Informality, Innovation, and Aggregate Productivity Growth

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28 May 2014

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February 26, 2016

Abstract

This paper investigates how the ability to innovate affects firms' decisions to operate informally and the aggregate consequences of their sectoral choice. I embed a sectoral choice model, where firms choose to operate in the formal or informal economy, into a richer general equilibrium environment to analyze the aggregate effects of firm-level decisions in response to government taxation. I calibrate the model and conduct simulations to quantify the impacts on the aggregate economy. I find that a change in tax rates from 50% to 60% leads to a 20.9% reduction in the size of the formal sector. This change is accompanied by a 0.07 percentage point reduction in TFP growth per year. Given that countries like Mali, Mexico, and Sri Lanka impose total tax rates near 50%, these findings have significant and applicable policy implications across a broad range of lesser developed countries. Even at lower tax rates, for instance 10%, a 10% increase, decreases the size of the formal sector by more than 7.7%.

Keywords: Informality; Innovation; Productivity Growth; TFP

JEL Classification Numbers: O17, H32, O31, O41

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1 Introduction

The fundamental question in development economics is what makes some countries so much more prosperous than others. Hall and Jones' (1999) seminal work posits that it is not physical or human capital accumulation that primarily drives differences in income but rather differences in total factor productivity (TFP) resulting from country-specific policies. In more recent work Hsieh and Klenow (2009) show that much of this TFP difference arises from misallocated factors of production that results in a much greater dispersion of TFP relative to the United States. These misallocations can presumably be understood to be the result of policy distortions.

The goal of this paper is to understand how firm-level decisions regarding innovation and informality affect economy-wide outcomes, and how those decisions depend on a country's tax policies. Firm productivity depends, among other factors, on innovation at the level of the firm. Aggregate outcomes, however, are also shaped by government policies. This paper analyzes how firm-level innovation decisions are affected by government policies, and how those decisions affect aggregate productivity (TFP) growth.

I construct a general equilibrium model where firms choose whether to participate in the formal or informal manufacturing sector. In equilibrium, this decision depends on institutional constraints in the form of taxation and law enforcement. I calibrate the model and conduct numerical experiments to estimate the effect of tax distortions on the size of the informal sector and on aggregate productivity growth. I find that a change in tax rates from 50% to 60% leads to a 20.9% reduction in the size of the formal sector. This change is accompanied by a 0.07 percentage point reduction in TFP growth per year. Given that countries like Mali, Mexico, and Sri Lanka impose total corporate tax rates near 50%, these findings have significant policy implications in lesser developed countries. Even at lower tax rates, for instance 10%, a 10% increase, decreases the size of the formal sector by more than 7.7%.

The model operates with two central tensions. At the firm-level, firms that choose to operate in the formal sector have the ability to innovate and improve future productivity, but must comply with government imposed taxes. Alternatively, they can choose to avoid these taxes in the informal sector, although they also forgo the choice to innovate. On the macro-level, fewer formal sector firms decreases TFP growth as the number of innovators decreases. Informal firms are counted in aggregate TFP, but since they do not directly innovate, they do not contribute to its future growth.

The differences in the ability to innovate are motivated by Rosenzweig and Binswanger's (1993) finding that poorer farmers are less likely to undertake risky investments. In addition, data from the World Bank Enterprise Survey indicate that smaller firms, which tend to be informal in developing countries, are much less likely to license foreign technology or utilize even simple technologies like e-mail. Furthermore, differences in risk preferences and access to credit may also play important roles in explaining differences in innovation rates. The assumptions of the model do not preclude productivity growth among informal firms. It does however make the growth exogenous to their decision making.

This paper is related to a large literature in development economics and international trade. It can be viewed as a link between models of monopolistic competition with innovation that are commonplace in the international trade literature, with the literature on informal economies. The theoretical basis for firm-size heterogeneity and innovation is Atkeson and Burstien (2010). This foundation is augmented by the decision of firms to enter either the formal market where they face taxes or the informal sector where they face punitive fines and forced closure. This environment generates a rich set of predictions regarding what types of firms, in terms of productivity, enter each sector, and how the decision to be formal is affected by government tax policies.

The informal economy in the present context refers to informal product markets. In this case, entrepreneurs make a decision whether to abide by laws and regulations governing firms in the formal sector, or operate in the informal sector to bypass these laws. Informal labor markets, on the other hand, refer to workers themselves who operate informally and often receive lower wages, worse working conditions, etc. The choice to emphasize informal product markets is in a similar vein to Nataraj (2011) while Goldberg and Pavcnik (2003) provide a classic example of work that evaluates informal labor markets. To be sure, the two formulations of the informal sector are not independent as workers at informal firms constitute informal employment. This paper does not address the changes in informal employment at formal sector firms.

Moreover, there is considerable divergence in what constitutes an informal firm, both in the literature and in country-specific contexts. In the United States, informal firms are most often associated with the production of illegal goods like narcotics. In other countries, like India, informal firms are often firms that are not required to register given their size. Certainly different data sources utilize different definitions. Arabsheibani, Carneiro, and Henly (2006) show that in the Brazil, these different definitions can be significant. Throughout, I define informality as suggested by Kanbur (2009): informality should be defined with regard to a specific policy or regulation. In the current context then, firms that choose to opt out of the formal tax environment are considered informal. In terms of policy applications, informal firms in the model likely represent firms that are informal on other margins as well, for instance in terms of the labor they hire or the goods they produce. This discussion of whether informal firms are synonymous with illegality will have important implications for

Table 1: Average Size of Informal Sector as Percentage of GDP in 2005

Region	Mean	Max
East Asia and Pacific	17.5%	51.0%
Latin America and the Caribbean	34.7%	66.1%
Middle East and North Africa	27.3%	37.2%
South Asia	25.1%	43.7%
Sub-Saharan Africa	38.4%	61.8%

Measurements are weighted by the size of GDP. Source: Schneider, Buehn, and Montenegro (2010).

how to interpret "tax enforcement" in the model.

The informal economy accounts for a large share of economic activity in developing countries. This is evident from Table 1: in regions with a high concentration of developing countries, a large percentage of the aggregate economy is considered informal. Moreover, this pattern is persistent. Thomas (1992) shows that informal economic activity was prevalent in developing countries in Latin America, Africa, and Asia from 1950 to 1986. He reports that most Latin American countries had 25% to 40% of their workforce participating in the informal sector. The percentages are even higher for many African and Asian countries. In India today, about 80% of the manufacturing sector is composed of informal firms and accounts for 20% of value-added (Nataraj (2011)).[1]

Several related papers explain the development and prevalence of informal firms in developing countries. Early theoretical justifications emphasize the existence of a wage-rate differential between the formal and informal sector created by the existence of an enforceable minimum wage in the formal sector. The seminal work in this area

[1] The informal sector in India operates differently from the traditional notion of informal firms. Informality in India does not connote illegal activity, rather it simply means that the firm is not required by law to register given its size. Typically the cut-off is 10 employees for firms that use electricity and 20 employees for firms that do no use electricity.

is Rauch (1991). Rauch (1991) analyzes a model with heterogeneous agents (differing productivities) who make a sector choice as in Lucas (1978). A productivity threshold determines which sector entrepreneurs enter: more productive entrepreneurs enter the formal sector and less productive ones enter the informal sector. This results in a strict size-dualism between the sectors as the smallest formal firm is necessarily larger than the largest informal firm.

Most research on the informal sector endorses a particular view of how informal firms operate in the economy. This paper, and the way it models informal firms, spans several of these traditions. In particular, the work of De Soto (1989, 2000) generally supports the idea that informal firms represent wasted entrepreneurial activity. This element is at the heart of the current paper, in that it looks at how innovation, and through it TFP, is affected by changes in formal sector participation. Additionally, informal firms are modeled as direct competitors to formal sector firms. Holding entrepreneurial skill constant, informal firms enjoy a competitive advantage by opting out of having to pay taxes. This modeling choice is echoed by Levy (2008). For a broader discussion of views on the informal sector see La Porta and Shleifer (2014).

Contemporary empirical work has identified the importance of government policies in determining whether firms choose to be informal. Dabla-Norris, Gradstein, and Inchauste (2008) show that the quality of a country's legal framework is fundamental in determining the existence of informal firms. Intuitively, a better legal system is able to better enforce laws regarding taxes and regulation. Not surprisingly, they also find that higher tax rates and greater regulation in the formal sector increase informality. These findings echo those of earlier work by Loayza (1996). Given the empirical importance of these institutions, the model in this paper captures both the role of tax enforcement and taxation in firms' profit maximizing decisions although the analysis is simplified by focusing on the latter. While previous empirical findings are informative, they have not addressed the dynamic decision making of firms. Additionally, and similar to many studies on the informal sector, Dabla-Norris, Gradstein, and Inchauste (2008) is compelled to use data that may not truly be indicative of the decision making of firms.[2]

Despite the realization that informal firms constitute a significant part of most developing economies and have been studied extensively, there has been little research on the sectoral choice of firms in a dynamic environment. Outside of the literature on informality, there is a large and evolving literature documenting important aspects of firm dynamics. These works generally use Lucas (1978) or Melitz (2003) as a starting point for modeling heterogeneous agents and their decisions. The dynamics in these papers have become increasingly complex and have been used to study everything from economic growth as in Luttmer (2007) to inefficient allocation of resources as in Hseih and Klenow (2009).

