\gamma)\tilde{c}_{t+1} = \beta\left((1-\delta) + \alpha\left(1-\tau^k+\eta\tau^k\right)(1-\tau^\eta)\tilde{k}_{t+1}^{\alpha-1}\tilde{h}_{t+1}^{1-\alpha}\right)\tilde{c}_t \tag{2.35}$$

Similarly, for equations (2.10), (2.21), (2.22), (2.15) and (2.16) and market clearing conditions, see that:

$$\frac{\theta\tilde{c}_t}{1-\tilde{h}_t} = \frac{(1-\alpha)\left(1-\tau^h+\eta\tau^h\right)(1-\tau^\eta)\tilde{k}_t^\alpha\tilde{h}_t^{-\alpha}}{1+\tau^c-\eta\tau^c} \tag{2.36}$$

$$\begin{aligned}\tilde{c}_t\left(1+\tau^c-\eta\tau^c\right) = {} & \left(1-\delta+\alpha\left(1-\tau^k+\eta\tau^k\right)(1-\tau^\eta)\tilde{k}_t^{\alpha-1}\tilde{h}_t^{1-\alpha}\right)\tilde{k}_t \\ & +(1-\alpha)\left(1-\tau^h+\eta\tau^h\right)(1-\tau^\eta)\tilde{k}_t^\alpha\tilde{h}_t^{1-\alpha} - (1+\gamma)(1+\zeta)\tilde{k}_t\end{aligned} \tag{2.37}$$

$$\tilde{g}_t = (1-\eta)\left(\tau^c\tilde{c}_t + (1-\alpha)\tau^h(1-\tau^\eta)\tilde{k}_t^\alpha\tilde{h}_t^{1-\alpha} + \alpha\tau^k(1-\tau^\eta)\tilde{k}_t^\alpha\tilde{h}_t^{1-\alpha}\right) \tag{2.38}$$

$$(1-\tau^\eta)\tilde{k}_t^\alpha\tilde{h}_t^{1-\alpha} = \tilde{c}_t + \tilde{k}_{t+1}(1+\gamma)(1+\zeta) - (1-\delta)\tilde{k}_t + \tilde{g}_t \tag{2.39}$$

$$\tilde{w}_t = (1-\alpha)(1-\tau^\eta)\tilde{k}_t^\alpha\tilde{h}_t^{-\alpha} \tag{2.40}$$

$$\tilde{r}_t = \alpha(1-\tau^\eta)\tilde{k}_t^{\alpha-1}\tilde{h}_t^{1-\alpha} \tag{2.41}$$

With equations (2.35) to (2.41) we can characterize the steady state for $\{\tilde{c}, \tilde{k}, \tilde{h}, \tilde{y}, \tilde{g}, \tilde{w}, \tilde{r}\}$ (note, as in the steady state variables remains constant over time, we are dropping the time subscript when talking about this state). Using the expression (2.35), see that:

$$\tilde{k} = \left(\frac{\alpha\beta\left(1-\tau^k+\eta\tau^k\right)\left(1-\tau^\eta\right)}{(1+\gamma)-\beta(1-\delta)} \right)^{\frac{1}{1-\alpha}} \tilde{h} \tag{2.42}$$

Denoting $\phi = \left(\frac{\alpha\beta\left(1-\tau^k+\eta\tau^k\right)\left(1-\tau^\eta\right)}{(1+\gamma)-\beta(1-\delta)} \right)^{-\frac{1}{1-\alpha}}$, it implies that:

$$\tilde{h} = \phi\tilde{k} \tag{2.43}$$

Substituting (2.43) in (2.36):

$$\tilde{c} = \frac{(1-\alpha)\phi^{-\alpha}\left(1-\tau^h+\eta\tau^h\right)\left(1-\tau^\eta\right)\left(1-\phi\tilde{k}\right)}{\left(1+\tau^c-\eta\tau^c\right)\theta} \tag{2.44}$$

From (2.43) and (2.37):

$$\tilde{c} = \frac{\tilde{k}\left\{(1-\tau^\eta)\phi^{1-\alpha}\left[\alpha\left(1-\tau^k+\eta\tau^k\right)+(1-\alpha)\left(1-\tau^h+\eta\tau^h\right)\right]-\delta-\zeta-\gamma-\zeta\gamma\right\}}{1+\tau^c-\eta\tau^c} \tag{2.45}$$

Matching the equations (2.44) and (2.45), see that:

$$\tilde{k}^* = \frac{(1-\alpha)\phi^{-\alpha}\left(1-\bar{\tau}^k\right)\left(1-\tau^\eta\right)}{\theta\left[\phi^{1-\alpha}\left(1-\tau^\eta\right)\left[\alpha(1-\bar{\tau}^k)+(1-\alpha)(1-\bar{\tau}^h)\right]-\xi\right]+(1-\alpha)\phi^{1-\alpha}(1-\bar{\tau}^h)\left(1-\tau^\eta\right)} \tag{2.46}$$

where $\bar{\tau}^k = \tau^k - \eta\tau^k$, $\bar{\tau}^h = \tau^h - \eta\tau^h$ and $\xi = \delta + \zeta + \gamma + \zeta\gamma$.

Therefore, equations (2.46), (2.44) and (2.41) gives us the expressions for $\tilde{k}, \tilde{c}$ and $\tilde{h}$, respectively, as function of our exogenous variables. Using the equations (2.37), (2.38), (2.39) and (2.40), it is possible to derive closed expressions for $\tilde{g}, \tilde{y}, \tilde{w}$ and $\tilde{r}$, but those will not be necessary in what follows so the algebra is omitted.

From equation (2.46), it can be seen that the capital stock is expressed only as a function of exogenous parameters, so that it is possible to verify the behavior of the former for variations in the latter. Thus, since the task carried out here focuses on the impact of variations in corruption on macroeconomic aggregates, the partial derivative of the steady-state effective capital-labor ratio in relation to the proxy that captures the level of corruption in the economy is presented in equation (2.47). From this, it would be possible to understand how a corruption shock first affects the capital stock and, subsequently, the entire economy. However, many nonlinearities are observed around η, so partial derivative analysis can be an infeasible undertaking.

$$\frac{\partial \tilde{k}^*}{\partial \eta} = \frac{\alpha\left(1+\tau^h-\eta\tau^h\right)}{\left\{(1-\alpha)(1+\theta)(1-\eta)\tau^h-\alpha\theta(1-\eta)\tau^k-1-\theta+\alpha\right\}\phi+(1-\tau^\eta)\,\theta\xi\phi^\alpha} \tag{2.47}$$

Once $\alpha\left(1+\tau^h-\eta\tau^h\right)>0$, for the partial derivative to be negative, the denominator must be negative. Then, we choose the parameters so that increases in the level of corruption have a negative impact on the capital stock, which hinders the growth of the economy.

Assumption 1: The model parameters are such that the increase in the level of corruption degrades the capital stock and the upper limit of taxation on hours worked is such that:

$$\tau^h < \frac{1+\theta-\alpha+\alpha\theta(1-\eta)\tau^k-(1-\tau^\eta)\,\theta\xi\phi^{\alpha-1}}{(1-\alpha)(1+\theta)(1-\eta)} \tag{2.48}$$

There is evidence to suggest that high labor income taxation can create incentives for corruption, as individuals may be more likely to engage in tax evasion or bribery in order to avoid or reduce their tax burden.

Acconcia *et al.* (2003), for instance, develops a model of corruption and tax evasion in which firms can choose to pay bribes to tax officials in order to reduce their tax burden. The authors find that higher tax rates can increase the incentive for firms to engage in bribery, leading to higher levels of corruption. Sanyal *et al.* (2000), on the other hand, use data on international trade flows to examine the relationship between taxation and corruption. The authors find that higher tax rates are associated with higher levels of corruption, as measured by the frequency of irregular payments made by firms.

All in all, in a corrupt system, tax collection may be undermined by various forms of corruption, such as bribery, embezzlement, or tax evasion. This can lead to a situation where a significant portion of tax revenues are lost, reducing the amount of resources available for public services and investments in infrastructure, education, and healthcare, for example. Furthermore, corruption may also influence the design and implementation of tax policies, leading to a regressive tax system that places a disproportionate burden on low-income workers while allowing wealthy individuals and corporations to evade or minimize their tax liabilities. In these situations, corruption and the high tax burden on labor income can create a vicious cycle, where a lack of trust in government institutions leads to more corruption, further reducing the effectiveness of tax collection and public services, reinforcing, ultimately the choice for corrupt activities.

These situations are illustrated by assumption 1, where from a certain taxation on labor income, it is optimal for the household to become corrupt in order to accumulate capital.

The economy will be calibrated in the next section, in order to ascertain the extent to which variations in the level of corruption have an impact on macroeconomic aggregates.

2.4 Economic Implications of the Model

In this section we describe the quantitative implications of a calibrated version of our model. We calibrate the model to match important characteristics of aggregate features of the Brazilian economy. We then compare the steady-state equilibrium with and without corruption and, additionally, generate impulse response functions of macroeconomic aggregates, since we model the level of corruption as a first-order autoregressive process (AR(1)).

2.4.1 Calibration and Parameterization

To carry out our numerical exercises, first we calibrate the parameters of the model so that the stationary equilibrium is consistent with target moments describing the empirical macroeconomic aggregates of Brazilian Economy: aggregate consumption, aggregate investment, government spending (all in %GDP). These parameters are the capital share (α), discount factor (β), Brazilian economy growth rate (γ), depreciation rate (δ), population growth rate (ζ), weight of leisure in utility (θ), consumption tax rate (τ^c), labor income tax rate (τ^h), capital tax rate (τ^k), and the proportion of workers in private sector (υ). Additionally, we will calibrate one more parameter that will be explained below. It is necessary to calibrate an additional parameter that will be duly explained.

If the level of perceived corruption in the country decreased, it is possible to assume that there is greater control over corruption. As their control is greater, it is no longer possible to divert so many resources to corruption, freeing them up for productive activities. These freed resources, which can now be invested in productive activities, represent the cost of corruption for the country. Thus, according to Federation of Industries of the State of São Paulo (2010), on average for the period (1990 to 2008), Brazil has an observed per capita product of US$ 7,954 and a CPI of 3.65 (2008 values). If it had a level of perception of corruption equal to the average of countries selected for comparison of 7.45, the per capita GDP of the country would increase to US\$ 9,184, that is, an increase of 15.5% in the average of the 1990-2008 period (equivalent to 1.38% per year). As a result, the average annual cost of corruption was estimated in this work at 1.38% of Brazilian GDP. Because of this, we will calibrate an additional parameter (ι), so that in the counterfactual exercises to be carried out, once the level of corruption in the economy tends to zero, the magnitude of the increase in GDP will be equivalent to 1.38%.

The inefficiency of the output is endogenously determined by the amount of corrupt public officials in the economy (η), along with an adjustment parameter that reflects the level of output lost by corruption (ι), as mentioned earlier. Therefore, the following penalty rate applies to the output:

$$\tau^{\eta} = 1 - e^{(-\eta/\iota)} \tag{2.49}$$

The combination of these two features affect the agent's maximization problem and the general equilibrium effects of policy changes. The calibrated values of the model parameters are summarized in Table 2.2 and each of these parameters is discussed in turn below.

Paes e Bugarin (2006) calculate the capital share by computing the marginal product of labor, and using data from the Brazilian Family Budget Survey (2002/03) to calibrate the values referring to the share of wages in income, they find $\alpha = 0.43$. The capital share usually orbits around 0.33, however it was necessary to use a slightly higher value in order to approximate the interest rate and the proportion of investment in the output of the Brazilian economy which were, respectively, 13.16% and 21.95% (averages in the period 2000-2019). With the fit of the investment to output ratio, the model ends up adapting well to the consumption and government spending shares of the Brazilian economy. The intertemporal discount factor, in turn, is obtained from Bezerra *et al.* (2014) and is within standard values in the literature, $\beta = 0.94$.

The model presents exogenous growth through the productive factor (A_t), which grows at the rate γ. We calibrate $1+\gamma$ at 1.13% which is the compound annual growth rate over the period 2000-2019, using PWT data.[11] The depreciation rate, in turn, is calculated over the

[11] Compound Annual Growth Rate (CAGR) is a measure of the average yearly growth of a variable over a certain time period. It tells us the average growth rate each year and better controls for the existence of outliers in the period. CAGR is defined as:

$$CAGR(t_0, t_n) = \left[\left(\frac{V(t_n)}{V(t_0)} \right)^{\dfrac{1}{t_n - t_0}} - 1 \right] \times 100$$

where $V(t_0)$ is the initial value, $V(t_n)$ is the end value, and $t_n - t_0$ is the number of years.

