Essays on Macroeconomic Theory: Technology Adoption, the Informal Economy, and Monetary Policy

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Preface

It is well known that cross-country differences in income per worker are very large. For example, the average per-capita income of the richest ten percent of countries of the Penn World Tables in 1996 is about thirty times that of the poorest ten percent. Development accounting uses cross-country data on output and inputs to measure the relative contribution of differences in factor quantities, and differences in Total Factor Productivity (TFP) or the efficiency with which those factors are used, in explaining these vast differences in income per worker. The consensus view in development accounting is that TFP is the most important factor in accounting for differences in income per worker across countries (See, for example, Klenow and Rodriguez-Clare (1997), Prescott (1998), Hall and Jones (1999), Ferreira, Issler and de Abreu Pessa (2000), and Caselli (2004).)

This suggests that in order to explain cross-country differences in income per worker we need to understand why TFP differs across countries. An emergent literature addresses this issue and shows that cross-country differences in the institutional environment, in policies, or in human capital can cause large differences in TFP. In particular, Acemoglu and Zilibotti (2001) emphasize the role of skill-mismatch. They argue that even if all countries have equal access to new technologies, the existence of technology-skill mismatch can lead to sizeable differences in TFP and output per worker; Parente and Prescott (2000) and Herrendorf and Teixeira (2004) build theories in which the protection of monopoly rights impedes the adoption of superior technologies; Rogerson and Restuccia (2004) argue that differences in the allocation of resources across heterogeneous plants may be a significant factor in accounting for cross-country differences in output per capita; Erosa and Hidalgo (2005) propose a theory in which capital market imperfections are at the origin of cross-country TFP differences; and Kocherlakota (2001) shows that limited enforcement and high inequality are crucial to understand the existence of institutions leading to the inefficient use of technologies.

The first chapter of this thesis makes a contribution to this literature by examining the role that labor market features and institutions have in explaining barriers to technology adoption, which have a direct impact on TFP. I build a model that includes labor market frictions, capital market imperfections and heterogeneity in workers' skills. I find that the unemployment rate together with the welfare losses that workers experiment after displacement are key factors in explaining the existence of barriers to technology adoption. Moreover, none of these factors alone is sufficient to build these barriers. The theory also suggests that welfare policies like the unemployment insurance system may enhance these kinds of barriers while policies like a severance payment system financed by an income tax seem to be more effective in eliminating them.

Two important characteristics shared by low income countries, which are likely to play an important role in explaining the observed international income differences, are that they have larger informal sectors and higher relative price of investment than rich countries (see, Loayza (1996), Schneider and Enste (2000), Easterly (1993) and Jones (1994)). Djankov, La-Porta, Lopez-De-Silanes and Shleifer's (2002) find that countries with heavier regulation of entry, which increase the start up cost of new business, have higher corruption and larger unofficial economies, while Restuccia and Urrutia (2001) show that the relative price of investment is negatively correlated with

PPP investment rates. According to Hsieh and Klenow (2003), low PPP investment rates in poor countries are not due to low savings rates or to high tax or tariff rates on investment but to low efficiency in producing investment goods.

Based on the previous two observations I study in the second essay in this thesis the extent to which one can account for international disparities on income and on the size of the informal sector with differences in policies that either increase the entry cost in the formal sector or distort the efficiency of the investment sector and, as a consequence, distort the accumulation of capital. To this end, I introduces an informal sector into an otherwise standard neoclassical growth model with monopolistic competition in the formal sector.