The addition of innovation into firm-level dynamics is of principal importance to the question at hand. Atkeson and Burstein (2010) embed both process and product innovation into a model of monopolistic competition. Process innovation in their model allows firms to improve their productivity through time.[3] While the authors use their model to study the effects of changes in marginal trade costs, their approach can be generalized and is useful for understanding how firms improve their production processes through time. Importantly, without these dynamics we cannot understand the existence of overlapping productivity distributions in the formal and informal sector as documented in Nataraj (2011).

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[2]They are only able to capture the decision making of informal firms indirectly from formal firms based on a survey question which asks how much the typical firm keeps "off the books." Due to the difficult nature of collecting data on informality, these types of empirical issues are quite common.

[3]This process is similar to quality ladder models. For instance, see Grossman and Helpman (1991).

The remainder of this paper proceeds as follows. Section 2 articulates the theoretical model. Section 3 documents the parameters and their values utilized in the simulations. Section 4 investigates the results of the numerical experiments. Section 5 discusses the key findings and limitations of the model. Section 6 concludes.

2 The Model

The central item of interest in this paper is the decision of firms to participate in the formal or the informal sector, given the ability to innovate in the formal sector. At the firm-level, firms producing differentiated products make decisions about which sector to enter. Firms choosing to operate in the formal sector must pay taxes, but they can also improve their future productivity through innovation. Firms in the informal sector cannot innovate, although they completely avoid taxes. They do, however, face a probability of being caught, fined, and closed for operating in the informal sector.[4]

2.1 The Aggregate Economy

The aggregate economy is a standard model of monopolistic competition in a closed-economy with discrete time.[5] Aggregate output is produced as a CES aggregate of M intermediate inputs:

$$Y_t = \left(\sum_{i=1}^{M} y_{it}^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}, \tag{1}$$

[4] This "tax enforcement" mechanism is discussed later in light of different definitions of informality and illegality.

[5] The structure of the model is similar to a closed-economy version of Atkeson and Burstein (2010) where all prices are in terms of the final good.

where y_{it} is the output of intermediate good producer, i, and $\rho > 1$ is the elasticity of substitution between goods. Final good producers choose Y_t and inputs, y_{it}, to maximize profits in a competitive market given input prices, p_{it}, and the price of the final good, P_t. The price of the final good is normalized to 1. Standard profit maximization dictates that in equilibrium, the demand curve for ith intermediate good is

$$p_{it} = \left(\frac{y_{it}}{Y_t}\right)^{-\frac{1}{\rho}}, \ \forall i \in \{1, ..., M\}. \tag{2}$$

2.2 Intermediate Good Producers

Each intermediate good producer supplies a unique input into the production of the final good. These transactions occur in monopolistically competitive markets. Firms seek to maximize their discounted profits by making decisions about which sector, formal or informal, to enter, how much labor to hire, how much to invest in innovation, and what price to charge. These decisions are made subject to (1) and (2) taking the level of aggregate output as given, as well as their initial productivity draw z_{i0}. Throughout, production decisions and innovation decisions are designated as $t \geq 1$ decisions that are based on the firm's sector choice in the first period.

Firms have access to constant returns to scale technology such that

$$y_{it} = e^{z_{it}/(\rho-1)} l_{it}, \tag{3}$$

where z_{it} is a firm specific productivity parameter and l_{it} is the firm's labor force.[6] Productivity in (3) is scaled by $\frac{1}{(\rho-1)}$ for expositional ease, since it allows for firms' static (within-period) profits and labor hiring decision to be proportional to e^z as in

[6] Unless they are explicitly required, I drop the subscripts for firm and time on the productivity parameter z_{it}, such that $z_{it} = z$.

Atkeson and Burstien (2010). Note that throughout this paper, firm productivity or firm TFP will refer to e^z rather than the productivity *parameter* z. This distinction will be important in maintaining consistency between firm level measures of TFP and aggregate measures of TFP.

2.3 Technology and Innovation

Firms producing in the formal sector can decide to innovate and improve their future productivity through process innovation.[7] Firms choose an amount to invest in innovation. The likelihood of an innovation being successful is increasing in the level of investment by the firm. This probability of success, denoted q, provides a conveniently bounded choice for the firm's dynamic programming problem. Atkeson and Burstien (2010) use a similar set-up to model firms' innovation decisions.[8] The costs for innovation are denoted $c(q)$, where $c(q)$ is an increasing and convex function of q.

A firm that invests $e^z c(q)$ has a probability of q of having productivity $e^{z+\Delta z}$ and probability $1 - q$ of having productivity $e^{z-\Delta z}$ in the following period. The costs of innovation are scaled by e^z to reflect the fact that innovation at higher levels of productivity is more expensive. Further, it is worth noting that productivity can only change by the fixed amount Δz. In this sense, the model operates much the same as a quality ladder with rungs at discrete intervals. This assumption is computationally helpful since the value of the state variable for each firm is always on the chosen grid, and there is no need to interpolate between grid points.

Firms must engage in research and development in order to maintain their pro-

[7] The firm's investment in innovation is best thought of as innovation in *process innovation*, rather than *product innovation*, or the introduction of new varieties of goods. This distinction is important in justifying entry and exit in the model (discussed below).

[8] Judd (1998) also provides a short discussion for this type of dynamic programming problem.

ductivity. Choosing not to engage in research, by choosing $q = 0$, necessarily leads to a firm's productivity decreasing in the next period. This process reflects a depreciation of productivity over time. For instance, this could capture a loss of market power due to a firm not adequately improving its supply chain. On an individual firm level, productivity necessarily changes each period to reflect the stochastic nature of innovation and productivity.

2.4 Government

Government in the model has two roles: collect tax revenue, T_t, and fine and close informal firms. Firms are taxed τ percent of their profits each period in the formal sector. Firms that decide to operate in the informal sector face a probability, μ, of getting caught each period. If a firm is caught in the informal sector, it is fined its entire profits for the period and is forced to exit. The tax rate and probability of being caught in the informal sector are exogenous and known by all firms. This "tax enforcement" mechanism can be interpreted more broadly to incorporate country specific differences where informality may not be synonymous with illegality. The parameter μ enters an informal firm's profit maximization problem just like the probability of firm exit, δ. In this sense, it can capture the fact that small and informal firms tend to have a much higher exit rates than larger firms. Likely, part of this differential is driven by access to legal systems which can efficiently adjudicate disputes. Better legal systems, i.e. higher μ, would likely increase the differences in exit rates between small and large firms and would therefore have the same effect as greater "tax enforcement."

Tax revenue is transferred back to households as a lump-sum payment.[9] This

[9] Adding uncertainty to these parameters and specifically modeling the government's objectives as a revenue-maximizing agent are left as an avenue for future work. Other work, specifically

formulation of the government, and the behavior of informal firms avoiding taxes, is consistent with the findings in Dabla-Norris et al. (2008). Specifically, the authors show that higher taxes and corruption increase the propensity of firms to operate informally, even when both variables are included in the same specification.

2.5 Entry and Exit

Each firm, i, is endowed with a firm specific level of productivity z_{i0}. Given this level of productivity, the firm decides whether to operate formally, carrying z_{i0} into the first period and producing with productivity $z_{i1} = z_{i0}$, or operating informally and receiving a spillover of technology from the formal sector as described below. Once firms decide which sector to operate in, they operate in that sector indefinitely. This implies that formal sector firms will continue to see their productivity levels change in response to their decisions, while informal sector firms will receive an exogenous (to them) spillover from the formal sector each period.

Since my primary interest is in the firm's sectoral choice and the effect of innovation, I simplify the entry and exit of new firms. Firms face an exogenous probability of death, δ, each period which discounts expected profits. I begin with a large number of firms that are drawn from an initial distribution and make decisions about which sector to enter. Previous work has shown that the lowest productivity firms exit the market due to a fixed cost of entry (for instance Melitz (2003)) which pins down the size distribution of firms. Given that this fact is well documented, I assume that the initial draw of firms is done after the decision to operate. Firms that exit are replaced by identical firms, such that the mass of firms does not actually change

Auriol and Warlters (2004) models the government as a revenue-maximizing agent. If firms have uncertainty regarding the probability of being caught in the informal sector, the government could maximize tax revenue by enforcing laws in the informal sector to an extent that exceeds firms' expectations.

from period to period.[10] These assumptions on entry and exit isolate the channels for aggregate changes. Allowing *product innovation* in addition to *process innovation*, through the entry of an increasing number of firms, creates a different channel for TFP growth besides the choice of sector and obfuscates the role that sectoral choice and innovation play.

2.6 Consumers

Households have preferences of the form $\sum_{t=0}^{\infty} \beta^t u(C_t)$, where C_t is consumption of the final good and $\beta \in (0,1)$ is the subjective discount rate. Households earn income from supplying their labor inelastically to intermediate good firms. The aggregate labor supply is denoted L and is fixed through time.[11] Households share ownership of all intermediate good producers. In addition to labor income, households receive income through lump-sum transfers, T_t, from the government and dividend streams, D_t, from the profits of intermediate goods producers. I assume that the final good is perishable and consumers have no ability to transfer wealth across time periods. They maximize their utility subject to the budget constraint $P_t C_t \leq w_t L + T_t + D_t$. Under the assumptions of the model

$$C_t = w_t L + T_t + D_t, \tag{4}$$

for all $t \geq 1$. The assumption of a perishable final good allows me to abstract away from the complications of saving.[12]

[10] This can be thought of as a perfect markets assumption. When firms' die, their assets and processes are acquired by a new owner, rather than being discarded.

[11] Labor growth could easily be implemented; however, fixing the labor supply isolates the source of growth in the economy to changes in TFP.