Table 2.2 – Benchmark parameter calibration

Parameter	Value	Description	Comment/observations
α	0.43	Capital share	Paes e Bugarin (2006)
β	0.94	Discount factor	Bezerra *et al.* (2014)
γ	0.0113	Economy growth rate	PWT 10.01, CAGR 2000-2019
δ	0.045	Depreciation rate	PWT 10.01, Average 2000-2019
ζ	0.0079	Population growth rate	PWT 10.01, CAGR 2000-2019
θ	1.98	Weight of leisure in utility	Santana *et al.* (2012)
τ^c	0.15977	Tax rate on consumption	Bezerra *et al.* (2014)
τ^h	0.1611	Tax rate on labor income	Bezerra *et al.* (2014)
τ^k	0.13	Tax rate on capital	Santana *et al.* (2012)
υ	0.885	Ratio of workers in private sector	PNAD (2010)
ι	4.673	GDP lost to corruption	Jointly calibrated

same period (2000-2019), but is obtained from the simple average, $\delta = 0.045$. On the other hand, ζ is obtained in the same way as the economy's growth rate, so that $1+\zeta = 0.79\%$.

The weight of leisure in the utility function generally orbits around 2. We used the value of 1.98, as well as in Santana *et al.* (2012). In turn, according to *Brazilian National Household Sample Survey* (PNAD), public employment represented only about 11.5% of the total employed in the country in 2010. Therefore, the percentage of the working age population in the private market corresponds to 88.5%, therefore $\upsilon = 0.885$.

Brazil has a very complex production and labor income tax code and characterizing it is beyond the scope of this paper. We follow Bezerra *et al.* (2014) and set the formal output tax rate $\tau^c = 0.15677$, i.e., consumption is taxed at a 15.677% rate. In the tax code, labor income is taxed at rates that range from zero to 27.5% (Ministry of Economy of Brazil). In our benchmark calibration, we follow Bezerra *et al.* (2014) and set $\tau^h = 0.1611$, since taxation on income is progressive and the maximum rate does not apply to most Brazilians. Finally, the rate that applies to the return on capital comes from Santana *et al.* (2012), and we set this value at 0.13.

The model also proposes to capture the share of public officials who are involved in corruption. As far as we know, such a metric has never been obtained in any work. As pointed by Paiva *et al.* (2021), Caldas *et al.* (2016) suggest that there is no existent direct data on corruption levels in Brazilian municipalities, so the use of a proxy is necessary to measure this variable.

To this end, the events of irregularities obtained from reports produced by the Program for the Corruption Prevention Program by Public Drawing (PFSP) were analyzed, which from 2015 onwards was called Control Program for Federative Entities, managed by the Office of the Comptroller General (CGU). Several other works have already used the database produced by this program, such as Ferraz *et al.* (2012), Caldas *et al.* (2016) and Paiva *et al.*

Table 2.3 – Basic statistics, Brazilian and baseline economy

	Brazilian economy	Benchmark model
Share of consumption in output (%)	59.34	57.38
Share of investment in output (%)	21.95	20.07
Share of gov spending in output (%)	20.03	22.53
Capital to output ratio	3.2	3.12
Interest rate (%)	13.16	13.77
Share of currupt bureaucrats (%)	4.88	5.25

Sources: Office of the Comptroller General (2023), Paes e Bugarin (2006), Penn World Table (PWT) 10.01 and Central Bank of Brazil.

Notes: The first three variables are, respectively, csh_c, csh_i, and csh_g, from PWT 10.01 (2000-2019 averages). The interest rate, on the other hand, was obtained from the Central Bank of Brazil (monthly average in 2000-2019).

(2021).

The Control Program for Federative Entities is carried out through a public draw, so that the municipalities drawn in each draw are random expressions of a population comprising all Brazilian municipalities with up to 500,000 inhabitants (PAIVA *et al.*, 2021; Office of the Comptroller General, 2023).

The corruption variable was obtained by adding the number of lawsuits filed, investigated and judged per year for each municipality included in the sample. Among these lawsuits, we consider: improper use of resources by public agents; irregular concession of benefits granted by them; acceptance of bribes or commissions and irregularities in certain careers in state-owned companies.

We chose the year 2010 as the basis for the processes filed at the CGU. That year, a total of 629 of the 5,570 Brazilian municipalities were investigated. It is noteworthy that only entities at the federal level were scrutinized, that is, public officials from institutions at the state and municipal levels were not investigated.

In order to capture the stock of jobs in each of the federal institutions in each municipality in the sample, Brazilian data from the Ministry of Labor and Employment, Annual List of Social Information (RAIS), available for formal workers in Brazil for 2010, was used.

The data used from the RAIS are identified, so that it is possible to visualize the name of the employer in a given municipality. In this way, the information made available by the CGU was merged with the employment stock of a given entity of the federation in the municipalities present in the sample. Subsequently, we added up the public officials involved in corruption and divided by the stock of jobs in all the respective institutions that employed such individuals. The result shows that about 4.88% of public workers are involved in corruption. It should be noted that only public workers employed in the Ministries of Brazil were used in the analysis, which is equivalent to more than 97% of the cases in the CGU sample.

With everything built from the model and its calibration, it is possible to infer the proportion of corrupt bureaucrats. Note that if we multiply both sides of the equation (2.9) by $\eta(1-\upsilon)$, together with the FOCs of the firms and households, the market clearing conditions and aggregating the consumption to all households ($N_t c_t = C_t$), we have that:

$$\eta(1-\rho)\psi_t = \eta\left\{\tau^c C_t + e^{(-\eta/\iota)}\left[\tau^h(1-\alpha)Y_t + \tau^k \alpha Y_t\right]\right\} \tag{2.50}$$

Dividing both sides by Y_t:

$$\frac{\eta(1-\rho)\psi_t}{Y_t} = \eta\left\{\tau^c \frac{C_t}{Y_t} + e^{(-\eta/\iota)}\left[\tau^h(1-\alpha) + \tau^k \alpha\right]\right\} \tag{2.51}$$

The left side of the equation (2.51) is the share of GDP lost to corruption which, as already mentioned, is around 1.38%. Substituting the parameters described in Table 2.2 on the right side of the same equation, isolate η in order to obtain an interval that contains a feasible amount of corrupt bureaucrats. The proportion of consumption in the output has to be calibrated and, according to data from PWT 10.01, it is around 60% (average 2000-2019). Finally, there is only one parameter left to be calibrated (ι). As highlighted earlier, this value is chosen to adapt the level of product lost due to corruption in counterfactual exercises. This value is calibrated at 4.673. Now, using numerical methods to solve for η, the amount of corrupt bureaucrats in the model is 5.25% of all public workers. This value is very close to that found in the CGU data. With all parameters calibrated, it is possible to establish the upper bound of the output penalty rate, which is around 19.26%, that is, $\tau^\eta \in [0, 0.1926]$.

The model matches the Brazilian economy fairly well along a number of dimensions that were calibrated (Table 2.3), as well as some statistics that were not calibrated, such as the capital to output ratio and the share of corrupt bureaucrats. It should be noted that Paes e Bugarin (2006) indicate this ratio (K/Y) as being equal to 3.2 and, moreover, this value does not have high fluctuations over the years.

2.4.2 Implications of the Model and Quantitative Exercises

In this section, we conduct several quantitative exercises to evaluate the impact on economic outcomes of corruption parameter changes. In particular, we focus on how the production, capital, hours worked, investment, tax collection, utility, wage and interest rate are affected by changes in the level of corruption in the economy. Due to the calibration of the model parameters, it is important to emphasize that Assumption 1 will always value any value of η.

2.4.2.1 Steady State Comparisons

Before going into this topic, it is important to enunciate a measure of long-term welfare implications of corruption changes that will be used in the exercise. We measure the impact as the log difference between the utility level for two different corruption levels that are equaled by the consumption compensation to be made to the agent so that she is indifferent to the new corruption level:

$$\left[ln\left((1+\mu)c^{\eta'}\right)+\theta ln\left(1-h^{\eta'}\right)+ln\left(\chi^{\eta'}\right)\right]-\left[ln\left(c^{\eta^*}\right)+\theta ln\left(1-h^{\eta^*}\right)+ln\left(\chi^{\eta^*}\right)\right]=0 \tag{2.52}$$

where μ is the percentage of consumption that the household must be compensated (or pay) to "accept" this new corruption level, η^* is amount of corrupt bureaucrats of the benchmark model, and η' is the new share of corrupt public workers, which can be higher or lower than the baseline model. Rearranging the terms, see that:

$$\mu=\left(\frac{c^{\eta'}}{c^{\eta^*}}\right)\left(\frac{1-h^{\eta'}}{1-h^{\eta^*}}\right)^{\theta}\left(\frac{\chi^{\eta'}}{\chi^{\eta^*}}\right)-1 \tag{2.53}$$

Results are presented in Table 2.4. To allow for comparisons, the column marked with an asterisk ($*$) shows the results for out benchmark parametrization. We then vary the parameter η at a time while keeping all other parameters constant at their benchmark levels.

The case $\eta^*+0.01$ is illustrative. Once the level of corruption in society increases in one percentage point from the benchmark model, i.e., $\eta=0.0637$, the output level of the economy drops (-0.26%), as well as the capital stock (-0.11%), household consumption (-0.06%), investment (-0.11%), and tax collection (-1.19%). Prices, in turn, follow the same pattern: an increase in the level of corruption of 1 percentage point put a downward pressure on both wages (-0.26%) and the economy's interest rate (-0.02 p.p.), the latter due to the lower demand for capital. Since the agent experiences a negative income effect due to the lower wage, she chooses to work more, which causes a slight increase in hours worked ($+0.01\%$). It is also noteworthy that the individual have to be compensated in terms of consumption to remain indifferent to a higher level of corruption: for the same increase in η, it would have to be offset by about 0.2% of consumption to remain indifferent to the new scenario. The shares of economic aggregates in the economy's output have slight changes.

Table 2.4 – Counterfactual analysis: variations in η

Variables	$\eta=0$	$\eta^*-0.01$	η^*	$\eta^*+0.01$	$\eta=0.1$	$\eta=0.25$	$\eta=0.5$	$\eta=1$
% Variation relative to benchmark model								
y	1.38	0.26	0	-0.26	-1.18	-4.92	-10.94	-22.09
k	0.57	0.11	0	-0.11	-0.5	-2.16	-5.05	-11.16
h	-0.04	-0.01	0	0.01	0.04	0.15	0.34	0.66
c	0.34	0.06	0	-0.06	-0.28	-1.17	-2.52	-4.87
i	0.57	0.11	0	-0.11	-0.5	-2.16	-5.05	-11.16
g	6.45	1.19	0	-1.19	-5.47	-22.79	-50.22	-100
w	1.43	0.26	0	-0.26	-1.21	-5.07	-11.24	-22.6
r^1	0.11	0.02	0	-0.02	-0.09	-0.39	-0.85	-1.7
μ	-1.09	-0.2	0	0.2	0.94	3.95	8.89	18.27
Economic aggregates (%)								
C/Y	56.33	57.12	57.38	57.48	58.15	60.97	65.96	77.13
I/Y	19.9	20.03	20.07	20.09	20.2	20.64	21.39	22.87
G/Y	23.77	22.85	22.53	22.43	21.66	18.39	12.66	0

Notes: *benchmark model (Brazil); (1) Only the interest rate variation is given in percentage points.

When η changes, which can be attributed to the fact that changes in law enforcement or increased oversight by legal authorities are either exacerbated ($\downarrow \eta$) or attenuated ($\uparrow \eta$), the net efficiency gap between the economy with and without corruption, $(1-\tau^{\eta})y_t$ also changes even if the family, initially, has a higher income when its member embezzles the public budget.

The results of the $\eta^*-0.01$ case are diametrically opposed to the previous one with very similar magnitudes. On the other hand, the cases in which $\eta \in \{0.1, 0.25, 0.5\}$ are presented to show the monotonicity of the variables. For these last three cases, it is worth noting the shares of economic aggregates: as the number of corrupt workers increases, notice that the shares of consumption and investment increase, while that of government spending decreases. This is because of the level of tax collection that decreases due to the increase in embezzlement from corruption.

Finally, the last two situations presented represent the most extreme and utopian cases of this economy, respectively: total spread of corruption ($\eta=1$) and total absence of it ($\eta=0$). In the ideal case, absence of corruption, the economic gains obtained from a correction of this friction are evident. The output of the economy would have an increase of around 1.38%, a pattern that is followed by the other variables, with different but relevant magnitudes: capital, consumption, investment and tax collection. Households, due to the higher wage, end up enjoying leisure to a slightly higher extent. Regarding prices, wages and interest rates, both show increases: the former has an increase of around 1.43% , while the latter has a positive variation of 0.11 p.p., which makes sense given the higher demand for capital. In this context of complete correction of corruption, households would have to give up 1.09% of consumption to return to the same utility level of the baseline economy.