The main finding of this chapter is that the model is able to generate income differences consistent with the observed international patterns for differences in the productivity of the investment sector that produce reasonable differences in the relative price of investment. To generate a relative price of investment of a factor of 4 with respect to the benchmark economy the model only requires a reduction in the productivity of the investment sector of a factor of 3.11, which is smaller than the distortions required by most models in the literature. I also perform a “De Soto experiment” to analyze how much of the differences in the size of the informal sector and in per capita income can be accounted by policies that increases the entry cost in the formal sector. The quantitative exercises suggest that higher entry costs are associated with both a higher size of the informal sector and a lower per capita income level. The results supports De Soto’s (1989) argument that the size of the informal sector is mainly determined by entry barriers, and they are consistent with Djankov et al.’s (2002) findings that countries with heavier regulation of entry have higher corruption and larger unofficial economies. The magnitude of this effect on income, however, is modest.

Although large entry costs alone are unable to explain all the observed international income differences across countries, when these costs are combined with distortions to the efficiency of the investment sector, they have the potential to explain an even larger part of the observed international income differences. This is a relevant result because these two distortions are likely to coexist in poor countries.

The third essay in this thesis, which is a joint work with Atanas Kolev, analyzes the effects that monetary policy might have on informal sector activity. We consider this as an interesting research question since in the past several years many studies have found that informal economic activity is a fact of life in market economies. Some claim that its share in measured GDP has been increasing in for the last 20 years to make the informal economic sector a significant phenomenon in many countries. Informal activity, by definition, is not officially documented. There is no official statistics about its parameters and dynamics and of course there is no information on the impact of different public policies on it. Clearly, it is very important that policy makers have a better understanding of both the causes of informal sector activity and its reaction to economic policy measures. While there exist studies on the effects of fiscal policy, social welfare, and institutions' quality on the informal sector we lack understanding of how, if at all, informal sector activity is affected by monetary policy.

This chapter makes a step towards estimating the potential effects of monetary policy on informal sector activity and understanding the mechanism behind these effects. We estimate a time series index of the informal sector in UK and find that informal sector activity reacts very differently to monetary policy than that in the formal sector. In order to get some insight of this somewhat surprising result we begin by examining the differences between the two sectors. In our opinion, two important differences have the potential to explain this result. First, informal sector activity typically does not have access to external financing and therefore is not directly affect by liquidity effects. Second, informal sector activity makes its transactions mainly in cash, so that inflation acts as a tax on these transactions. Based on these two observations, we build a two-sector monetary business cycle model that captures quite well what we have found in our estimation. In future work we plan to repeat the estimation for various countries with significant informal sector, such as Spain, Italy, and Greece, and to calibrate the model to these economies incorporating aggregate uncertainty. This will allow us to study the business cycle properties and bring us better understanding of how the mechanism works.

Chapter I

Labor Market Frictions, Social Policies, and Barriers to Technology Adoption

1 Introduction

Barriers to technological changes have recently been shown to be a key element in explaining differences in output per worker across countries (see Parente and Prescott (1999, 2000)). These barriers can have a first order effect on total factor productivity (TFP), which is the most important factor in accounting for differences in output per worker across countries (See, for example, Hall and Jones (1999), Caselli (2004), Ferreira et al. (2000) and Prescott (1998)).[1]

In this chapter I examine the role that labor market features and institutions have in explaining barriers to technology adoption. Technological changes imply many

[1] Parente and Prescott (2000) argue that *"Differences in international incomes are the consequences of differences in the knowledge individual societies apply to the production of goods and services. ..., these differences are the primary result of country-specific policies that result in constraints on work practices and on the application of better production methods at the firm level. Many of these constraints, or barriers, are put in place to protect the interests of groups vested in current production processes. Such barriers at the individual production unit level imply differences in output per unit of the composite input at the aggregate level, that is, differences in total factor productivity (TFP). Most of the differences in international incomes, thus, are the result of differences in TFP."*(p.2).

different changes for workers. Among the more important ones is the possibility of switching from operating a low productive technology to operating a more productive one, and this switch may imply higher future wages. If, however, the new technology is labor substituting or skill biased or the firm faces an inelastic demand, the change may imply the displacement of part of the staff. In this case workers face the risk of becoming unemployed or of losing the skills accumulated with the old technology, since skills may not be transferable across technologies if the technological change is implemented.[2] The possibility of being displaced or of loosing skill are associated with substantial earning losses, and these losses might make workers reluctant to adopt new technologies, specially when the likelihood of finding a new job is low.