[12] Given the wide variety of savings methods and interest rates for informal and formal borrowers, it is best to leave the effects of different savings channels for future work.

2.7 Firm's problem

Each firm faces the decision problem of which sector to enter, how much labor to hire, and how much to invest in innovation. In doing so, they take aggregate output, Y_t, as given and take into account the demand curve for their products from (2). Firms in both sectors are risk neutral. Firms that enter the formal sector (F) earn operating profits of

$$\Pi_t^F(z) = \max_{p_{it},l_{it}}(1-\tau)\left(p_{it}y_{it} - w_t l_{it}\right). \tag{5}$$

Firms that decide to enter the informal sector (I) earn operating profits of

$$\Pi_t^I(\bar{z}_t) = \max_{p_{it},l_{it}}\left(p_{it}y_{it} - w_t l_{it}\right). \tag{6}$$

Since taxes are levied on total profits, the amount that formal firms invest also plays a crucial role in determining their total tax burden, as can be seen below in formal firms' value function.

While (5) and (6) appear similar, there is a fundamental difference with respect to the productivity level of informal firms. Informal firms are not able to innovate, and they instead receive a spillover of productivity, $\bar{z}$, from the formal sector. This parameter is meant to capture imitation by firms in the informal sector. Even though informal sector firms may not innovate in the sense of *creating* new technology, they still increase their production processes by observing and adopting technologies seen in the formal sector. For instance, informal firms may adopt the use of e-mail upon seeing how formal sector firms integrate it into their production processes. The productivity spillover is determined by the entry of firms into either sector. It follows that firms must forecast the value of $\{\bar{z}_t\}_{t=1}^{\infty}$ before making their sector choice. The size of this spillover is time dependent, as the productivity level of firms in the formal sector fluctuates over time. A complete discussion of the size of this spillover is reserved for Section 3.

Additionally, firms in the informal sector face the prospect of being fined and closed for operating informally and avoiding taxes.[13] Given the static level of profits in (5) and (6), and subject to (2) and (3), firms set their price as a constant mark-up over marginal cost:

$$p_{it} = \frac{\rho}{\rho - 1}\left(\frac{w_t}{e^{z_{it}/(\rho-1)}}\right). \tag{7}$$

Given the evolution of firm productivity as described above, the discounted present value of expected profits for all firms with an initial productivity draw z_0 satisfies a Bellman equation:[14]

$$V(z_0) = \max[V^I(\bar{z}_1), V^F(z_0)] \tag{8}$$

$$V^I(\bar{z}_1) = \max \sum_{t=1}^{\infty} \left(\beta(1-\mu)(1-\delta)\right)^t \Pi_t^I(\bar{z}_t) \tag{9}$$

$$\begin{aligned} V^F(z_0) = \max_{q\in[0,1]} \big\{ & \Pi_1^F(z_0) - (1-\tau)e^{z_0}c(q) \\ & + \beta(1-\delta)\left(qV^F(z_0+\Delta z) + (1-q)V^F(z_0-\Delta z)\right) \big\}. \end{aligned} \tag{10}$$

Equation (9) is the value function associated with entering the informal sector, where the firm would operate with a productivity of $\bar{z}_1$, after opting to forgo producing using its endowed productivity level of z_{i0}. Equation (10) on the other hand, indicates that a firm that decides to enter the formal sector for the first period will operate with its endowed productivity given at $t = 0$. While the Bellman system can be generalized

[13]Note that $1 - \mu$ in the informal firms' value function acts as an additional discount factor as previously discussed.

[14]Typically, the firm's value could also be zero if it decided not to operate. Since entry and exit are exogenous in the model, that option is excluded.

in terms of time t, it is explicitly written in terms of firms' entry decisions at $t = 0$. This is to emphasize that I am looking at an irreversible entry decision by firms into either the formal or informal sector.

The value function in the formal sector $V^F(z_0)$ is strictly decreasing in the tax rate. Similarly, the value function for firms operating in the informal sector is strictly decreasing in the probability of getting caught, μ, for a fixed level of the productivity spillover $\bar{z}_t$.[15] In order for firms to operate in the formal sector, they must have an initial productivity draw, z_0, such that

$$V^F(z_0) > V^I(\bar{z}_1). \tag{11}$$

Let $\hat{z}_1$ be the least productive firm, based on its z_{i0} productivity and the size of the spillover, $\bar{z}_1$, that enters the formal sector for $t = 1$.

Firms in both sectors share a profit maximizing rule for hiring labor. Using (5) and (6) firms in both sectors demand for labor is

$$l_{it}^F = w_t^{-\rho} \left(\frac{\rho - 1}{\rho} \right)^\rho Y_t e^{z_{it}}, \tag{12}$$

and

$$l_{it}^I = w_t^{-\rho} \left(\frac{\rho - 1}{\rho} \right)^\rho Y_t e^{\bar{z}_t}, \tag{13}$$

respectively. Finally, Equation (10) implies that the first-order condition governing

[15]As μ increases, firms will be driven from the informal sector into the formal sector. A marginal change in the tax rate will incentivize the most productive informal sector firm to switch; however, the most productive informal firm would be the least productive formal sector firm. This sectoral switch will lower the average productivity in the formal sector, in turn decreasing the productivity spillover to the informal sector.

formal firms' investment decisions is

$$c'(q) = \left(\frac{\beta(1-\delta)}{1-\tau} \right) \left(V^F(z_0 + \Delta z) - V^F(z_0 - \Delta z) \right). \tag{14}$$

2.8 Equilibrium

The economy operates with a fixed labor supply, L. Labor market clearing requires that

$$L = \sum_{i=1}^{M} l_{it}. \tag{15}$$

Substituting (12) and (13) for the appropriate mass of firms given $\hat{z}_t$, and simplifying, yields the equilibrium wage rate for the economy:

$$w_t = \left(\frac{L}{Y_t Z_t} \right)^{-\frac{1}{\rho}} \left(\frac{\rho - 1}{\rho} \right), \tag{16}$$

where $Z_t = \sum_i e^{z_{it}}$ is a measure of aggregate TFP that includes both formal and informal firms.[16] The equilibrium wage rate can be used to simplify the first-order condition for firm's labor decisions. Substituting (16) into (12) and (13) implies that

$$l_{it}^F = \left(\frac{e^{z_{it}}}{Z_t} \right) L, \tag{17}$$

and

$$l_{it}^I = \left(\frac{e^{\bar{z}_t}}{Z_t} \right) L. \tag{18}$$

[16]Note that the wage rate differential that generated previous results, like Rauch (1991), is no longer present. This implies that the formal/informal dichotomy is generated instead using restrictions on innovative activity between the two sectors. This serves to illustrate that the decision to be informal may be more complicated than an optimization with respect to a binding minimum wage.

The simple intuition of this condition is that firms that constitute a larger fraction of aggregate TFP, hire more labor.[17] Finally, in equilibrium, aggregate output is

$$Y_t = Z_t^{\frac{1}{\rho-1}} L. \tag{19}$$

Given that L is constant, the expected growth rate of output is

$$g_Y = \frac{Z_{t+1}^{\frac{1}{\rho-1}} - Z_t^{\frac{1}{\rho-1}}}{Z_t^{\frac{1}{\rho-1}}}. \tag{20}$$

A complete derivation of the growth rate of aggregate output is included in Appendix A.

Definition An equilibrium in this economy consists of a collection of aggregate quantities $\{C_t, Y_t, Z_t, T_t, D_t\}$, aggregate prices $\{w_t, P_t\}$, firm decisions $\{l_{it}, q_{it}, p_{it}, y_{it}\}$, productivity levels $\{z_t, \hat{z}_t, \bar{z}_t\}$, and an initial distribution of productivity $\{z_0\}$ such that all firms maximize the discounted present value of their expected profits, the aggregate labor constraint is met, and households maximize their utility subject to their budget constraints.

3 Quantitative Application

This section outlines the parameters and variables utilized in the numerical simulations. The main question that I ask is how does taxation affect the sectoral choice of firms, and how do these choices influence aggregate outcomes? To do this, I vary tax rates in three different innovation environments: a low cost economy, a moderate

[17] This condition results from the fact that initial labor demands were proportional to productivity e^z and were scaled by $\frac{1}{(\rho-1)}$ in firms' production functions.

Table 2: Innovation Cost Calibrations

Innovation Costs	b	Target	Avg. q	Actual Growth Rate
Low	3	All firms innovate	1.00	0.67%
Moderate	5.5	No growth	0.50	0.00%
High	50	No firms innovate	0.00	-0.65%

cost economy, and a high cost economy. The functional form for innovation costs is He^{bq} as in Atkeson and Burstien (2010). I set $H = .001$ to pin down the level of costs and then calibrate the parameter b, to generate positive growth, zero growth, and negative growth environments.[18] The innovation costs are calibrated using a baseline 20% tax rate. The lowest cost innovation environment is calibrated such that all firms in the formal sector choose to innovate. I use the highest cost that achieves this criteria. Further decreases in the costs of innovation marginally increase growth but only through more firms switching to the formal sector. Likewise, in the high cost environment, I find the lowest cost in which no firm decides to innovate. Further increases in cost decrease growth, but only on the margin of sector choice. Table 2 outlines the cost structures and growth rates used in the simulations.

Table 3 serves as a reference to the variables in the model, and Table 4 reports specific parameter values use in the simulations. All of the simulations report results for the first period in which firms operate, after making their sector choice. The elasticity of substitution, ρ, is set to 5 as in Atkeson and Burstien (2010). While this value is fairly standard, Hseih and Klenow (2009) discuss how even greater values than $\rho = 5$ may be appropriate.[19] Section 4.4 investigates the robustness of the results to alternative values of ρ.