On the other hand, in the extreme scenario of complete widespread corruption among public agents, the scenario is the opposite. For $\eta = 1$, the output of the economy would fall by about 22%. The other results are diametrically opposed to the case where $\eta = 0$. It is worth noting that the elasticity of tax collection in relation to corruption is the highest among all the other variables studied in the model.

In summary, there is a negative relationship between corruption and GDP. Corruption, as already highlighted, is a form of inefficiency that distorts the allocation of resources and undermines economic growth. Countries with higher levels of corruption tend to have lower GDP per capita, as shown in Figure 2.2. Corruption also can have a significant negative impact on stock capital accumulation, as it can reduce investment, increase the cost of doing business, and create market distortions. This ends up putting negative pressure on aggregate consumption, as well as tax collection.

An interesting result obtained by the model concerns hours worked. There is no clear consensus on the relationship between corruption and hours worked. However, there are some possible ways in which corruption could affect the number of hours worked by individuals or the overall labor force.

Firstly, corruption can lead to a lack of economic opportunities, particularly for those who do not have connections or resources to engage in corrupt practices. This can result in high unemployment rates or low-paying jobs, which may force individuals to work longer hours or take on multiple jobs to make ends meet.

Secondly, corruption can lead to inefficiencies in the economy, as resources are misallocated and businesses may not operate in a transparent or competitive manner. This can result in lower productivity levels, which may require longer working hours to achieve the same level of output.

For example, in countries with high levels of corruption, there may be a lack of transparency and accountability in the workplace, which could lead to longer working hours as employees are required to put in extra time to meet unrealistic targets or to cover up unethical behavior (GOLDEN, 2012). In the same vein, another study found that long working hours can lead to fatigue and stress, which can increase the likelihood of unethical behavior, including corruption (SCHERER *et al.*, 2006).

On the other hand, when corruption is prevalent in a society, it can discourage individuals and businesses from investing in the country, which can lead to a decrease in economic activity and a reduction in employment opportunities Kaufmann e Wei (1999). Corruption can also create opportunities for rent-seeking behavior, which can lead to individuals or businesses earning profits without engaging in productive work (SHLEIFER; VISHNY, 1993). This can result in a culture of laziness or a lack of incentive to work longer hours, as individuals may rely on connections or bribes to achieve success.

Overall, the relationship between corruption and hours worked is complex and can vary depending on the specific circumstances of a given country or region. However, it is clear that corruption can have a significant impact on economic opportunities and productivity, which may affect the number of hours worked by individuals or the overall labor force. The model results point in the direction that a higher level of corruption requires a greater amount of hours worked by the households, being in accordance with the first hypothesis previously raised. In addition, the results obtained from the model are in line with the empirical evidence presented in Table 2.1, in which it is possible to verify that in countries with a higher level of corruption, there are a greater number of higher hours worked.

2.4.2.2 Dynamic Responses

The persistence of corruption refers to the tendency of corrupt practices to persist over time in a society or a country and can have significant effects on economy, such as economic growth, investment, and development. As shown in Figure 2.1, there seems to be some persistence in the level of corruption across countries.

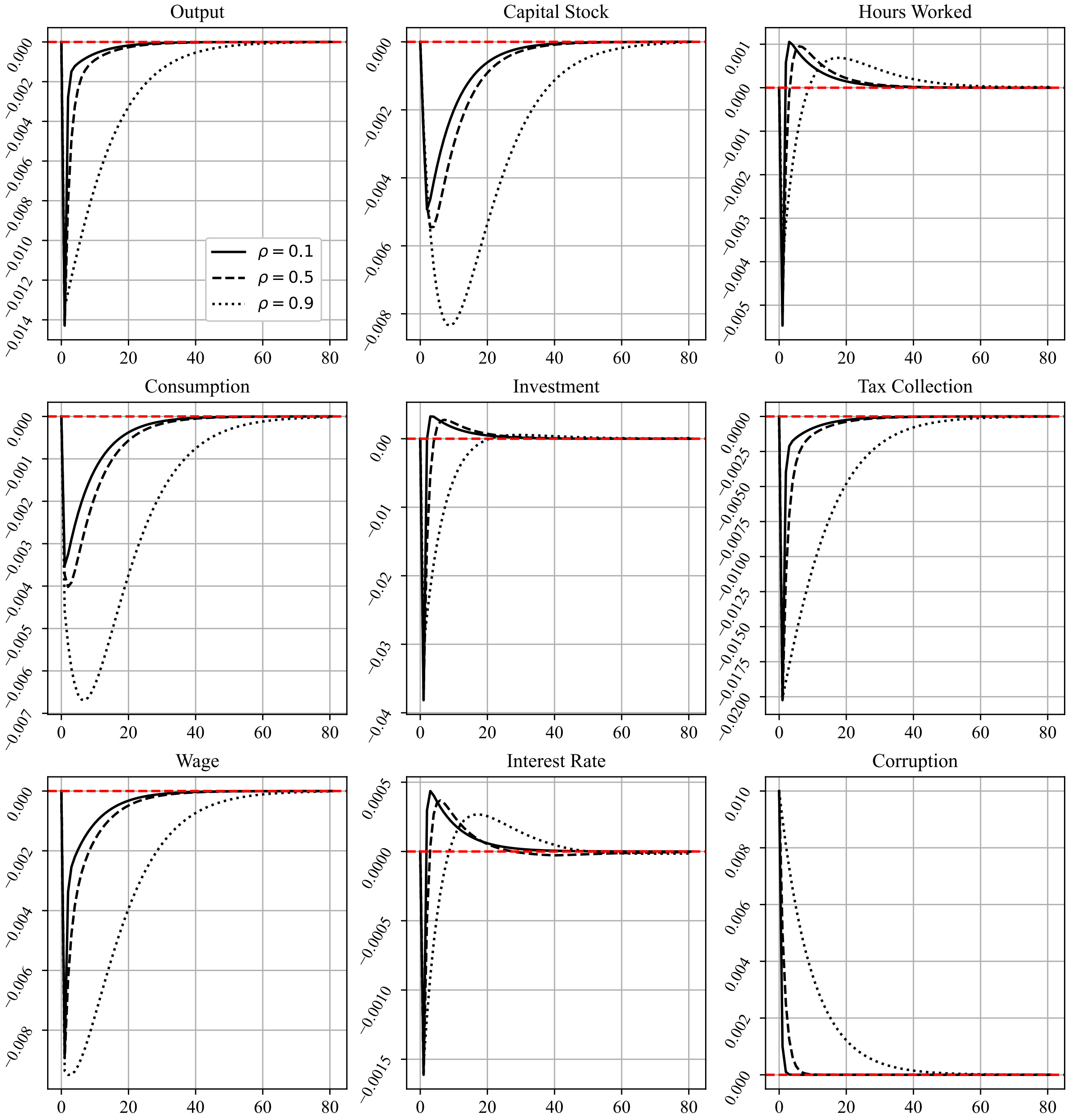
Our strategy to assess the role of a potential persistence of corruption in the economy and its impacts on economic aggregates is similar to that carried out in the work of Němec *et al.* (2021). They model corruption as a stochastic AR(1) process and use three persistence values to assess the impacts of this friction on formal and informal sector GDP. Therefore, we model corruption as an AR(1) process,

$$\eta_t = \kappa + \rho \eta_{t-1} + \varepsilon_t, \tag{2.54}$$

where κ is a constant equal to the η^* of the baseline economy, ρ is the persistence and ε_t is the error.

Figure 2.4 show impulse responses to an 100 basis points exogenous shock in

Figure 2.4 – Variable responses to a 1pp increase in corruption (log-deviations from steady-state)



corruption, η_t, for 80 periods and for three persistence values: $\rho \in \{0.1, 0.5, 0.9\}$. In general, the direction of the responses proceeds as described in the literature and follow the same direction as the empirical evidence presented in Figure 2.2.

The results reveal that when the corruption shock is more persistent, capital stock, consumption and real wages decline more on impact and have hump-shaped responses. The intuition is as follows. A corruption shock immediately causes a sharp drop in tax collection and impairs firm productivity. Clearly, for higher levels of corruption persistence, the longer it takes for the tax collection response to dissipate.

As productivity decreases due to the penalizing rate, the need for capital ends up being lower, which implies a fall in the investment and, consequently, in capital stock. The inverted-U shape of the capital stock is more prominent for higher corruption persistence values and it takes longer to recover from the shock. The investment decreases in the same magnitude for each evaluated persistence, but it also takes longer to return to the steady state level for higher values. On the other hand, for lower persistence, the level of investment quickly returns to the steady state, just after two periods, however remaining above this level for some time, since the productivity of the economy gradually returns to higher levels. Despite the rapid recovery of investment to values above the steady state in this case, the initial shock is so strong that the cumulative responses in all periods still remain negative.

For hours worked, a corruption shock initially resonates negatively on this variable, causing it to decrease by the same magnitude for each level of persistence. It is interesting to note that for $\rho = 0.1$, hours worked remain below the steady state only in the first period after the shock, staying above this level for the rest of the analysis. For the other persistences analyzed, $\rho = 0.5$ and $\rho = 0.9$, hours worked also recover quickly from the shock, remaining above the steady state from the fourth and tenth period, respectively. The accumulated responses of hours worked end up being positive for each of the shocks.

With regard to prices, the influence of the corruption shock on wages is particularly noteworthy. For low and medium persistences, the variable seems to have V-shaped recovery, taking 40 periods to return to the steady state value. As for high persistence, the response of the variable is hump-shaped and takes an additional 20 periods to return to the steady state value.

On the other hand, regarding the interest rate, it is seen that it has a similar behavior for each persistence level under analysis, with an initial decay, later positioning itself above the steady state. It is noteworthy that although the responses of this variable reach the steady state by positive values, the accumulated of all responses is negative, thus maintaining a parallel with the analyzes made in Table 2.4.

Finally, the impact on wages, together with the lower return on capital and a lower level of capital, cause individuals' consumption to regress, and such impacts are greater and longer lasting for higher levels of persistence of corruption shocks.

2.5 Conclusion

This study has shed light on the relationship between corruption and economic growth through the use of a simple growth model. We develop a framework in which the family is formed by private workers and corrupt or honest public workers, in which the corrupt ones misappropriate public funds, thus imposing distortionary effects on economic growth through their detrimental effect on the private sector in line with the “sand the wheels hypothesis”. The paper’s findings suggest that corruption negatively affects economic growth by reducing investment, which in turn reduces capital accumulation and productivity.

Our model is consistent with many empirical findings about the Brazilian economy, such as the level of GDP lost to corruption and the number of corrupt bureaucrats. With a calibrated version of our model for the Brazilian economy, we study the quantitative implications of changes in the level of corruption on economic performance by comparing steady state and transition paths of the variables.

In terms of the existing literature, the contribution of this paper lies in its use of a simple growth model to illustrate how corruption affects economic growth. While there is already substantial research on this topic, the paper’s approach allows for a clear understanding of the mechanisms through which corruption hinders economic growth and development. In addition to the empirical evidence presented, this paper study a tractable economy in which it is possible to evaluate the responses of economic aggregates, via steady state analyzes and dynamic responses to variations and corruption shocks.

Furthermore, the study’s findings are consistent with previous studies that found a negative correlation between corruption and economic growth. However, it is worth noting that our growth model may not capture all of the complex interactions between corruption and economic growth, and more research is needed to explore this relationship in more detail.

Overall, this study highlights the importance of addressing corruption in order to promote economic growth and development. Policymakers should take note of the negative impact of corruption on investment and capital accumulation and take measures to reduce corruption levels in order to promote sustainable economic growth.

3 THE IMPLICATIONS OF CORRUPTION NETWORK FOR BUSINESS CYCLES

3.1 Introduction

This chapter examines the relationship between social networks, and corruption in Brazil. Networks can facilitate corruption propagation by providing corrupt agents with opportunities to meet and collude with each other. We reconsider a conventional framework of a real business cycle model with search frictions (Merz (1995) and Andolfatto (1996)) in which we embed a social network model along the lines of models of the transmission of corruption opportunities in large, complex networks (CALVO-ARMENGOL; JACKSON, 2004). In our model, agents are endowed with an exogenous network structure and engages in socializing with peers belonging to their social network to affect their earnings, a channel absent from most previous quantitative studies of Brazilian business cycles. We derive a matching function using the mean-field approach Vega-Redondo (2007) to take into account both network and direct search efforts by agents. We assume that power-law distributions govern the structure of social networks because they exhibit many of the same properties as real-world social networks (JACKSON *et al.*, 2008). In our model, although efforts to seek involvement in corrupt activities are predetermined, social networks allow individuals to learn more quickly about corruption opportunities.