Jacobson, LaLonde and Sullivan (1993) and Topel (1991) present substantial evidence that job losses are associated with loss of skills and large earning losses. In particular, Jacobson et al. (1993) find that the earnings of displaced workers remain 25% lower than those of similar non-displaced workers even five years after displacement. Figure I.1, taken from Jacobson et al.'s (1993), shows the disparate expected earning-patterns of long-tenure workers who were displaced in the first quarter of 1982 compared to workers who remained employed throughout the period.

To study the role that labor market features and institutions have in explaining barriers to technology adoption I introduce technical change into an otherwise standard Mortensen and Pissarides model of unemployment. In my framework there is matching between workers and firms. When a worker is matched with a firm they bargain the wage at any moment in time. Firms receive stochastic opportunities of adopting a more productive technology. Workers are risk averse and face the risk of loosing their jobs or skills when a technological change is implemented. Because capital markets

[2] By skill I mean the experience that a work has with the technology and the industry specific knowledge that can imply an increase in wages while the worker is attached to the firm and which are lost when the worker becomes unemployed.

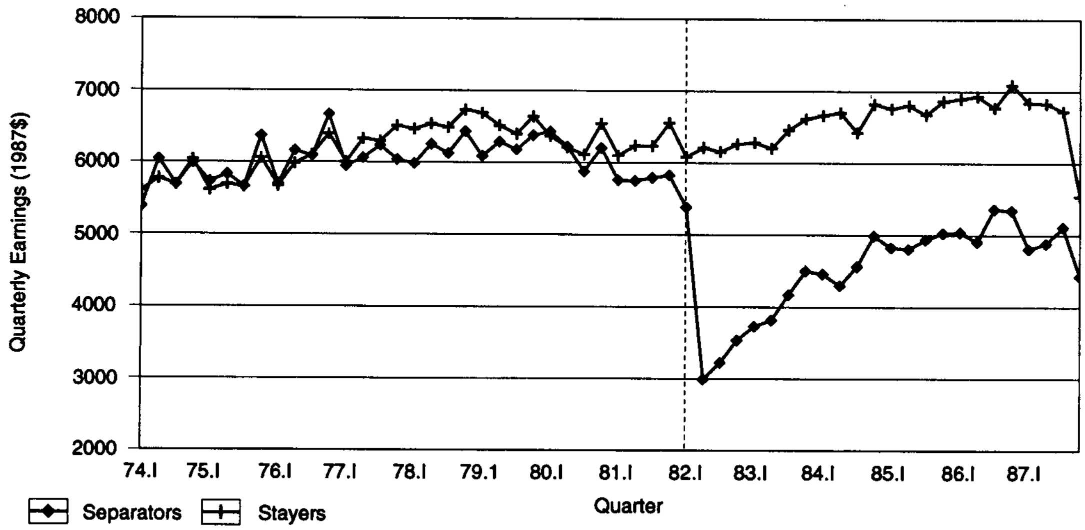

Figure I.1: Quarterly earnings of high-attachment workers separated in the first quarter of 1982 and workers staying through 1987. The sample is from Pennsylvania. Source: Jacobson et al. (1993).

are imperfect, workers can not be insured against labor income risk. Workers might become reluctant to a technological change if the risk of becoming unemployed or losing skills after the adoption of the new technology is high. Since my focus is on the circumstances that may lead workers to reject a technological change, I assume that workers have the power to block the technological change if it is not optimal for them. Therefore, the new technology is adopted if and only if the firm and workers agree on it. When the firm is willing to adopt the new technology but workers reject it, I say that *there is a barrier to a technological change*. Firms, however, cannot commit to compensate displaced workers after the technological change.