[18] Because the only source of growth in the model is increases in TFP, the maximum growth rate is determined by the parameter Δz.

[19] Although, ironically, they use $\rho = 3$.

Table 3: Variables of the Model

Variable	Definition	Variable	Definition
ρ	Elasticity of substitution	$c(q)$	Cost function for innovation
δ	Probability of exit	q_{it}	Probability of successful innovation
τ	Tax rate on profits	$\bar{z}_t$	Spillover to informal sector
M	Number of firms	Γ	Distribution of z_0
w_t	Wage rate	β	Discount rate of firms
$\hat{z}_t$	Formal cut-off	Δz	Step-size of innovation
L	Labor Supply	μ	Probability of detection

Table 4: Parameter Values

Variable	Value	Source
ρ	5	Atkeson and Burstein (2010)
Δz	0.027	Brandt et al. (2012)
τ	Varies	World Development Index 2012
δ	0.10	Standard
β	0.96	Standard
M	10000	Scale parameter
L	100000	Scale parameter
Γ	Uniform distribution	See note below
q_{it}		Endogenously determined
w_t		Endogenously determined

The model is calibrated so that each time period corresponds to a year. Firms anticipate a 10% chance of exit each year. I calibrate the step-size of innovation, Δz, to correspond to 2.7% growth in TFP for the mean firm in the initial draw. This estimate comes from Brandt et al. (2012) who estimate the average TFP growth of manufacturing firms in China to be 2.7%. The implied discount rate, β, the exogenous death rate, δ, and the step-size of innovation meet the parameter restrictions to bound the net present value of firms. Specifically, $\beta(1-\delta)e^{\Delta z} < 1$. If these parameter restrictions are not met, firms would be able to innovate faster than future variable profits are discounted.

The productivity spillover is calibrated using Nataraj (2011).[20] It reports mean TFP for both the formal and informal sectors. Using these means and an estimate of the variance, I generate a normal distribution to fit the distribution of log TFP that she reports. I then calibrate the spillover such that the σ percentile of the formal sector generates the mean TFP for the informal sector. I estimate that $\sigma = 48.8$, that is, the 48.8th percentile of the formal sector matches the mean in the informal sector. The value of $\bar{z}_t$ in the model is calculated as the TFP of the 48.8th percentile of firms operating in the formal sector in time period t.

The initial distribution for z is drawn from a uniform distribution centered on $z = 0$. As noted in the introduction, this does not translate into productivity being uniformly distributed. Observed productivity in the model is $e^{z/(\rho-1)}$, so that the distribution of productivity is exponentially distributed.[21] Importantly, this distribution shares many of the same characteristics of the Pareto distribution, mainly the concentration of firms at the lower tail. Further discussion of the initial distribution of firms is left for Section 5.

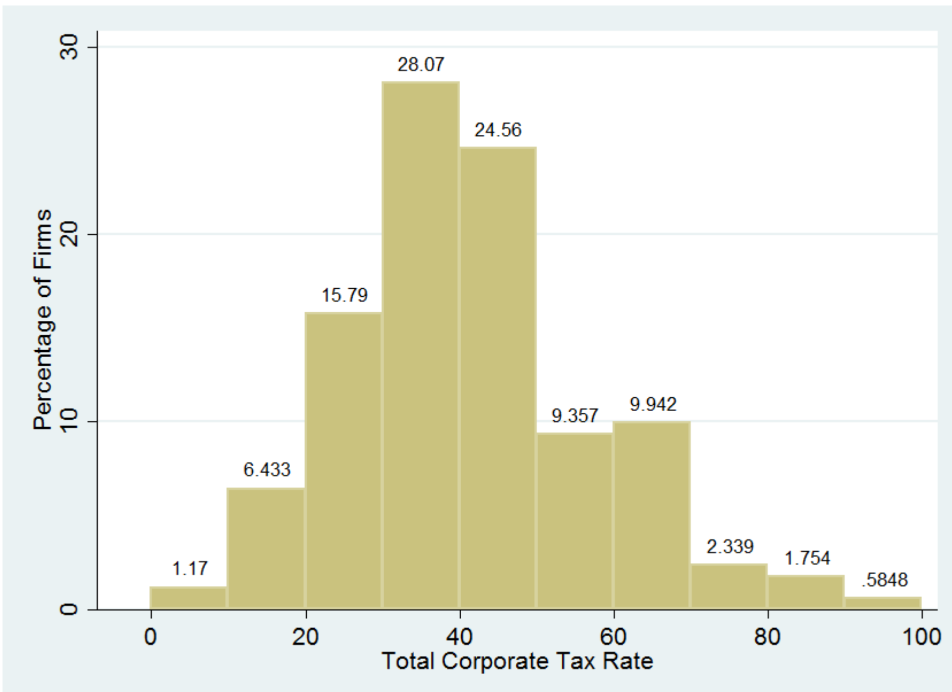
The range of taxes on profits is informed by data from the World Bank's World Development Indicators for 2012. Specifically, it reports the "Total Tax Rate," which is the total tax rate that firms pay as a percentage of their profits. It includes taxes on profits, labor taxes, and other taxes like property and municipal taxes. For a vast majority of countries, these taxes range from 10% to 70% of profits. Figure 1

[20]Her data is for pre-reform India in 1989, but it is the only data set I am aware of containing TFP estimates for both formal and informal firms. Hsieh and Klenow (2010) report the distribution of plant size for both informal and formal firms in India, but do not provide firm-level productivity figures.

[21]This assumption is no different that assuming an exponential distribution for the initial productivity draw and allowing firm productivity to be simply z_{it}.

illustrates the range of tax rates and growth rates for a randomly selected subset of countries included in the data. There are, however, several outliers that have tax rates beyond 100%. These outliers seem to be driven by high "Other Tax Rates," likely reflecting political shocks that are beyond the scope of the current project (like one-time taxes on property).

Figure 1: Total Tax Rates (% of Firm Profits)



Source: World Development Indicators 2012. The histogram includes 171 countries that have available data on total tax rates as a percentage of firm profits. Countries with total tax rates above 100% are excluded.

In addition, the tax rate in the model should be understood to include corruption. It is not quite clear whether this inclusion should raise or lower the actual tax rate faced by formal sector firms. The 2005 World Bank Development report indicates that informal firms paid approximately 2 times more (as a shares of sales) in bribes than formal sector firms. On the other hand, the incidence of paying bribes in the informal sector was only about 50% of that in the formal sector. Given these ambiguous factors, as well as the broad range of bribes and corruption documented in Olken and Pande (2012), I take a conservative approach and suggest that the presence of corruption may add from -5% to 5% (relative to the informal sector) to the range of taxes in the formal sector. In totality, I look at tax rates (τ) from 5% to 75% in the formal sector.

Finally, q is endogenously determined since firms choose the likelihood with which their research and development is successful. However, in Atkeson and Burstein (2010) the value of q is calibrated for large firms in order to keep the dynamics of those firms constant through time. In the current model, *all* firms make decisions regarding how much to innovate. In both the high cost and low cost environments, there is little to no heterogeneity in firms' choice of q, but there is considerable heterogeneity in the costs associated with innovation.

4 Results

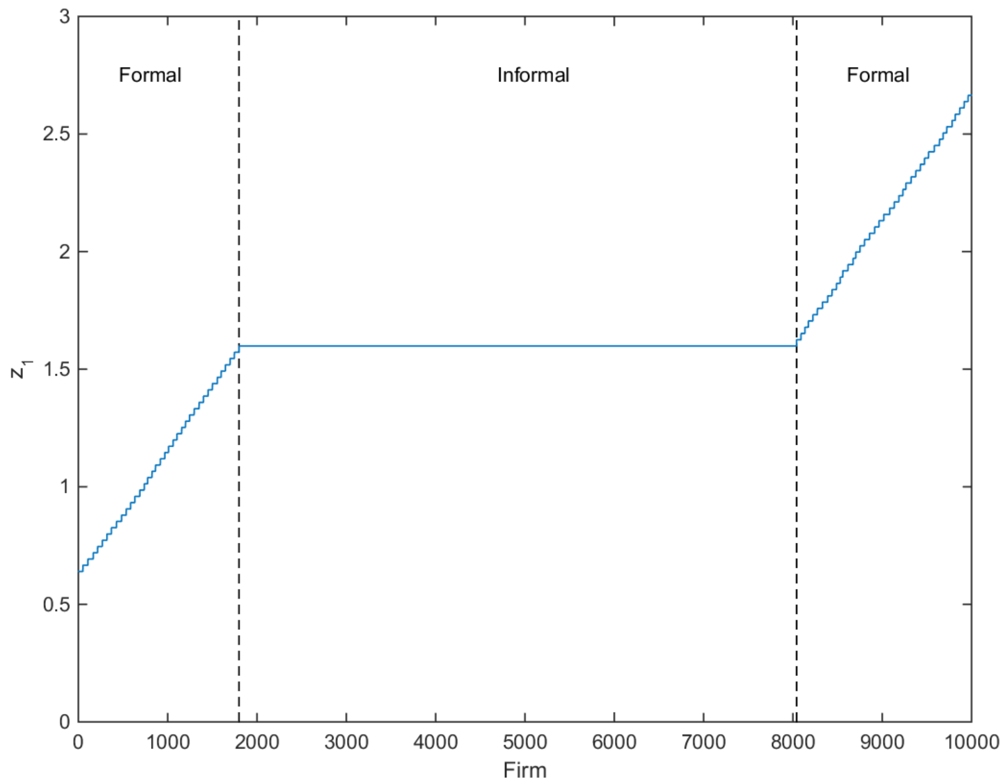
The results are presented in four sections. The first section explores and develops intuition for how the model operates. Specifically, it illustrates the distribution of productivity resulting from firm sectoral choice and the spillover of technology. The next set of results investigates how innovation affects the sectoral decision of firms. It clearly shows that changes in tax rates have significant impacts on the size of the informal sector. The third section looks at the aggregate effect of the changes in sector choice. I find that changes in the tax rate have significant impacts on the size of the informal economy and TFP growth. The final section tests the robustness of the model to changes in the substitutability of intermediate firms' goods. All results are for $t = 1$, the first period in which firms realize their sector decisions and operate in their chosen sector. Therefore, changes in innovation costs and tax rates should be seen as changing this initial sector decision and not as a reallocation within the first period.