Public sector employees who are motivated to engage in corruption actively seek opportunities by investing time and effort in social activities that build strong ties to their peers. They make a conscious effort to develop their social networks in order to increase their chances of finding opportunities for corruption. Those who are interested in corruption invest time in building relationships with their peers, as these connections can provide them with the opportunities they need to engage in corrupt activities. We focus on the network structure of social interactions, where the strategic interaction between peers is determined by the network structure, not by the agents' search efforts. We restrict our analysis to the interaction between formal and informal search in an agent's decision, where search efforts are not strategically chosen. When both search efforts are endogenous, individual search effort and network investment can be either strategic substitutes Merlino (2014) or strategic complements Cabrales *et al.* (2011).

We discuss the implications of the findings for the design of anti-corruption policies. Policies should be aimed at weakening labor market networks and increasing the transparency of government procurement and contracting processes.

We show that a shock on corrupt vacancies leads to an initial increase in the corrupt opportunities arrival rate. The distortion caused by corruption negatively impacts the economy's productivity, resulting in a lower demand for capital. This leads to a decrease in investment and the capital stock. The shape of the capital stock follows an inverted-U pattern, which is more pronounced in economies with a higher average number of peers. Investment experiences an immediate reduction.

Regarding the technological shock, there is a positive effect on all components of aggregate demand and real wages, temporarily changing their levels. However, the effect on the arrival rate of corrupt opportunities differs for the way in which the effect on the economy's output is modeled: the first way we modeled this effect lives up to the sand-in-the-wheels hypothesis, while the second refers to the grease-in-the-wheels hypothesis. We also demonstrate that the heterogeneity in the average number of peers affects the progression of corruption, along with metrics related to macroeconomic aggregates.

The paper highlights the importance of social networks in facilitating corruption. This is an important reminder that corruption is not just a problem of individual morality, but is also a social phenomenon that is embedded in networks of relationships.

Related Literature: Corruption is a major problem that affects countries around the world. It can lead to economic inefficiency, political instability, and social unrest. There is a growing body of research on the causes of corruption, and one of the factors that has been shown to be important is the presence of social networks (FISMAN; SVENSSON, 2007; OLKEN, 2006).

Social networks are informal social ties that connect people who work in the same industry or occupation. They refer to the social connections between workers, employers, and other actors in the labor market, including unions, government agencies, and educational institutions. These networks, for instance, can provide corrupt officials with opportunities to meet and collude with each other. For example, if two corrupt officials are both members of the same labor market network, they may be more likely to trust each other and to share information about corrupt opportunities.

There is evidence that the strength of social networks is positively correlated with the likelihood of corruption (LUNA-PLA; NICOLÁS-CARLOCK, 2020; GRANADOS; NICOLÁS-CARLOCK, 2021). This means that officials who are more embedded in social networks are more likely to be corrupt. Networks can be used to perpetuate corrupt practices. For example, employers may use their connections with government officials or labor unions to secure favorable treatment or contracts, even if they do not meet the necessary qualifications or standards. Moreover, networks can also create a culture of nepotism, in which personal connections and loyalty are valued over merit and qualifications. This can lead to a lack of transparency and accountability in the labor market, as well as a breakdown in ethical standards and trust.

There is evidence to suggest that social networks in the labor market can play a role in facilitating corrupt activities. Several papers have shown that individuals who are well-connected within their labor market network may be more likely to engage in corrupt practices, as they have greater access to information and opportunities for rent-seeking behavior (i.e., using their position to gain personal benefits).

Acemoglu e Verdier (2000) found that labor market networks can contribute to corruption in the form of collusion between firms. The authors argue that when individuals are connected through their employment relationships, they may be more likely to engage in collusive behavior, such as price-fixing, which can lead to higher profits but ultimately harms consumers. On the other hand, these networks can facilitate coordination and reduce transaction costs, which can help to promote economic efficiency and reduce corruption.

In the same vein, Campos e Giovannoni (2007) examine the relationship between lobbying, corruption, and political influence, focusing on the ways in which interest groups can use their economic and political power to shape public policy in their favor. It highlights the role of rent-seeking behavior, in which interest groups seek to extract economic rents from the political system, and suggests that corruption is often a byproduct of this process. The paper also discusses various strategies for reducing the influence of interest groups and promoting more transparent and accountable government.

Fernández e Fogli (2006), in turn, explore the relationship between labor market networks and the prevalence of corruption, focusing on the role of social norms and culture. They argue that social norms can play a crucial role in shaping behavior within labor market networks, and that networks with stronger norms of honesty and integrity are less likely to be plagued by corruption.

It is important to note that the relationship between social networks in the labor market and corruption is complex, and there are other factors that may also contribute to corrupt behavior. Additionally, not all individuals who are well-connected within their labor market network engage in corrupt activities, and some may use their connections for positive purposes, such as sharing information and promoting innovation.

Overall, the impact of labor market networks on corruption depends on a variety of factors, including the legal and regulatory environment, the level of trust and social capital within the network, and the overall culture of the society in question. While labor market networks can be a powerful tool for promoting transparency and accountability, they can also be vulnerable to corruption and abuse if not properly regulated and monitored.

Besides this introduction, this paper is organized in three additional sections. Section 3.2 presents the model. In Section 3.3 we present the results for a calibrated version of the model and conduct counterfactual analyses. Section 3.4 concludes.

3.2 A Corruption Network Model

3.2.1 Household

In a typical household there are a measure ν of family members employed in private sector and a measure $1-\nu$ employed in the public sector. We assume that a fraction of public sector members engage in corruption, $\eta(1-\nu)$, while the rest remain uninvolved in such practices, $(1-\eta)(1-\nu)$. All employed members supply labor hours l_t. The public sector workers who engage in corruption seek out such opportunities by making exogenous effort e and spend time x in social activities, which develop their social connections, increasing the strength of their ties to their peers. We assume that bureaucrats are connected to one another in a social network, whose structure is exogenous. Every agent has peers with whom he can interact and learn about corruption opportunities directly.

Preferences of the household are represented by the following utility function

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ log(c_t) + \Phi_1 \left[\nu + (1-\nu)(1-\eta) \right] \frac{(1-l_t)^{1-\chi}}{1-\chi} + \Phi_2 \left[(1-\nu)\eta \left(\gamma \frac{(1-l_t-e_t)^{1-\chi}}{1-\chi} + (1-\gamma) \frac{(1-l_t-x_t)^{1-\chi}}{1-\chi} \right) \right] \right\} \quad (3.1)$$

where $\mathbb{E}$ denotes the expectation operator, β is the discount rate which lies in $(0,1)$, c_t is consumption, Φ_1, Φ_2 are the weight on leisure depending on the household's status and $\chi \neq 1$.

The previous expression deserves additional comments. As stated earlier, the fraction of public sector workers who engage in corruption is given by $(1-\nu)\eta$. Among these, a fraction γ engages in corruption directly by spending time and effort e_t, that is, learning about corruption opportunities directly. On the other hand, a fraction $(1-\gamma)$ engages in corruption indirectly by making contact with their peers, x_t.

3.2.2 Corruption Network

Corruption in the economy is the stochastic match between exogenous corruption opportunities and corrupt bureaucrats. It is modeled by means of a standard matching function embedded with network search as follows[1]

$$M_t = v_t^{\alpha}\left[(1-v)\eta\left(e_t^{\gamma}P_t^{1-\gamma}\right)\right]^{1-\alpha} \tag{3.2}$$

where M_t represents corrupt activities created in t and γ is the relative weight of individuals' direct search on the aggregate rate of corruption formation, i.e., the arrival rate of corruption opportunities.

The aggregate probability that bureaucrats of different types z receive a corruption opportunity via corruption network is

$$P_t = \int_{z=1}^{\infty} p_t D_z dz \tag{3.3}$$

where $p_t = 1-(1-\Omega_t)^z$ is the probability an agent of type z receives at least one opportunity to engage in corrupt activities via a peer in his social network, D_z is the proportion of bureaucrats who has $z \in [1,\infty)$ corrupt peers, $\Omega_t = (\phi(x_t)/\langle z\rangle)\,\eta$ is the probability a bureaucrat is exposed to a corrupt opportunity from a corrupt peer, and $\phi(x_t)$ is the rate at which information on corruption opportunities is passed from corrupt bureaucrats to their peers which depends on how much effort, x, agents spend on socializing.[2]

It is important to highlight that in the next subsection, which refers to the presentation of the production function, the functional form of the effect function that affects the output will not initially be presented, being left to the model parameterization section, when we will work with more than one functional form.

3.2.3 Output and Effect Function

Output y_t is produced according to a standard production technology

$$y_t = E(\Gamma M_t)k_t^{\theta}(A_t l_t)^{1-\theta} \tag{3.4}$$

[1] Notice that corruption arises randomly by a match between corruption opportunities and corrupt agents and through their social networks. In our model, social network increases the efficiency of the matching process between corruption opportunities and corrupt agents.

[2] See Appendix C for detailed description of network process.

where k_t is the capital stock, A_t is a stochastic productivity shock, and $\theta \in (0,1)$. A effect function denoted by $E(\Gamma M_t)$ is introduced. We assume that the economic outcome due to corruption are the mapping from corruption to economic effects measured as a percent of final good output.[3] The effect function therefore characterizes the aggregate amount of redirected resources, where M_t is given by equation (3.2) and Γ represents the exogenous amount of resources reallocated by corruption in each period, as a proportion of aggregate output and proportional to the aggregate rate of corruption formation. We assume that $E_{M_t}(t) < 0$, but note that we do not specify the sign that Γ can assume, so that this parammeter can orbit between positive and negative values, that is, $\Gamma \in [-1,1]$, which implies that $\Gamma E_{M_t}(t) \gtrless 0$.

3.2.4 Resource Constraint

The aggregate resource constraint of the economy must be satisfied

$$c_t + k_t + \kappa M_t = y_t + (1-\delta)k_{t-1}. \tag{3.5}$$

Notice, from the previous expression, that the greater the amount of corruption, the smaller the net product destined for consumption and investment. However, there is also the direct costs associated to corruption. First, the greater the incidence of corruption, the lower the time dedicated to production of the final consumption good, which lowers aggregate production. Finally, there is the impact of the costs, if $\kappa > 0$, or compensation, if $\kappa < 0$, of creating corruption opportunities on equilibrium (κM_t), which also distorts optimal decisions.

3.2.5 Planner's Problem

In this environment the social welfare problem is to choose a contingency plan $\{c_t, l_t, k_t, v_t\}_{t=0}^{\infty}$ in order to maximize (3.1) subject to the resource constraint, equation (3.5), the law of motion for the corruption and technology shocks and an initial condition $(k_0, l_0, \varepsilon_0)$. The firms' and household's problems are similar to the ones agents face in an economy with search only, for instance as in Arbex *et al.* (2016), Andolfatto (1996) and Merz (1995), and the planner's optimal allocation decisions can be implemented as a stationary equilibrium of a centralized network search economy.

The Lagrangian associated with the Central Planner problem is given below, where

[3] This is modeled in the the spirit of integrated assessment models (IAMs) pioneered by Nordhaus (1991), Nordhaus (1992), Nordhaus (2008).