4.1 Developing Intuition

It is important to develop some intuition for how firms enter each sector. Firms that decide to enter the informal sector forgo the ability to innovate and instead receive a productivity spillover from the formal sector, $\bar{z}_t$. Figure 2 illustrates how this assumption operates. It orders firms from lowest productivity to highest productivity after firms have made their sectoral choice. It clearly illustrates the division of firms into each sector and underscores why it is important to model the dynamic decisions of firms. The left-hand side of Figure 2 is populated by lower productivity firms that operate in the formal sector. These firms anticipate the gains from innovation to exceed the lost profits from taxation. Since these firms produce a unique intermediate good, they are not driven out of the market. A large swath of the economy operates informally with the fixed (within each period) productivity $\bar{z}$. The right-hand side of Figure 2 is populated by high productivity formal sector firms. It is still the case, as in Rauch (1991), that a firm with a higher initial productivity parameter, z_{i0}, will tend to enter the formal sector.

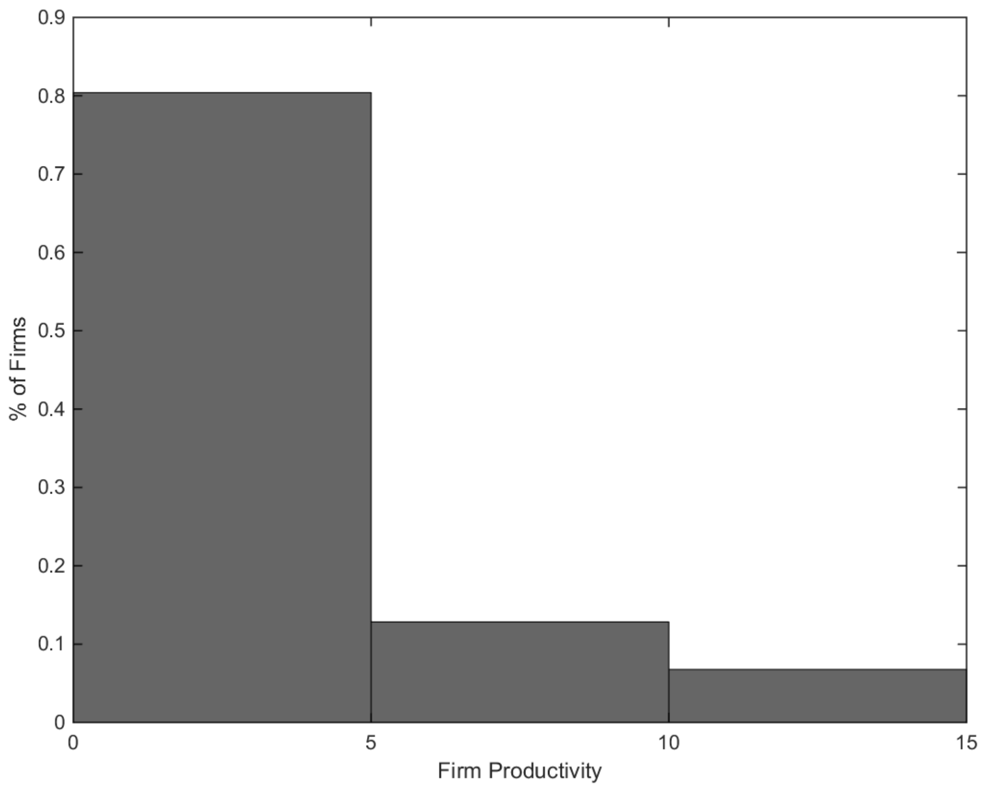
The model generates a large mass of firms at the lower end of the distribution of productivity, as can be seen in Figure 3. Since firms hire labor proportionally to e^z, Figure 3 also implicitly determines the distribution of firm size. For now, it is important to note that there will be a large number of relatively small firms. The coarse bins are intended to illustrate that 80% of firms in the model begin operating at roughly $\frac{1}{3}$ the productivity level of the most productive firms. Further discussion of alternative distributions for initial productivity and the desirability of this distribution is left for Section 5.

Figure 2: Firm Productivity



The figure is generated using 10,000 firms that face a 20% tax rate on profits in the formal sector. Innovation costs are moderate ($b = 5.5$) and $\rho = 5$. Note that observed productivity in the economy is actually $e^{\frac{z}{\rho-1}}$, which means that $z = (\rho - 1)log(\text{observed TFP})$. In the figure above, 61.3% of firms operate in the informal sector.

Figure 3: Distribution of Firm TFP

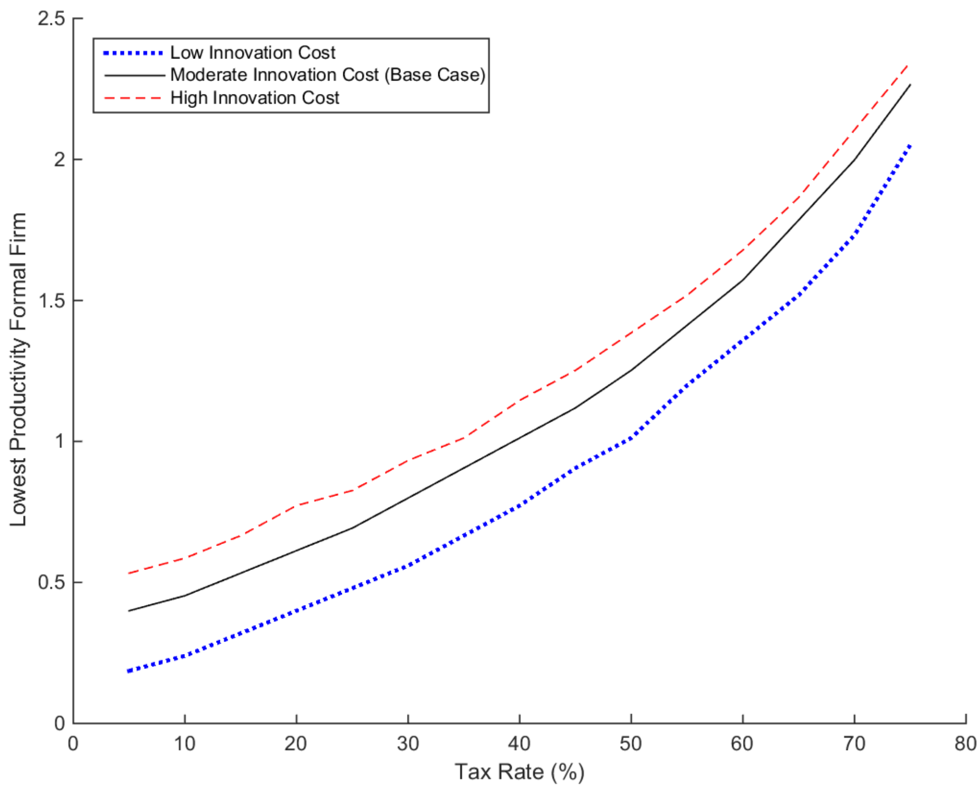


The figure is generated using the same parameter values as in Figure 2. Firm TFP is $e^{z_{it}}$.

4.2 Informality and Innovation

In order to discuss impacts on aggregate variables, it is first necessary to illustrate the role that innovation has on firm sector choice. If innovation does not have a significant impact on firm choice, the complexity added through integrating innovation within a model of monopolistic competition is likely not an improvement over earlier static models of sector choice. Figure 4 plots the cut-off value, $\hat{z}$, for firms to enter the formal sector.

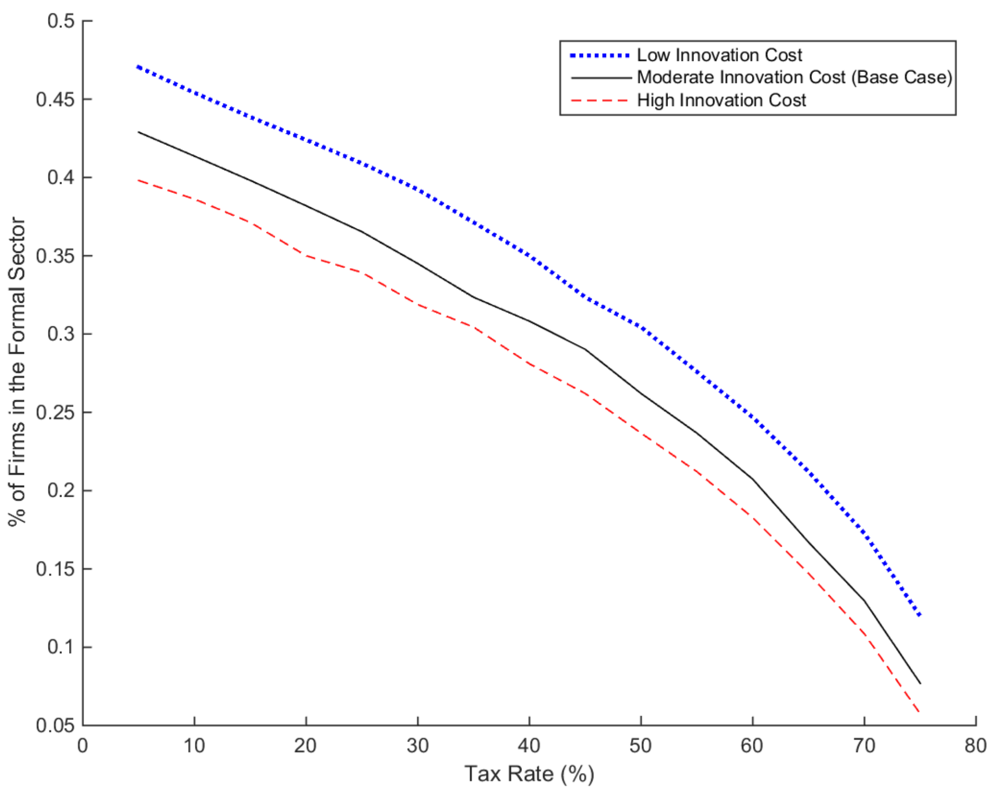
Figure 4: Cut-off Value of Initial Productivity for Entry into the Formal Sector



Innovation costs are as referenced in Table 2. The tax rate corresponds to τ in the model.

The effect of taxation on the productivity cut-off is illustrated for the three different cost levels of innovation as described in Table 2. The more expensive innovation is, the less incentive there is to operate formally. The value of $\hat{z}$ with high innovation costs is always higher than $\hat{z}$ under lower innovation costs. Since $\hat{z}$ represents the lowest value of productivity that firms would need to enter the formal sector, lower values of $\hat{z}$ correspond to additional firms entering the formal sector. Lowering the cost of innovation raises the valuation of firms in the formal sector who can pursue innovation to increase their future productivity and profits.

Figure 5: Percentage of Firms Operating in the Formal Sector



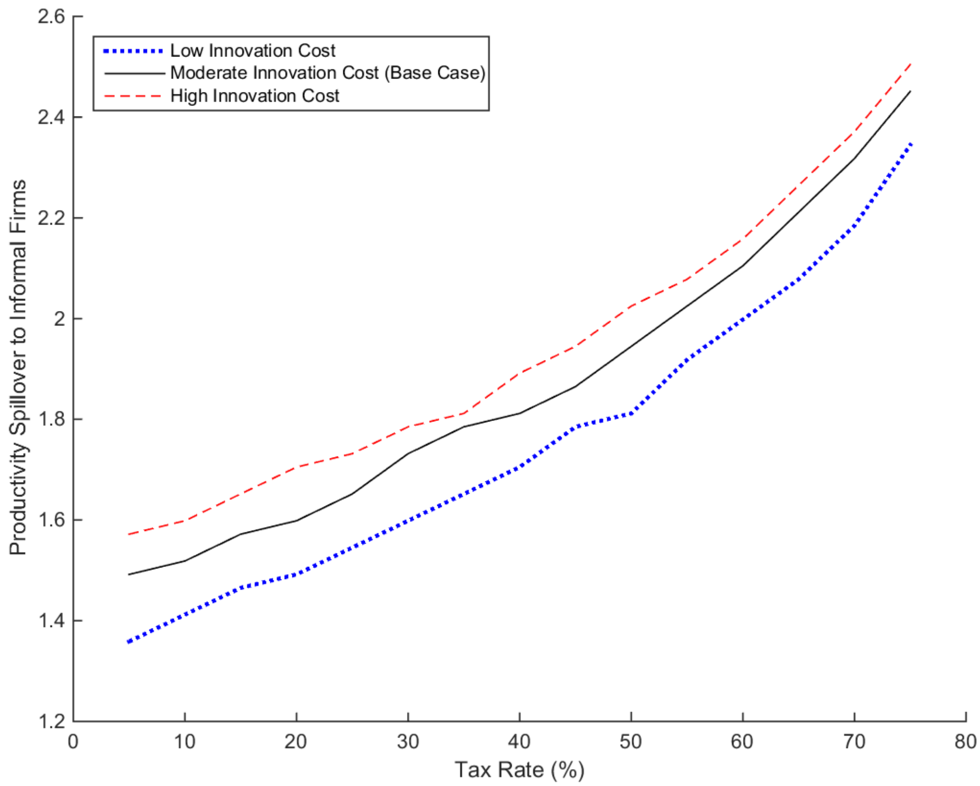
Innovation costs are as referenced in Table 2. The tax rate corresponds to τ in the model.

These results are corroborated in Figure 5. Reducing the cost of innovation increases formal sector participation at every tax rate. More firms opt to improve their production processes rather than simply produce using the productivity spillover from the formal sector. These changes in sector size over the different tax rates are quite sizable. In the moderate cost innovation environment the formal sector is reduced by 82% across all tax rates considered (5% to 75%). Smaller changes in the tax rate have important effects too. For instance, an economy with a 50% tax rate would see a 17.5% increase in the size of the formal sector from cutting taxes by 10% or a 20.9% increase by raising them 10%. Notice that at higher levels of τ, firms opt into the informal sector at an increasing marginal rate.

The process above is augmented by the gradual increase in the size of the spillover as firms migrate to the informal sector. Suppose that taxes are increased just enough to persuade one additional firm to be informal rather than formal. This marginal change affects the size of the spillover from the formal sector. As the lowest productivity firm in the formal sector switches to the informal sector, it raises the average productivity in the formal sector, increasing the spillover, $\bar{z}_t$, to the informal sector. This process is illustrated in Figure 6.

An immediate effect of the technology spillover is that higher costs of innovation lead to higher productivity levels in the informal sector. This feature has two intuitive interpretations. First, it reflects the fact that in economies with higher costs of innovation, more productive entrepreneurs may eschew innovation and instead evade taxes in the informal sector. Second, it also implies that higher innovation costs lead to a smaller dispersion of productivity. While it may be counter-intuitive that the informal sector ought to be more advanced in a society with higher innovation costs, this effect is temporary. Firms in the low cost economy innovate with $q = 1$, while firms in the moderate cost economy innovate with $q = .5023$. Since greater values

Figure 6: Productivity Spillover to Informal Firms



The productivity spillover to informal firms is captured in the model as $\bar{z}$. It is calibrated to match Indian data that shows that the mean informal firms has the same productivity as the 48.8th percentile formal sector firm. Innovation costs are as referenced in Table 2. The tax rate corresponds to τ in the model.

of q correspond to greater innovation and TFP growth, the lower innovation costs today, the higher the productivity of formal sector firms in the future.

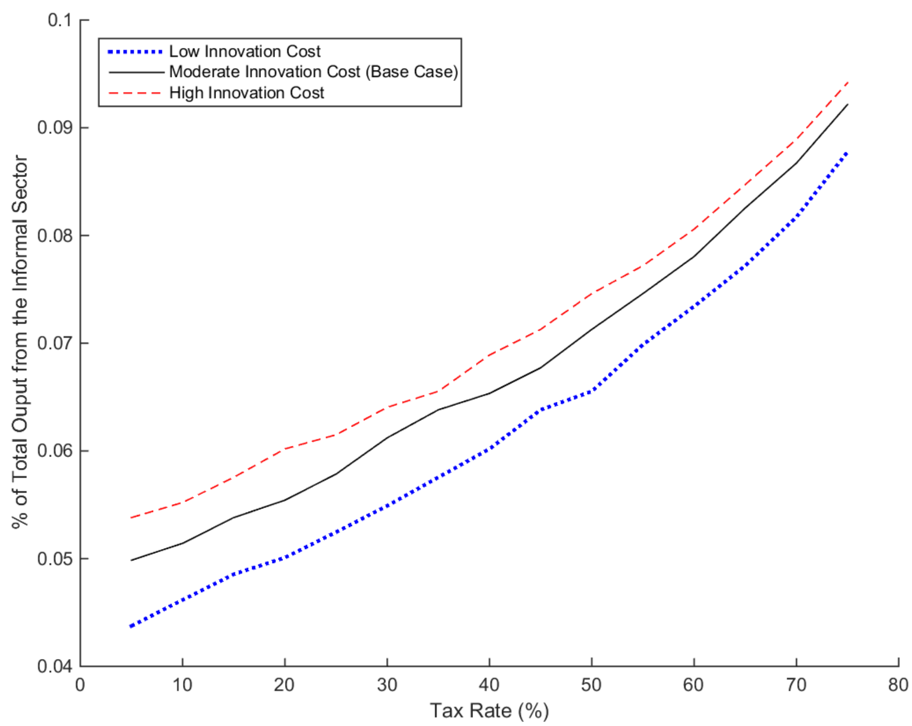
4.3 Informality and Aggregate Effects

As the tax rate increases, the ratio of output in the informal sector to total output increases, as can be seen in Figure 7. In absolute terms, however, the amount of output that is produced in the informal sector is relatively small when compared to data on the size of informal sectors in developing counties, as seen in Table 1. Informal firms, with their smaller productivity levels of $\bar{z}$, operate on a smaller scale than their formal sector counterparts. They are, however, more numerous under all of the specifications I evaluate. Further discussion of this result is also left for Section 5.