λ_t is the multiplier associated with equation (3.5).

$$\begin{aligned}\mathscr{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ & log(c_t) + \Phi_1 \Big[\nu + (1-\nu)(1-\eta) \Big] \frac{(1-l_t)}{1-\chi}^{1-\chi} + \\ & \Phi_2 \Big[(1-\nu)\eta \Big(\gamma \frac{(1-l_t-e_t)}{1-\chi}^{1-\chi} + (1-\gamma) \frac{(1-l_t-x_t)}{1-\chi}^{1-\chi} \Big) \Big] + \\ & \lambda_t \Big[y_t + (1-\delta)k_{t-1} - c_t - k_t - \kappa M_t \Big] \Bigg\}. \end{aligned} \tag{3.6}$$

The first-order conditions associated with the problem are given below.

$$\frac{\partial \mathscr{L}}{\partial c_t} = \frac{1}{c_t} - \lambda_t = 0 \tag{3.7}$$

$$\begin{aligned}\frac{\partial \mathscr{L}}{\partial l_t} = & -\Phi_1 \Big[\nu + (1-\nu)(1-\eta) \Big] (1-l_t)^{-\chi} \\ & - \Phi_2 (1-\nu)\eta \Big[\gamma (1-l_t-e_t)^{-\chi} + (1-\gamma)(1-l_t-x_t)^{-\chi} \Big] \\ & + \lambda_t \Big[(1-\theta) E(\Gamma M_t) k_{t-1}^{\theta} A_t^{1-\theta} l_t^{-\theta} \Big] = 0 \end{aligned} \tag{3.8}$$

$$\frac{\partial \mathscr{L}}{\partial k_t} = -\lambda_t + \lambda_{t+1} \Big[\theta E(\Gamma M_t) k_t^{\theta-1} (A_{t+1} l_{t+1})^{1-\theta} + 1 - \delta \Big] = 0 \tag{3.9}$$

$$\frac{\partial \mathscr{L}}{\partial v_t} = \Gamma E_{M_t}(t) k_t^{\theta} (A_t l_t)^{1-\theta} - \kappa = 0 \tag{3.10}$$

Added to the equations (3.2), (3.4) and (3.5), combining the conditions (3.7) – (3.10) together with the optimal prices from the firm's problem, we obtain the following competitive equilibrium conditions:

$$\begin{aligned}\frac{w_t}{c_t} = \Big\{ & \phi_1 \left[v + (1-v)(1-\eta) \right] (1-l_t)^{-\sigma} \\ & + \phi_2 (1-v)\eta \left[\left(\gamma (1-l_t-e_t)^{-\sigma} \right) + (1-\gamma)(1-l_t-x_t)^{-\sigma} \right] \Big\} \end{aligned} \tag{3.11}$$

$$\frac{1}{c_t} = \frac{\beta r_{t+1}}{c_{t+1}} \tag{3.12}$$

$$\Gamma E_{M_t}(t) = \frac{\kappa}{k_{t-1}^{\theta} (A_t l_t)^{1-\theta}} \tag{3.13}$$

$$w_t = (1-\theta) E(\Gamma M_t) k_{t-1}^{\theta} A_t^{1-\theta} l_t^{-\theta} \tag{3.14}$$

$$r_t = \theta E(\Gamma M_t) k_{t-1}^{\theta-1} (A_t l_t)^{1-\theta} + 1 - \delta \tag{3.15}$$

Conditions (3.11) and (3.12) have well-known interpretations: the former governs determines the intratemporal allocation of consumption and leisure and the latter governs the intertemporal pattern of consumption. At first glance they seem fairly standard. However, when corruption affects the agent's utility and output through production damage function, and consequently through the prices of the factors of production and marginal utility, they affect agent's optimal allocations decisions in non-trivial and interesting ways.

Notice that while this intratemporal choice is not affected by corruption directly, to the extent that the marginal productivity of labor (w_t) changes when corruption experiences some perturbation, corruption affect the agent's choice of consumption and leisure. The same phenomenon occurs with the household's intertemporal choices.

Equation (3.13), on the other hand, represents how the creation of corrupt opportunities dialogues with the effect function that perturbs the economy's output. Two distinct cases emerge from the sign that κ can assume: the "grease the wheels" vs. the "sand the wheels" hypothesis.

If, on the one hand, $\kappa > 0$, as already mentioned, note that there will be a kind of cost in the equilibrium for firms when creating corrupt vacancies. However, since $E_{M_t}(t) < 0$, $\kappa > 0 \Rightarrow \Gamma < 0$, i.e., firms face a cost in creating corrupt vacancies in their budget constraints, but this ends up generating better conditions for their operation, since the damage function that previously generated a negative distortion in the economy's product starts to promote more economic efficiency, so that $E(\Gamma M_t) > 1$. Advocates of what they refer to as "efficient corruption" frequently argue that offering bribes can enable businesses to expedite their operations in an economy marked by bureaucratic bottlenecks and stringent regulations (LEFF, 1964; HUNTINGTON, 2006). According to Méon e Weill (2010), corruption is less detrimental to efficiency in countries where institutions are less effective and it may even be positively associated with efficiency in countries where institutions are extremely ineffective, such as underdeveloped countries.

On the other hand, if $\kappa < 0$, the diametrically opposite case occurs, which is considered in the literature as the "sanding the wheels" hypothesis. As $E_{M_t}(t) < 0$, $\kappa < 0 \Rightarrow \Gamma > 0$. In other words, when firms post corrupt vacancies and fill them, they obtain a positive payoff arising from corruption, otherwise they would have no incentive to create them. However, if the creation of corruption implies a benefit on the budgetary constraint side, there is a loss on the production side due to the damage function, which becomes less than unity in this situation, $E(\Gamma M_t) < 1$, reducing the aggregate efficiency of the economy. Aidt (2009) proposes that there is scant support for the 'grease the wheel' theory and highlights a robust negative connection between per capita wealth and corruption. Furthermore, Aidt asserts that the adverse impact of corruption on GDP per capita ultimately results in unsustainable development. On the other hand, Cooray e Schneider (2018) contends that corruption can exact a significant economic toll, endorsing the 'sand the wheels' hypothesis.

The debate over whether corruption predominantly "greases" or "sands" the wheels of economic activity is context-dependent and varies from one country or situation to another. In practice, corruption often has a complex and multifaceted impact, with both positive and negative effects coexisting within an economy. Policymakers and researchers continue to study these dynamics to understand how best to address corruption while promoting economic growth and development.

3.3 Quantitative Analysis

In this section we describe the quantitative implications of a calibrated version of our model. Then, we simulate the benchmark steady state equilibrium and conduct several exercises. In particular, we study how an economy in the midst of the existence of corruption behaves given the occurrence of technology shocks and corrupt vacancies shocks.

3.3.1 Model parameterization and calibration

We assume agents have on average five peers, $\langle z \rangle = 5$, with $a = 2.25$ and the network search effort is very efficient by setting $\lambda = 0.95$ (ARBEX; O'DEA, 2014; ARBEX *et al.*, 2016). The other parameters that configure the network components also come from the same cited studies and are presented in Table 3.1: $\alpha = 0.6$, $\gamma = 0.4$.

Regarding preferences, the discount rate, β, and the weight on leisure, χ, are set to 0.99 and 2, respectively. The capital share, θ, and the capital depreciation rate, δ, are set to 0.35 and 0.025, in that order. The four parameters in question come from Arbex *et al.* (2016).

It is important to highlight that time effort looking for a corrupt opportunity is split between direct search and network search as follows: $e = x = (1/4)l^*$, keeping the total amount of time an agent gives up in terms of leisure the same, i.e., $(1/2)l^*$.

In Brazil, according to the Ministry of Labor and Employment, based on microdata from the Annual Social Information List (RAIS) available for formal workers in Brazil, public employment represented in 2010 around 18.42% of total formal jobs in the country. Thus, the percentage of the population employed in the private market corresponds to 81.57%, therefore

$\nu = 0.8157$.

In order to calibrate the share of public officials involved in corruption, η, the events of irregularities obtained from reports produced by the Program for the Corruption Prevention Program by Public Drawing (PFSP) were analyzed, which from 2015 onwards was called Control Program for Federative Entities, managed by the Office of the Comptroller General (CGU). Several other works have already used the database produced by this program, such as Ferraz *et al.* (2012), Caldas *et al.* (2016) and Paiva *et al.* (2021).

The Control Program for Federative Entities is carried out through a public draw, so that the municipalities drawn in each draw are random expressions of a population comprising all Brazilian municipalities with up to 500,000 inhabitants (PAIVA *et al.*, 2021; Office of the Comptroller General, 2023).

The corruption variable was obtained by adding the number of lawsuits filed, investigated and judged per year for each municipality included in the sample. Among these lawsuits, we consider: improper use of resources by public agents; irregular concession of benefits granted by them; acceptance of bribes or commissions and irregularities in certain careers in state-owned companies.

We chose the year 2010 as the basis for the processes filed at the CGU. That year, a total of 629 of the 5,570 Brazilian municipalities were investigated. It is noteworthy that only entities at the federal level were scrutinized, that is, public officials from institutions at the state and municipal levels were not investigated.

In order to capture the stock of employment in each of the federal institutions in each municipality in the sample, the identified RAIS was used, so that it is possible to visualize the name of the employer in a given municipality. In this way, the information made available by the CGU was merged with the employment stock of a given entity of the federation in the municipalities present in the sample. Subsequently, we added up the public officials involved in corruption and divided by the stock of jobs in all the respective institutions that employed such individuals. The result shows that about 4.88% of public workers are involved in corruption, so $\eta = 0.0488$. It should be noted that only public workers employed in the Ministries of Brazil were used in the analysis, which is equivalent to more than 97% of the cases in the CGU sample.

There remains only two parameteres to be set, κ and Γ. First, we will discuss the functional forms that the effect function will take in our numerical exercises. We follow a similar example of effect function to that used by Arbex e Batu (2020). The authors see the effect

Table 3.1 – Model parameters

Preferences					Technology		Network search components						Shocks	
(2)	(2)	(2)	(3)	(4)	(2)	(2)	(2)	(1)	(1)	(1)	(1)		(2)	(2)
β	χ	$\Phi_j^{\dagger}$	ν	η	θ	δ	α	λ	γ	a^*	$\langle z \rangle^*$		ρ_{ε}	$\sigma_{\tilde{\varepsilon}}$
0.99	2	0.5	0.8157	0.0488	0.35	0.025	0.6	0.95	0.4	2.25	5		0.95	0.007

Sources: (1) Arbex e O'Dea (2014); (2) Arbex *et al.* (2016); (3) Ministry of Labor and Employment of Brazil; (4) Office of the Comptroller General (CGU).
Notes: *Benchmark values; $^{\dagger}j = 1,2$.

function as a type of impact that the temperature deviation reverberates on the output.[4] We then assume two functional forms for the effect function, $E(\Gamma M_t)$:

$$E(\Gamma M_t) = 1 - \Gamma_0 M_t \tag{3.16}$$

$$E(\Gamma M_t) = 1 - \Gamma_1 M_t - \Gamma_2 M_t^2 \tag{3.17}$$

where $\Gamma_0, \Gamma_1, \Gamma_2 \gtrless 0$ and note that $E_{M_t}(\cdot) < 0$.

Before explaining the strategy for calibrating the Γ parameters, it is imperative to discuss the Corruption Perception Index (CPI). This index falls under the classification of composite measures, which are created through the amalgamation of various corruption indicators. This approach incorporates additional data and removes potential one-sided discrepancies from the acquired outcomes. Its scale of this index goes from 0, the highest level of corruption, to 10, the lowest level.[5]

Therefore, our strategy to calibrate the Γ parameters will be to regress the outcome in relation to variables that make up a Cobb-Douglas aggregate production function, in addition to the effect function. The production function is given by:

$$Y_t = e^{E(\Gamma M_t)} K_t^{\theta} (A_t L_t)^{1-\theta} \tag{3.18}$$

Taking the logarithm, we see that:

$$ln(Y_t) = E(\Gamma M_t) + \theta ln(K_t) + (1-\theta) ln(A_t L_t) \tag{3.19}$$

4 In this work, the effect function takes the form $E(T) = (1 + \pi_1 T + \pi_2 T)^{-1}$, where $\pi_1 > 0$ and $\pi_2 > 0$ and T is the temperature. Note that because the function parameters are always positive, any increases in temperature will negatively impact the output.

5 It is crucial to emphasize that the CPI functions as a subjective gauge rather than a direct indicator of real corruption levels. It relies on surveys and evaluations conducted by professionals and business individuals who possess knowledge about corruption within a specific nation. Nevertheless, a high CPI rating can imply that a country has implemented successful anti-corruption strategies and is regarded as a reliable and open environment for conducting business. This index is available from 1995 to 2022. However, the historical series of indicators for the countries underwent a methodological change in 2012, so that after that year the indices are no longer comparable to the previous ones. To get around this problem and gain more degrees of freedom, it is possible to use the series provided in the CANA dataset (CASTELLACCI; NATERA, 2011), which extends the CPI series to the period 1980-1994, thus extending the database from 1980 to 2011.

Table 3.2 – Calibrated parameters of the effect function

Functional form	Parameter values		
$1-\Gamma_0 M_t$	$\Gamma_0 = 0.2347$	$\Rightarrow$	$\kappa = -0.2347$
$1-\Gamma_1 M_t - \Gamma_2 M_t^2$	$\Gamma_1 = 0.2946$ $\Gamma_2 = -0.1351$	$\Rightarrow$	$\kappa = -0.2770$

Sources: Penn World Table 10.1 and Castellacci e Natera (2011).

where $E(\Gamma M_t)$ will be proxied by the CPI indexes, i.e., $E(\cdot) = 1 - CPI$ or $E(\cdot) = 1 - CPI - CPI^2$. We then use data from the Penn World Table for output, capital, labor and TFP and data from the CANA dataset (CASTELLACCI; NATERA, 2011) for the CPI for Brazil from 1980 to 2011. It is important to highlight that, to improve the interpretation of the results, we changed Brazil's CPI, first dividing the index by 10 to orbit between 0 and 1, later we adapted it so that the closer to 1, the greater the level of corruption, and the more closer to 0, the lower this level will be.[6] The regression results are shown in the following Table 3.3.

The coefficients for the standard variables that make up the aggregate production function are in accordance with the economic literature, all that remains is to evaluate the signs of the coefficients of the corruption proxies. Considering that from now on, $CPI \in [0,1]$, and the closer it is to 1, the higher the level of corruption, it can be seen from the first regression that any increases in the level of corruption have a negative impact on economic activity. On the other hand, from the second regression, the relevance of the quadratic relationship between the level of corruption and the output is denoted: firstly, increases in the level of corruption have a negative impact on economic activity, but the quadratic term presents itself in the opposite direction, mitigating the negative impact of corruption. Therefore, we will use such coefficients to proxy the Γ parameters, which in turn will determine the κ values.[7] Therefore, we set the value of Γ_0 in the equation (3.16) equal to 0.2347, which implies a value of κ equal to -0.2347 (see equation (3.13)). The values for Γ_1 and Γ_2, in the equation (3.17), are set at 0.2946 and -0.1351, respectively. The two values imply, from the equation (3.13), $\kappa = -0.2770$. The values of the effect function parameters and their respective κ are presented in Table 3.2.

Finally, to capture the impact of corruption on the economic environment, we model a corruption shock on the corrupt opportunities created in each period. The corruption shock ε_t evolves according to an AR(1) process:

$$\varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \tilde{\varepsilon}_t, \tag{3.20}$$

[6] Basically, we multiply the index by -1 and add 1 to all values.
[7] In this case, we normalize the steady-state output to unity.

Table 3.3 – Regression Results

	$ln(GDP_t)$	
constant	32.1957	32.2683
	(5.5228)	(5.6313)
CPI_t	-0.2347	-0.2946
	(0.0672)	(0.0710)
CPI_t^2		0.1351
		(0.0808)
$ln(K_t)$	0.5339	0.5346
	(0.0536)	(0.0547)
$ln(L_t)$	3.7545	3.7657
	(0.6976)	(0.7119)
$ln(A_t)$	1.0199	1.0127
	(0.0838)	(0.0908)
R-squared	0.9886	0.9886
R-squared Adj.	0.9869	0.9864

Sources: Penn World Table 10.1 and Castellacci e Natera (2011).

where $\rho_\varepsilon \in (0,1)$ and $\tilde{\varepsilon}_t$ is an i.i.d random variable. Thus, the rate of new corruption opportunities is given by $exp(\varepsilon_t)v_t$. In the same vein, we also model the technology shock, also using an AR(1) process that is standard in the literature, as well as the same parameters which are taken from Arbex *et al.* (2016): $\rho_\varepsilon = 0.95$, $\sigma_{\tilde{\varepsilon}} = 0.007$.

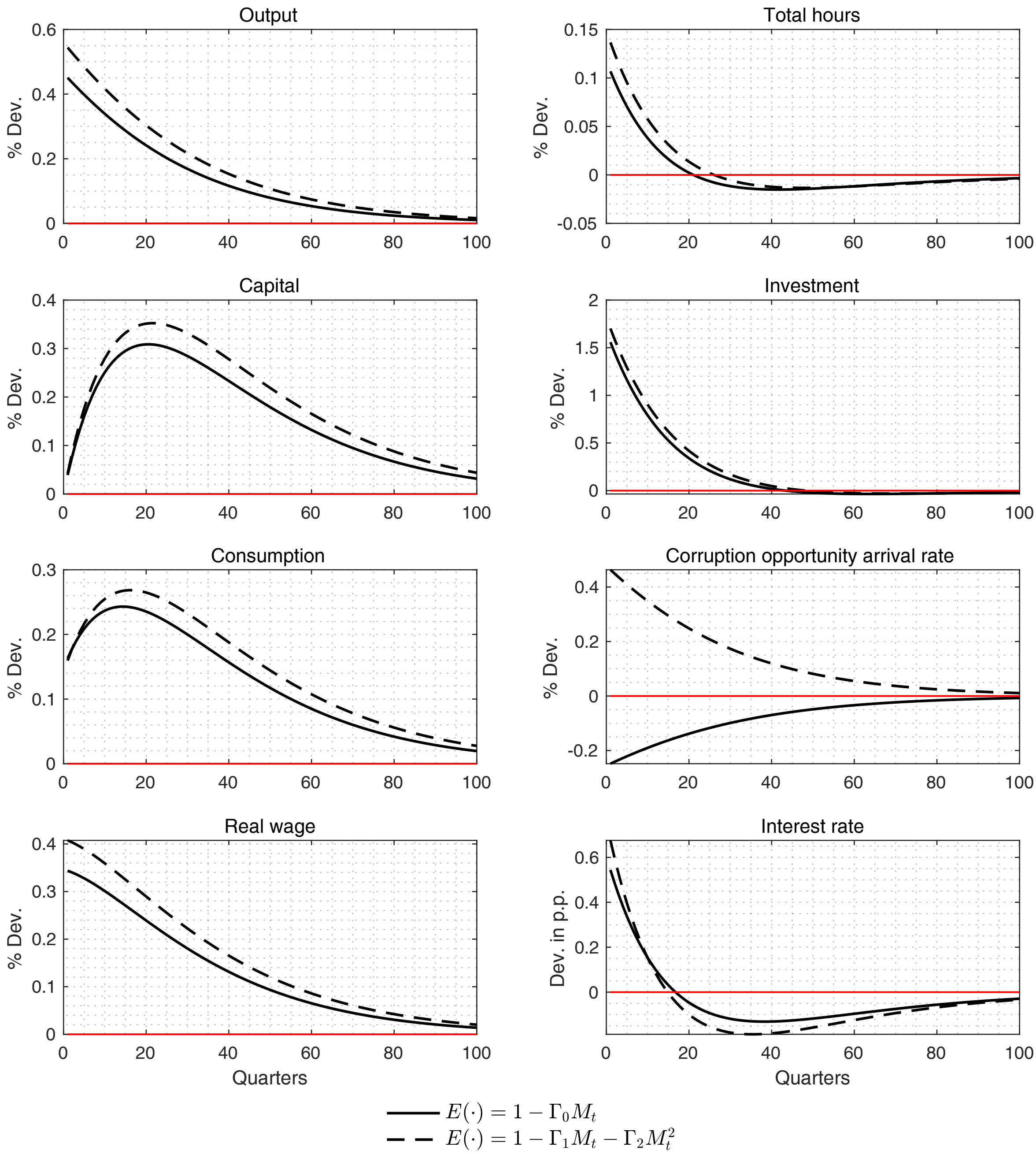
3.3.2 *Technology Shock*

The impulse response functions to a one standard deviation of a productivity shock are reported in Figure 3.1 for the two functional forms of the effect function. In general, a temporary technology shock affects positively all aggregate demand components and real wage, temporarily shifting their levels.

Initially, the strongest response is to the investment variable. Capital becomes more productive, encouraging capital accumulation. Therefore, the interest rate presents a positive deviation in percentage points due to the greater demand for capital. The demand for labor also increases, given that it is now more productive. The higher productivity is translated into higher real wages. Such effects imply a higher level of output in the short and medium term until the effect of the shock wears off. This is expressed in a higher level of household consumption.

What is interesting to note is the difference in the shock for both functional specifications of the effect function. On the one hand, with higher productivity, employees may have less incentive to engage in corrupt practices. If their salaries and benefits are improving due to

Figure 3.1 – Technology Shock



increased output, the perceived need for additional income through corrupt means diminishes. In other words, there may be a negative deviation from the steady state in the arrival rate of corrupt opportunities represented by the equation (3.2). This event occurs for the first functional form of the effect function, equation (3.16). When an economy is experiencing a positive productivity shock, there may be an increase in legitimate employment opportunities in the face of corrupt activities. As more legal occupations become available, individuals may be less inclined to engage in illegal or corrupt activities as they have better prospects in the legal job market.

On the other hand, increased productivity and economic growth may create more opportunities for individuals and groups to seek rents or extract economic benefits beyond what they would earn in a competitive market. This can lead to the creation of corrupt opportunities where individuals exploit their positions for personal gain, often through bribery, kickbacks, or other illegal means. To put it differently, we might observe an increase above the steady state level in the rate at which corrupt opportunities present themselves, as expressed in equation (3.2). This fact happens for the second functional form of the effect function, equation (3.17). During periods of economic expansion, there may be a focus on rapid growth and profit generation, which could lead to a reduced emphasis on regulatory oversight and compliance. Government agencies and regulatory bodies might be understaffed or less vigilant, making it easier for corrupt practices to go unnoticed or unpunished.

In general, equation (3.16) lives up to the sand the wheels hypothesis, while equation (3.17) refers to the grease the wheels hypothesis. As previously stated, critics argue that widespread corruption "sands the wheels" of economic progress by diverting resources away from productive uses, discouraging investment, and undermining trust in institutions. This can ultimately stifle economic growth. While, on the other hand, proponents of "effective corruption" argue that in certain contexts, corruption can "grease the wheels" of economic activity, making it easier for businesses to operate and invest. This is especially thought to be the case in countries with overly complex or burdensome regulations, such as Brazil.

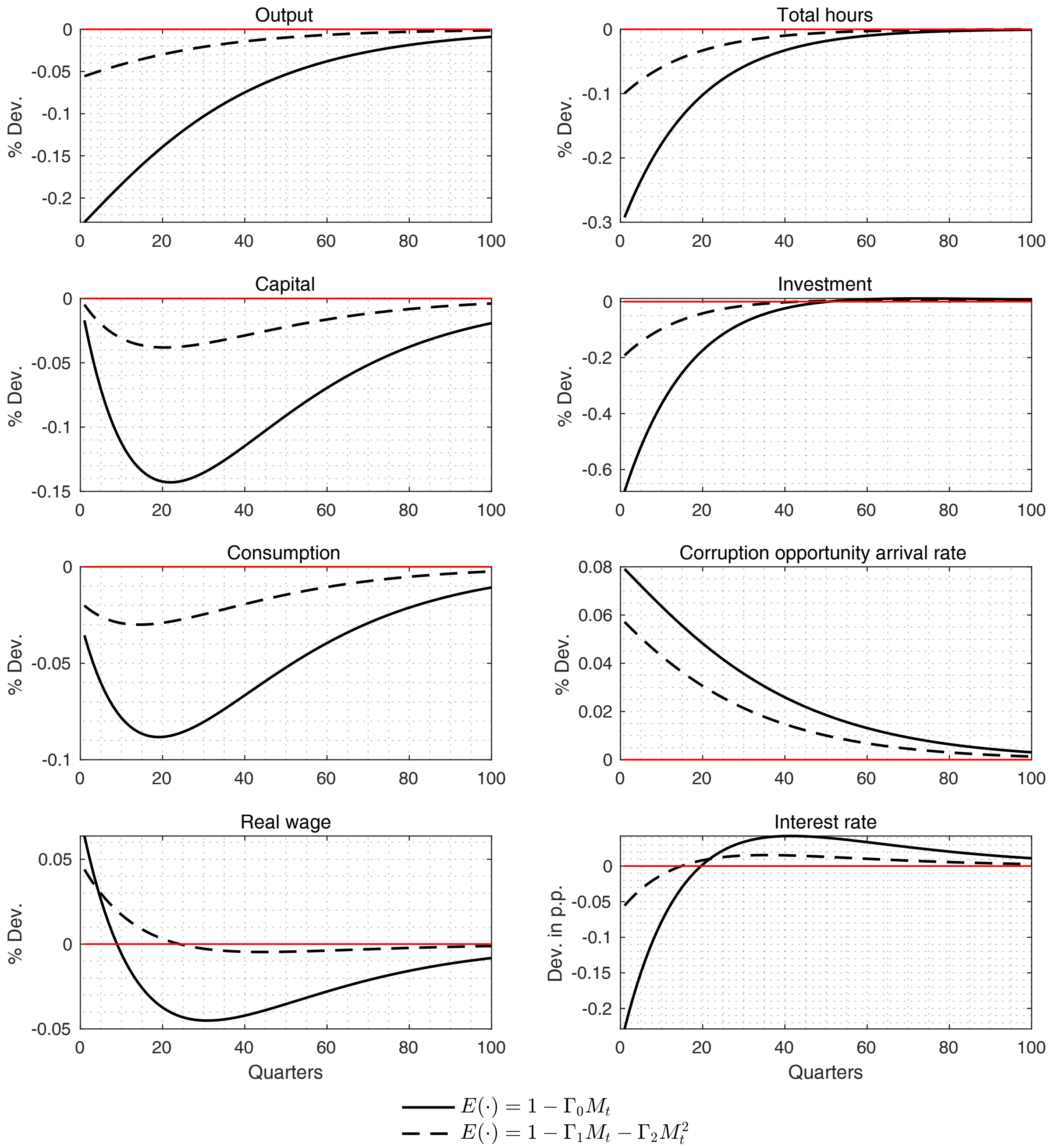
3.3.3 Corruption Shock

The impulse response functions for one standard deviation of a shock in new corruption opportunities are reported in Figure 3.2 also for the two functional forms of the effect function. In general, it is seen that a temporary shock in this variable negatively affects the components of aggregate demand.