In certain innovation environments, the tax rate changes the rate of TFP growth. This process is plotted in Figure 8. As taxes increase, the returns to innovating in the formal sector decrease. This entails both lower innovation rates, as well as lower formal sector participation as documented previously. I find that TFP growth decreases by .07% for a 10% tax increase from 50% to 60%. This affect occurs despite the fact that the size of the spillover to the informal sector mechanically increases as the tax rate increases. For a fixed productivity spillover, the decrease in TFP growth would be substantially larger.

In both the high and low cost environments, the costs of innovation dominate changes in the tax rate such that the innovation rate does not change, and hence TFP growth rate does not change. In those settings, as τ increases, firms flee the formal sector, leaving fewer innovators, as seen in Figure 5. This process also drives up the spillover to the informal sector. The combination of these effects, without

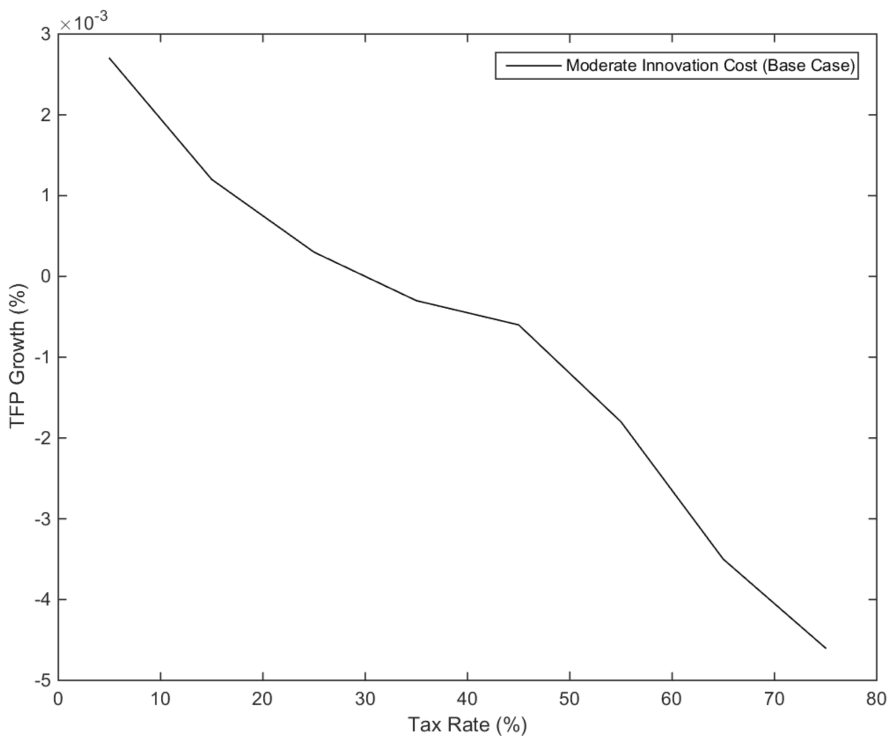
Figure 7: Percentage of Output Produced in the Informal Sector



The figure above illustrates the percentage of total output produced in the informal sector across innovation and tax rates. Innovation costs are as referenced in Table 2. The tax rate corresponds to τ in the model.

any accompanying change in innovation rates among formal sector firms leads to no change in TFP growth. Firms in the real world are not likely at either of those bounds and do change their innovation activities in response to changes in corporate tax rates. Recall that in these extreme environments firms invest in research sufficiently to ensure success or make failure a certainty. Given that real world innovation does not likely follow this model, I focus my analysis on the moderate costs environment.

Figure 8: Growth in Aggregate TFP



Changes in the aggregate TFP growth rate are calculated under moderate innovation costs as outlined in Table 2. TFP growth rates are plotted at 10% intervales from 5% to 75%.

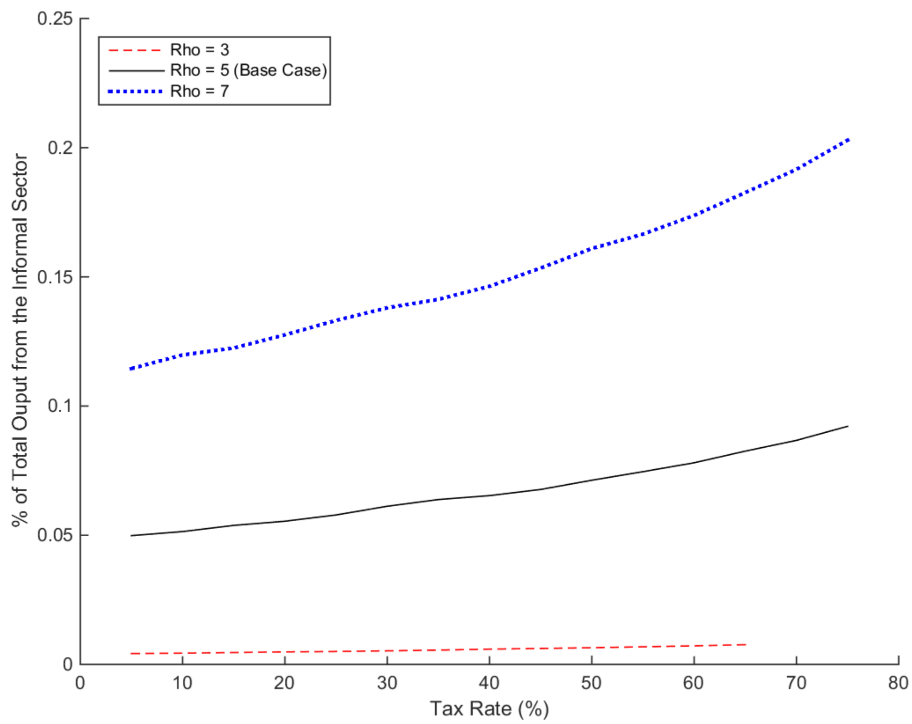
4.4 Robustness

Below I investigate the effects of changing the value of ρ in the simulations. The parameter ρ governs the substitutability of different intermediate goods in the production of the final good. As ρ increases, the substitutability between goods increases, decreasing market power and the incentives for firms to innovate in the formal sector. This result is illustrated in Figure 9. Notice that the percentage of total output produced in the informal sector increases with ρ. In the case of $\rho = 7$, the informal economy has a much larger impact, constituting 11.5% to 20.2% of the economy.

Changes in ρ also affect TFP growth, as can be seen in Figure 10. The case of $\rho = 3$ is unique. In that case, changes in the tax rate are dominated by incentives to innovate. Mainly that given the costs, lowering ρ increases the profitability of innovating, as static profits are proportional to productivity in the model. This is a very similar set of circumstances that explained why TFP growth did not vary for $\rho = 5$ (base case) in the high and low cost innovation environments. Raising the value of ρ lowers the level of TFP growth as firms are less profitable because their market power diminishes. Overall, changes in the value of ρ have predictable effects resulting from static profits decreasing as ρ increases. This translates into decreasing the profitability of innovation.

The sensitivity of the model to changes in the elasticity of substitution should not be surprising. In fact, it reflects an unresolved question in the literature on informality: do formal and informal firms compete? According to recent work by La Porta and Sheifer (2014) firms do not compete across sectors. On the other hand, data from the World Bank Enterprise surveys suggests that many formal firms do in fact compete. It could also be that there is a strong complementarity between sectors as suggested by Sundaram et al (2012). Given the open nature of this question, the

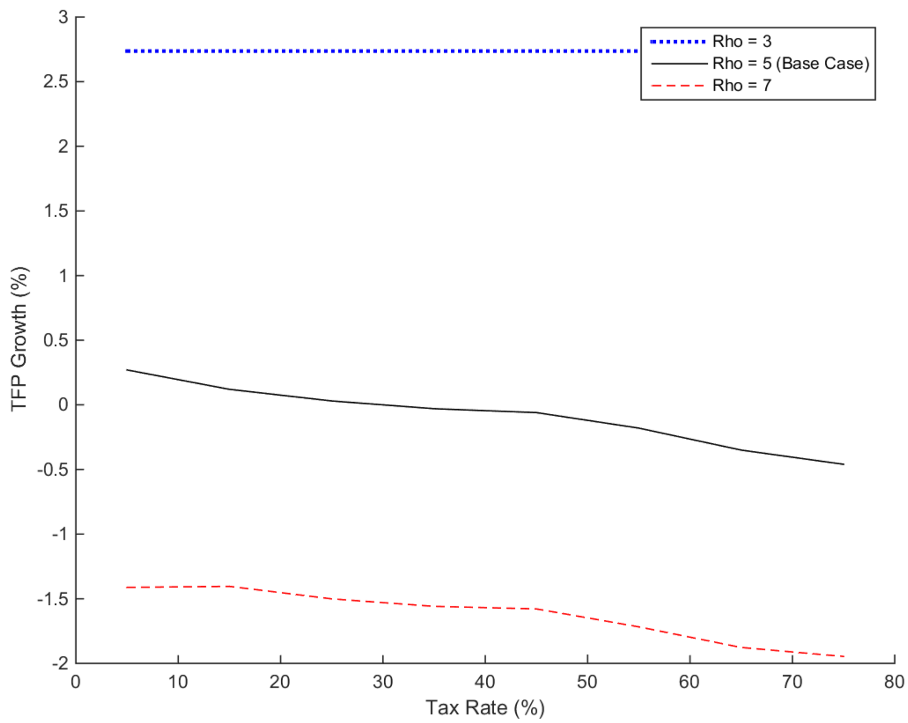
Figure 9: Percent of Total Output Produced by Informal Firms



Innovation costs are as referenced in Table 2. The tax rate corresponds to τ in the model. The curve for $\rho = 3$ does not appear for levels of $\tau \geq .65$ in either Figure 9 or Figure 10. For higher tax rates, the simulation does not converge. The high tax rate and low level of ρ create a situation in which all firms want to innovate, driving up the value of $\bar{z}$. This in turn drives a large portion of firms into the informal sector, driving $\bar{z}$ back down. This process continues indefinitely.

choice of $\rho = 5$ seems like prudent choice given its previous use in the literature. Modeling firms as competing in monopolistic competition seems to be a compromise between alternatives in the literature that allows reasonable levels of competition.