In the same way as was seen for the technology shock for both functional forms of the effect function, differences can also be seen in the deviations of macroeconomic variables. The second functional form, equation (3.17), acts to mitigate the corruption shock for all variables, possibly because Γ_1 and Γ_2 have opposite signs. It is also interesting to note that the arrival rate of corrupt opportunities is also lower for such a functional form.

As productivity decreases due to the effect function, the need for capital ends up being lower, which implies a drop in investment and, consequently, in the capital stock. The

Figure 3.2 – Corruption Shock



inverted-U shape of the capital stock is more prominent for the first functional form, equation (3.16), and the variable takes longer to recover from the shock. Investment decreases by more than three times compared to equation (3.17), but it takes the same time to return to the steady state level. The same phenomenon occurs for aggregate consumption.

For hours worked, a corruption shock has a negative impact on this variable, causing it to fall below the steady state level until the shock disappears and, in the same way, we see that the impact is more than three times greater for the functional form represented by equation

(3.16). All these effects imply in a reduction in the output, causing the same phenomenon of greater intensity to occur again in the same context, about four times greater.

Regarding prices in the economy, wages initially show a positive deviation in relation to the steady state, given the lower supply of labor, but quickly fall below that level due to the reduction in productivity caused by the effect function. Regarding the interest rate, it appears that it behaves in an opposite way to the real wage: initially, there is a notable negative deviation in percentage points in relation to the steady state, due to the reduction in the level of investment. Subsequently, the variable returns to values slightly above the steady state, the effect disappearing over time.

The impact on wages combined with the lower return on capital together with a lower level of this variable, causes individuals' consumption to decrease, but also with greater intensity for the equation (3.16).

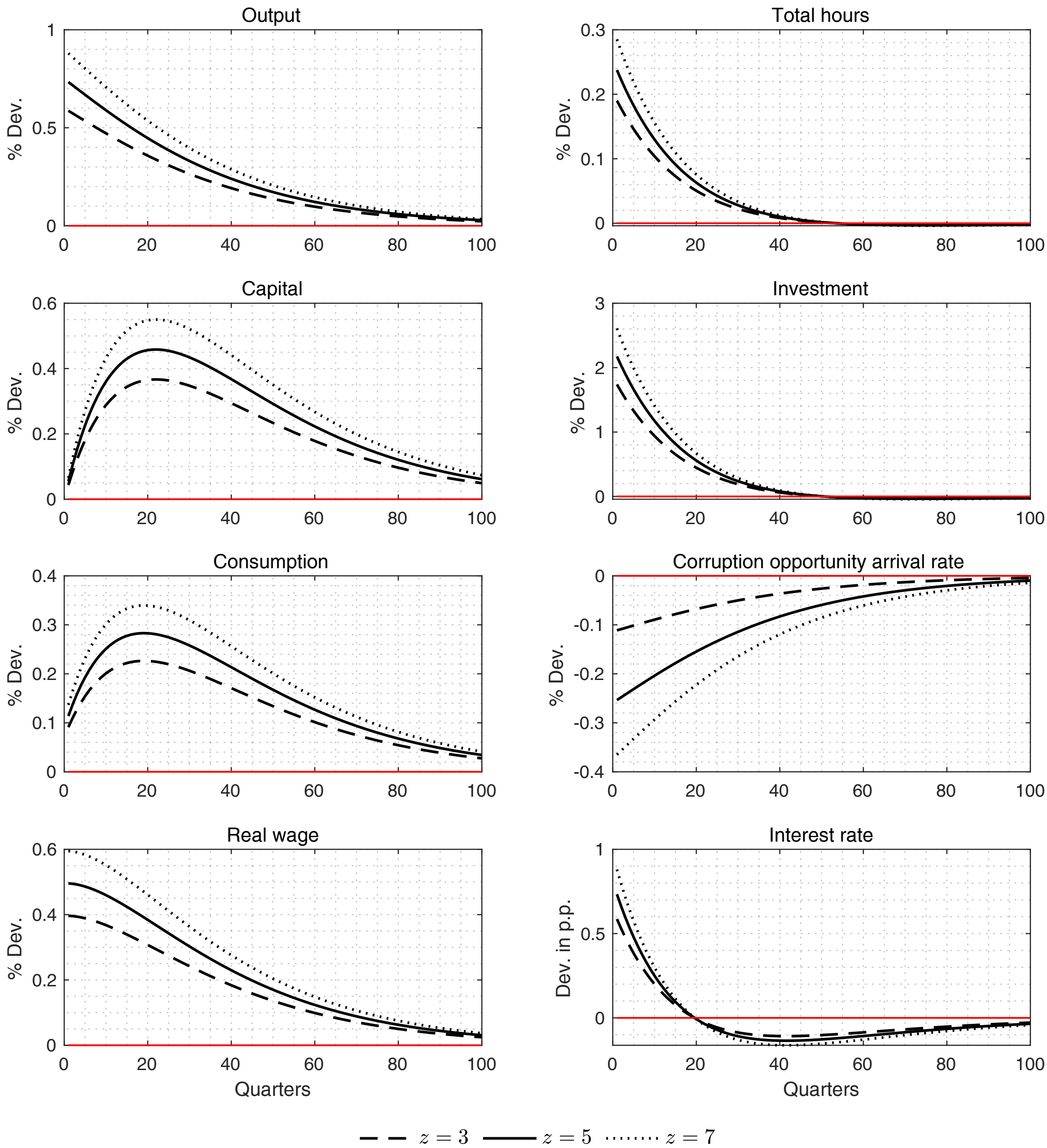
3.3.4 Changes in the number of peers

It is instructive to consider how the nuances of the economy change relative to the average number of corrupt peers bureaucrats have, when moving on to the analysis of the shock of technology and corrupt opportunities. Because of this, we analyze the impact on the economy if public agents have more $\langle z \rangle = 7$ or less $\langle z \rangle = 3$ peers compared to our benchmark $\langle z \rangle = 5$. This strategy if equivalent to André *et al.* (2023)'s baseline SIR (Susceptible-Infected-Recovered) macroeconomic model in the presence of a network environment.[8]

Figures 3.3 and 3.4 present the main model results, changing the number of peers an agent has on average, i.e., it illustrates the impact of heterogeneity in the number of connections on the progression of corruption. Compared to the benchmark case, ($\langle z \rangle = 5$), if agents have more peers on average (i.e., $\langle z \rangle = 7$), the impact of corruption initially spreads significantly faster through more connected individuals, however, due to the attenuation of the shock as the economy evolves such propagation decreases and its effect approaches zero. This reflects the fact that, as the grooming of corrupt individuals in the public sector progresses, fewer peers (but higher in comparison with the benchmark case) remain likely to become involved in such activities. On

[8] The authors study the behavior of the pandemic for different types of network, from a low connected one to a high connected one and show how a network structure can determine the evolution of an epidemic. They find the expected relationship: more connected economies (economies with a higher average number of links/peers) spread the virus faster, they face harder consequences in a pandemic scenario, such as a greater fall on aggregate consumption and hours worked due to both the higher number of deaths and the susceptible agents' higher attempt to stay at home and avoid physical contacts.

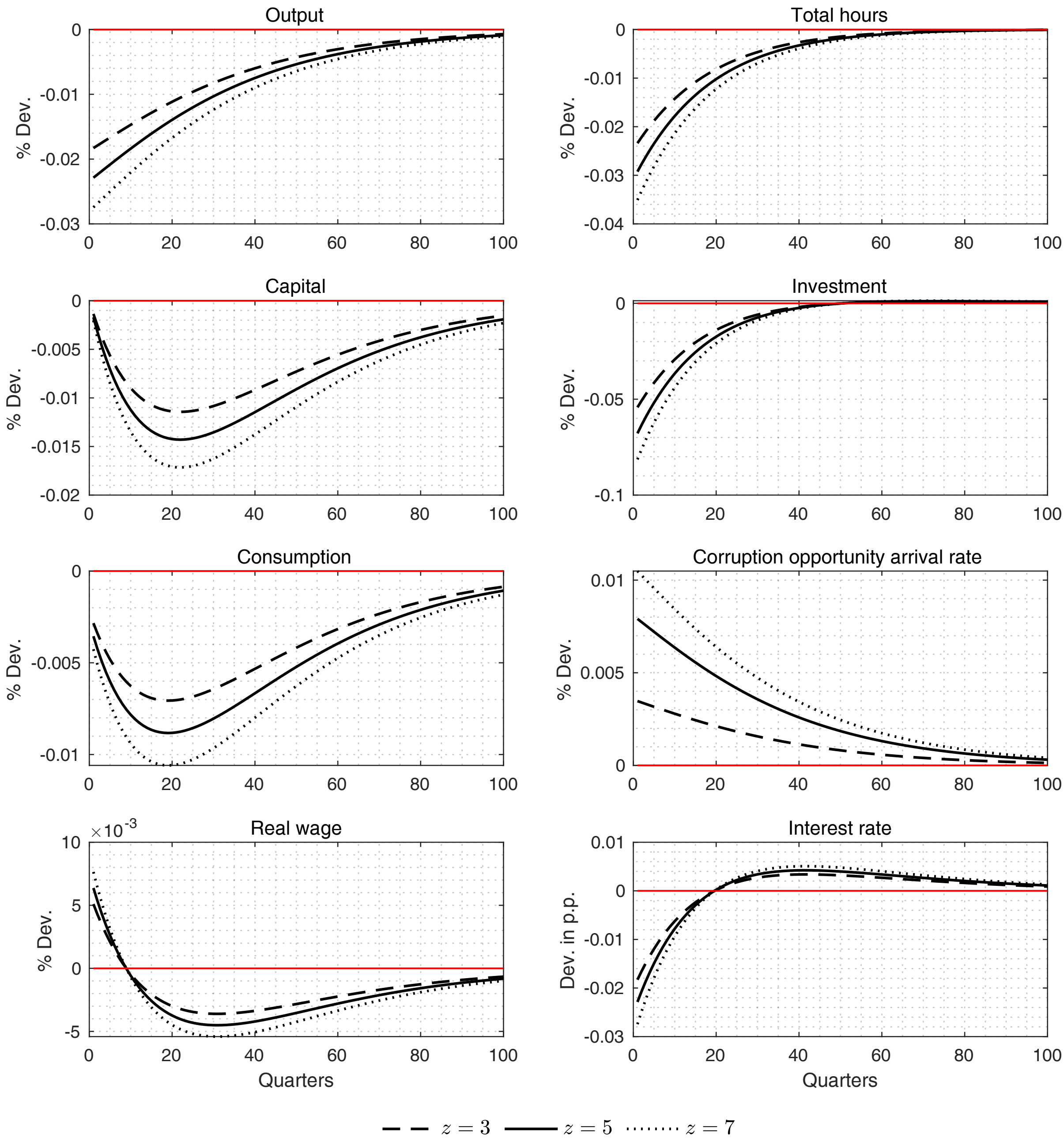
Figure 3.3 – Technology Shock for different number of peers on average



the other hand, with fewer links to facilitate the co-option of these individuals, e.g., $\langle z \rangle = 3$, the criminal behavior in question spreads more slowly and the number of corrupt public officials ends up being smaller, thus generating a slightly smaller impact on the economy. Overall, the technology and corrupt opportunities shocks propagate in a similar fashion it does in the three cases. It is important to mention that the effect function used was that of equation (3.16) and that the interpretation of the results using the other functional form does not change substantially.

The intuition is as follows. A shock in corrupt activities, Figure 3.4, immediately

Figure 3.4 – Corruption Shock for different number of peers on average



causes a sharp increase in the job arrival rate, thus reducing the total hours. However, due to the type of distortion in the output caused by the formation of corruption, the productivity of the economy drops, so that the need for capital ends up being lower, which implies a drop in investment and, consequently, in the capital stock. The inverted-U shape of the capital stock is more prominent for an economy where agents have more peers on average and it takes longer to recover from the shock. Investment is immediately, making more prominent negative jumps for the greater number of peers on average that agents have, remaining for some time below the steady state, since the productivity of the economy gradually returns to higher levels.

The effect on the economy's output is always negative, so that the variable remains below its steady-state value, while the shock wears off, so the accumulated responses of output end up being negative for each $\langle z_j \rangle$ for $j = 3, 5, 7$. It is interesting to observe that this phenomenon occurs in a more accentuated way for higher values of $\langle z \rangle$: the initial impact in the output is greater for economies where individuals are more connected. In other words, relative the the benchmark $\langle z \rangle = 5$, if individuals interact (on average) with more (less) contacts at work the drop in output is higher (lower). The same phenomenon occurs for aggregate consumption.

The consequences of corruption again result in an initial jump (fall) in wage levels (interest rates), subsequently remaining below (above) their steady-state value, with such effects being more prominent for more connected economies.

On the other hand, the interpretation for a technology shock, Figure 3.3, is understood in a similar way: the arrival rate of corrupt opportunities presents negative deviations in relation to the steady state in more connected economies, which means that the effect on output and other economies macroeconomic variables is amplified, a result that corroborates with Arbex *et al.* (2016).

Therefore different values of $\langle z \rangle$ highlight the effects of heterogeneity in the number of (average) contacts in work for the progression of corruption, as well as measures of macroeconomic aggregates. Our results suggest that, on the one hand, greater connectedness at work has a stronger recessive effect on corruption shocks, but, on the other hand, technology shocks are amplified in economies in which the average number of peers an individual has is higher.

3.4 Conclusion

We have shown that network search effort by the bureaucrats officials can amplify the response of economic aggregates to a shock on technology and corrupt vacancies. Social networks can facilitate the propagation of corruption. This is because networks can provide corrupt individuals with access to potential corrupt partners, as well as information about how to engage in corrupt behavior. The strength of social networks is positively correlated with the level of corruption. We demonstrate that varying values of $\langle z \rangle$ bring into focus how heterogeneity in the average number of peers affects the advancement of corruption, along with metrics related to macroeconomic aggregates.

Regarding the technological shock, there is a positive effect on all components of aggregate demand and real wages, temporarily changing their levels. However, the effect on the arrival rate of corrupt opportunities differs from the functional form of the effect function to be used: equation (3.16) lives up to the sand the wheels hypothesis, while equation (3.17) refers to the grease the wheels hypothesis.

In the same way as was seen for the technology shock for both functional forms of the effect function, differences can also be seen in the deviations of macroeconomic variables for a shock in corruption, but the equation (3.17), the second functional form, acts to mitigate the propagation of this shock to all variables.

The implications of these findings for policy are that policies that can weaken social networks at labor market, such as promoting competition in the labor market, can help to reduce corruption. Policies that can increase transparency and accountability in the labor market, such as making it easier for people to report corrupt behavior, can also help to reduce corruption.

The findings of this paper are consistent with the economic literature on corruption. For example, a study by Fisman e Svensson (2007) found that corruption is more likely to occur in countries with strong social networks in labor market. Similarly, Olken (2006) found that corruption is more likely to occur in countries where government officials are more likely to have personal connections with each other.

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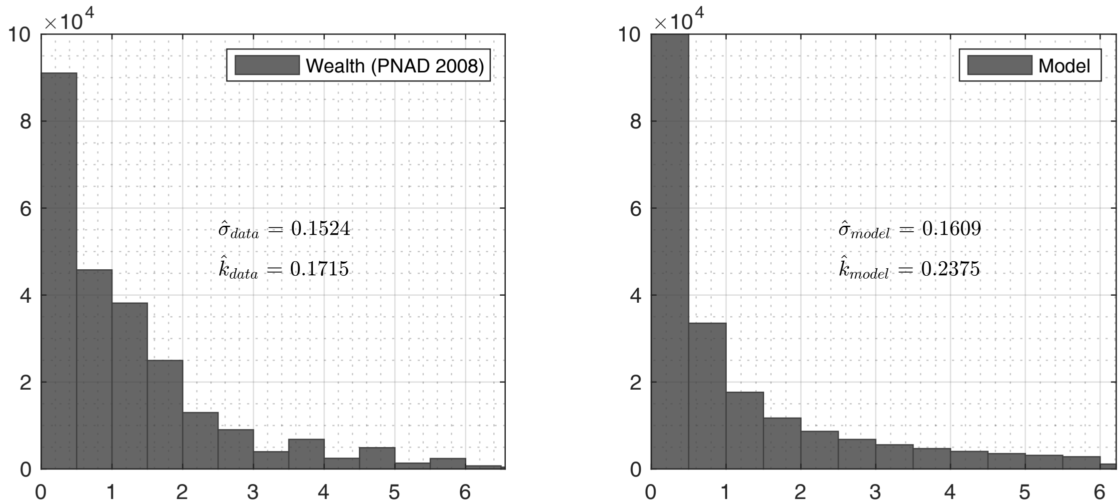
APPENDIX A – TOLERANCE OF INFORMALITY AND OCCUPATIONAL CHOICES IN A LARGE INFORMAL SECTOR ECONOMY

We estimate the parameters $\sigma_{data} = 0.1524$, $\kappa_{data} = 0.1715$ of a standard Pareto distribution via maximum likelihood methods for Brazil, using data from the *Brazilian Household Survey PNAD* (*Pesquisa Nacional por Amostra de Domicílios*), year 2008, which provide answers to a set of questions regarding an individual's assets and income. Our estimated parameters suggest an income distribution that is concentrated in the group of poor agents and it has a thicker tail. Figure A.1 shows that our model stationary wealth distribution is very similar to the Brazilian empirical wealth (*PNAD*) distribution.

Figure A.1 – Brazilian Income Distributions, Real and Simulated



Notes: Left panel - PNAD Income Distribution for the Brazilian Economy, 2008. Right panel - Simulated Economy.

APPENDIX B – THE ROLE OF CORRUPTION IN A SIMPLE GROWTH MODEL

Table A.1 – Groups of countries separated into quartiles of GDP per capita ordered by CPI

Countries	Income group	Averages of 1980-2011	
		CPI	$\ln(GDP_{pc})$
Denmark	High income	9.60	10.42
New Zealand	High income	9.41	10.20
Finland	High income	9.32	10.34
Iceland	High income	9.25	10.55
Singapore	High income	9.22	10.66
Sweden	High income	9.19	10.44
Canada	High income	9.05	10.52
Netherlands	High income	8.85	10.48
Norway	High income	8.77	10.62
Australia	High income	8.73	10.49
Switzerland	High income	8.66	10.77
United Kingdom	High income	8.61	10.32
Ireland	High income	8.33	10.38
Germany	High income	8.05	10.38
Israel	High income	7.68	10.27
United States	High income	7.62	10.72
Austria	High income	7.41	10.42
France	High income	6.80	10.33
Japan	High income	6.69	10.36
Belgium	High income	6.23	10.38
Slovenia	High income	5.37	10.14
Spain	High income	5.33	10.12
Czech Republic	High income	4.82	10.10
Greece	High income	4.77	10.04
Italy	High income	4.11	10.35
Chile	Upper middle income	7.03	9.40
Portugal	Upper middle income	6.31	9.92

Botswana	Upper middle income	6.04	9.21
Costa Rica	Upper middle income	5.91	9.23
Estonia	Upper middle income	5.40	9.65
Malaysia	Upper middle income	5.27	9.55
Poland	Upper middle income	5.16	9.44
Trinidad and Tobago	Upper middle income	5.14	9.79
Mauritius	Upper middle income	5.01	9.45
South Africa	Upper middle income	4.97	9.24
Hungary	Upper middle income	4.87	9.66
Lithuania	Upper middle income	4.33	9.56
Turkey	Upper middle income	4.27	9.46
Uruguay	Upper middle income	4.22	9.37
Argentina	Upper middle income	3.98	9.34
Panama	Upper middle income	3.95	9.23
Bulgaria	Upper middle income	3.48	9.26
Croatia	Upper middle income	3.39	9.61
Mexico	Upper middle income	3.34	9.55
Slovakia	Upper middle income	3.31	9.83
Latvia	Upper middle income	2.89	9.52
Romania	Upper middle income	2.85	9.15
Venezuela	Upper middle income	2.77	9.25
Kazakhstan	Upper middle income	2.58	9.31
Russia	Upper middle income	2.44	9.58
Namibia	Lower middle income	5.78	8.81
Tunisia	Lower middle income	5.11	8.97
Jordan	Lower middle income	4.74	8.59
Peru	Lower middle income	4.60	8.68
Morocco	Lower middle income	4.11	8.50
Jamaica	Lower middle income	3.99	8.68
Brazil	Lower middle income	3.83	9.11
Armenia	Lower middle income	3.75	8.51
Sri Lanka	Lower middle income	3.61	8.45

Dominican Republic	Lower middle income	3.61	8.96
Georgia	Lower middle income	3.42	8.58
Guatemala	Lower middle income	3.23	8.51
Philippines	Lower middle income	3.23	8.39
Egypt	Lower middle income	3.22	8.47
Albania	Lower middle income	3.20	8.49
Thailand	Lower middle income	2.95	8.99
Ecuador	Lower middle income	2.95	8.87
Colombia	Lower middle income	2.95	9.04
China	Lower middle income	2.76	8.45
Nicaragua	Lower middle income	2.75	8.29
Indonesia	Lower middle income	2.57	8.43
Ukraine	Lower middle income	2.56	8.90
Azerbaijan	Lower middle income	2.35	8.79
Uzbekistan	Lower middle income	1.87	8.52
Paraguay	Lower middle income	1.66	8.74
Mongolia	Low income	4.38	8.25
Kyrgyzstan	Low income	3.96	8.09
Zimbabwe	Low income	3.91	8.23
Malawi	Low income	3.79	7.04
Ghana	Low income	3.46	8.11
Senegal	Low income	3.44	7.90
Mozambique	Low income	3.39	6.77
El Salvador	Low income	3.39	7.82
Ethiopia	Low income	3.31	6.59
Zambia	Low income	3.30	7.54
Burkina Faso	Low income	3.16	7.17
Viet Nam	Low income	3.14	7.75
Bolivia	Low income	2.94	8.12
India	Low income	2.90	7.74
Kenya	Low income	2.67	7.69
Uganda	Low income	2.56	7.14

Republic of Moldova	Low income	2.54	8.17
Pakistan	Low income	2.46	8.01
U.R. of Tanzania: Mainland	Low income	2.42	7.26
Haiti	Low income	2.23	7.41
Madagascar	Low income	2.11	7.20
Honduras	Low income	1.99	8.14
Cameroon	Low income	1.82	7.93
Nigeria	Low income	1.66	7.75
Angola	Low income	1.49	8.23

Sources: Castellacci e Natera (2011) and Penn World Table (PWT) 10.01.

APPENDIX C – THE IMPLICATIONS OF CORRUPTION NETWORK FOR BUSINESS CYCLES

A network is described by a degree distribution $\{D_z\}_{z=1}^{\infty}$, where D_z is the proportion of bureaucrats who has $z \in [1,\infty)$ corrupt peers. We assume power-law distributions (i.e., agents with many links are more likely to have access to corruption opportunities) and apply the mean field approach (VEGA-REDONDO, 2007). The power-law network has distribution

$$D_z = (a-1)z^{-a}, \tag{C.1}$$

where the power-law exponent, a, determines how heavy the tail of the distribution is, i.e., how common are nodes with much higher than the mean number of peers.

The probability a given bureaucrat has s peers is

$$\psi_s = (sD_s)/\langle z \rangle, \tag{C.2}$$

where $\langle z \rangle = \int_{z=1}^{\infty} (zD_z)\, dz$ is the *average degree* in the network. Note that $\psi_s \neq D_s$, i.e., the probability one of your peers has s links is not equal to the proportion of the population that has s links. This is because agents with many peers and a large s are disproportionately likely to be your peers, so we must scale D_s by $s/\langle z \rangle$ (ARBEX *et al.*, 2016; ARBEX *et al.*, 2019). The measure of corrupt bureaucrats with s peers is η_s.

The rate at which information on corruption opportunities is passed from corrupt bureaucrats to their peers depends on how much effort, x, agents spend on socializing, i.e.,

$$\phi(x_t) = x^{1-\lambda}, \tag{C.3}$$

where λ is a parameter that measures the efficacy of this technology. Integrating over all possible values of s, the probability a bureaucrat is exposed to a corrupt opportunity from a corrupt peer is therefore

$$\Omega_t = \int_{s=1}^{\infty} \frac{\phi(x_t)}{s} \psi_s \eta_s = \frac{\phi(x_t)}{\langle z \rangle} \eta. \tag{C.4}$$

Hence, the probability an agent of type z receives at least one opportunity to engage in corrupt activities via a peer in his social network is

$$p_t = 1 - (1-\Omega_t)^z \tag{C.5}$$

And the aggregate probability that bureaucrats of different types z receive a corruption opportunity via corruption network is

$$P_t = \int_{z=1}^{\infty} p_t D_z dz \tag{C.6}$$