Figure 10: TFP Growth across Values of ρ



Innovation costs are as referenced in Table 2. The tax rate corresponds to τ in the model. See caption on Figure 9 for an explanation why $\rho = 3$ does not appear for levels of $\tau \geq .65$.

5 Discussion

Below, I focus on three areas of particular concern/interest: the parameterization of the initial distribution of productivity, the formulation of the technology spillover to the informal sector, and the assumption of firms making a single entry decision. These areas seem to be responsible for both the desirable qualities of the model, as well as some of its shortcomings.

The parameterization of initial productivity in the model is a particularly nebulous issue. In most developing countries, the distribution of productivity generates a firm-size distribution with a large number of small firms as documented in Tybout (2000). In the current application, firm-size is linked to firm productivity such that less productive firms are also smaller. In this sense, the current parameterization captures the ubiquity of small firms that is documented by Tybout (2000). Choosing a realistic initial distribution hinges on two competing concerns. First, the dispersion of productivity is responsible for determining how relevant the informal sector is. A smaller dispersion of productivity implies that firms in the informal sector will produce a greater percentage of total output. Drawing the initial productivity from a narrower range of z would increase the significance of informal firms.

On the other hand, the desire to calibrate the distribution to match data regarding the size of informal economies must be tempered by a realistic assessment of how productive formal sector firms are compared to informal sector firms. As the 2013 World Development Report points out, few countries collect reliable data on the informal sector, and there are few reliable estimates of the true ratio of productivity between the sectors. Hsieh and Klenow (2009) establish a lower bound by reporting that the ratio log TFP for the 90th percentile to the 10th percentile is 5.0 for India and 4.9 for China. These numbers represent a lower bound since both small and informal firms are excluded from their data sources.

As a means for comparison, in a simulation with moderate innovation costs and a tax rate of 20%, the ratio of the highest productivity firm to the productivity of firms in the informal sector (based on $\bar{z}$) is 1.67, and the ratio of the highest

TFP to lowest TFP is 4.17. Especially with regard to the second statistic (which is most similar to that of Hseih and Klenow (2009)), the initial productivity draw seems entirely plausible. The first statistic is more difficult to compare since, to my knowledge, there is no analog in the literature.[22] The World Bank Enterprise Survey (WBES) has collected data on both formal and informal sector firms, but those data sets are usually collected in different years and do not yield comparable measures of productivity across formal and informal firms.

It is important to note that based on the data in Nataraj (2011), the model incorporates the overlap in productivity between the formal and informal sector. This element is not seen in earlier models of sectoral choice. In those models, such as Rauch (1991), there is a strict dualism where firms in the informal sector are always less productive than the least productive formal firms.

Closely related to the choice of initial distribution of firm productivity is how productivity spills over to the informal sector. Decreasing the size of the spillover, for instance, by endowing firms in the informal sector with the lowest quartile of productivity in the formal sector, would decrease the incentives to switch sectors when taxes increase. At the same time, such a change would increase the ratio of productivities between the sectors by lowering productivity in the informal sector. Ultimately, the spillover used in the model is the only one that can be readily justified given the available data.

A larger question: does such a spillover make sense? The nature of the spillover is intended to capture the fact that firms in the informal sector tend to adopt changes investing substantially less in innovation. In this sense, their productivity improves

[22] This measure is tied to the size of the spillover from the formal to informal sector. The calibration of the spillover is extrapolated from Nataraj (2011) as described in Section 3. However, even her database of firms is based on 1989 data.

over time, but is not at the technological frontier. For instance, evidence from the World Enterprise Survey indicates that smaller (highly correlated with informal) firms are less likely to utilize e-mail. This indicates that some firms choose to adopt new technologies that are already commonplace in the formal sector. Informal sector firms did not invent e-mail or revolutionize its applications, but adopt its usage to improve their productivity when they see its widespread usage in the formal sector.

The answer to how realistic the specification of the spillover is, ultimately hinges on country-specific context. For instance, informal production in some countries may resemble relatively simple home production. This production may occur in rural areas that are not in close proximity to dense manufacturing areas. On the other hand, in places like India, some data indicates that there is a complementarity between production in the formal and informal sectors. Sundaram et al. (2012) document a strong positive correlation between factor movements in the formal sector and informal sector. They conclude that there is likely a strong complementarity between the sectors. In this case, spillovers may be larger than currently specified in the model.

Part of the complementarity that Sundaram et al. (2012) document is the ability of the informal sector to absorb excess labor and provide employment for workers who cannot find work in the formal sector. One reason the model does not accurately reflect the size of informal economies is that labor is the sole factor of production. Informal firms tend to be more labor intensive, while formal sector firms tend to be more capital intensive. Introducing a complementarity between the two sectors may increase the size of the informal sector so that it better reflects the available data. Additionally, as noted in Section 4.4, a higher level of substitutability between the formal and informal sector (i.e. higher ρ) could also explain the size of the informal sector in some economies.

Finally, it is worth discussing the validity of looking at firms' sector decisions, assuming that they stay in that sector rather than switching in a later period. While this assumption is made principally to isolate the role of innovation on firms' decisions, there are reasons to suggest that there are barriers to switching sectors. Nataraj (2011) reports that few firms in India switch from formal to informal despite having fewer employees than is necessary to be required to register as a formal firm. Additionally, barring a bad series of innovation shocks, the incentives for firms that reach high enough productivity levels to have them opt into the formal sector, would still seek to stay there. On the informal side, there is substantial data to suggest that there are large barriers to entry for the formal sector that are not explicitly modeled here. These costs would be incurred in addition to a higher tax rate, and they may deter firms from switching sectors.

6 Conclusion

This paper investigates how firms react to changes in government policy and determine whether to operate formally or informally. Not only are firms' decisions shown to be significantly affected by taxes and innovation costs, but their sectoral choices also have important impacts on aggregate variables such as TFP growth. Considering the importance of TFP in determining cross country income differences, understanding how firms' dynamic sectoral decisions are influenced by taxation is a positive step in understanding the process of development.

By modeling how firms react to changes in tax rates, make innovation decisions, and decide which sector to operate in, I am able to generate relevant policy implications. Specifically, governments limit TFP growth through taxation by pushing firms into the informal sector and lowering the innovation rates of formal sector firms. Secondly, institutions that lower the costs of innovation are better for enticing firms to operate formally. This work improves on previous understanding of the informal sector by explicitly modeling the dynamic decision making process of firms. Ultimately, it underscores the role of government policy in shaping the incentives of individuals and firms. Given the right incentives, these individuals and firms are able to generate income and innovations to aid in the process of development.

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Appendix A

This section outlines the derivation, calculation, and assumptions for calculating aggregate output growth. Let the aggregate growth rate be designated

$$g_Y = \frac{Y_{t+1} - Y_t}{Y_t}. \tag{21}$$

Substituting (19) in for Y_t and its equivalent for Y_{t+1}, yields (20). Recall that

$$Z_t = \sum_i e^{z_{it}}, \tag{22}$$

for all firms, both formal and informal. Aggregate productivity can be split into formal and informal sectors as

$$Z_t = \sum_{\hat{z}}^{z_{max}} e^{z_{it}} + \sum_{z_{min}}^{\hat{z}} e^{\bar{z}_t}, \tag{23}$$

with a slight abuse of notation with the indexing on the sums. The formal sector is composed of all firms with draws of $z \in [\hat{z}, z_{max}]$. Recall that $\bar{z}_t$ is equal to the σ percentile of productivity in the formal sector. Let ω be the number of firms that participate in the formal sector. Similarly, let ξ be the number of firms that operate in the informal sector. Aggregate TFP at time t then is

$$Z_t = \sum_{\hat{z}}^{z_{max}} e^{z_{it}} + \xi e^{\bar{z}_t} \tag{24}$$

A similar expression can be derived for the expected value of Z_{t+1}. Given the process of innovation outlined in Section 2.3, firm's expected productivity in the formal sector is

$$E_t e^{z_{it+1}} = q_{it} e^{z_{it} + \Delta z} + (1 - q_{it}) e^{z_{it} - \Delta z}. \tag{25}$$

Thus, $E_t Z_{t+1}$ can be written similarly to (24):

$$E_t Z_{t+1} = \sum_{\hat{z}}^{z_{max}} E_t e^{z_{it+1}} + \xi E_t e^{\bar{z}_{it+1}}, \tag{26}$$

subject to (25). Notice that this result utilizes the fact that firms make a decision to enter a given sector under assumption that they will stay in that sector. Under this assumption, the distribution of firms into each sector, mainly the parameters ω and ξ are fixed. Combining equations (20), (24), and (26) allows for the calculation of expected output growth. Expected output growth is a function of the distribution of firms productivity, z_t, the cut-off value $\hat{z}$ that determines ω and ξ, and firms' choices for innovation, q_{it}.