I study how unemployment affects barriers to technological change and examine the consequences of different welfare policies for technology adoption. Welfare policies may seem to be a natural way to provide commitment through institutions to distribute the aggregate gains of a technological improvement. Therefore, well defined institutions may help to reduce workers' resistance to those changes.

I find that both unemployment and the loss of skills caused by technological changes are key factors behind barriers to technological changes. This work also suggests that welfare policies have to be careful designed since no well designed policies can have negative effects on technological progress.

A well intentioned policy maker can think that an unemployment insurance (UI) system may reduce barriers to technological change because it can reduce the unemployment risk. My work suggests that UI may, instead, enhance the barriers. If I consider two economies with the same unemployment rate but with different level of unemployment benefits, the economy with the higher unemployment benefit is certain to exhibit weaker barriers because the unemployment risk is smaller. In a general equilibrium context an increase in the unemployment benefit leads to a higher unemployment rate, and a higher unemployment rate leads to higher barriers.[3] In contrast I find that a severance payment system financed by an income tax seems to be more effective in eliminating these barriers. Severance payments are a more effective device for dealing with the earnings variability induced by displacement and do not discourage employment, since they provide a cash transfer to the worker that is not contingent on the worker choosing not to work.

As an example of how unemployment risk can lead to barriers to technology adoption, consider the textile industry in England at the end of the 19th century. This example shows that when new technologies threat the job stability of a group of workers in an industry, no matter how productive it may be, the introduction of that technology is certain to face strong rejection by the affected group. The case is provided by Randall (2002).[4] The example he provides is the attempts of Shearers to block the introduction

[3]Ljungqvist and Sargent (1998), among others, argue that a significant component of the rise in European unemployment can be accounted for by the fact that displaced workers in Europe can receive unemployment benefits for very long periods.

[4]An extensive list of evidence concerning barriers to technology adoption or implementation of more efficient work practices can be found in Parente and Prescott (1999, 2000). Schmitz (2002) also provides an industrial case that illustrates how changes in work practices lead the U.S. and Canadian

of the gig machine at the end of the eighteen century in English woollen industry. The Shearers were responsible for the finishing of fine cloth and were the best paid. In 1793 the gig mill was found to be suitable for the finishing of fine cloth, although it was not a new invention at that time. With the use of this machine one man and two boys could accomplish in 12 hours what it took one man to do by hand in 88 to 100 hours. With this huge labor savings, the use of this machine was certain to finish the job of the majority of shearers. Not surprisingly, the Shearers resisted the gig mill's application to the finishing of cloth and were successful in delaying its adaptation to finishing cloth for nearly twenty-five years in some regions.

Other historical episodes illustrate that workers are very concerned about the distribution of the potential gains due to a technological change between the winners and losers of the process (see Parente and Prescott (2000)).[5]

Many recent papers can be related to my work. Aghion and Howitt (1994) discuss the relation between growth and long-run unemployment, where growth is modelled as technological progress, and shows that unemployment is affected by growth both directly through the job-destruction rate, and indirectly through its effects on the incentive for firms to create job openings and hence on the job-finding rate. In contrast, my work suggests that unemployment may have a negative effect on the growth rate by making more difficult the adoption of new technologies.

My findings complement those in a recent paper by Rogerson and Schindler (2002).

iron-ore industries to double their labor productivity in the middle 1980s. Some other examples about several innovations in English woollen industry, the adoption of which were delayed for many years on account of workers blocking then, can be found in Randall (2002).

[5] Parente and Prescott (2000) document an increase in labor productivity by a factor of 3 in the U.S. subsurface coal mining industry in the 1949-1969 period. The reason for this increase in productivity was basically the introduction of the boring machine to replace pick-and-shovel technology. These machines were widely used to construct tunnels for many years before their use in coal mining. They had not been used in mining because union contracts had explicitly prohibited their use. They were introduced when their use benefited the miners, which was when cheap substitutes for coal, namely, oil and natural gas, became available in the late 1940s. When coal miners allowed the introduction of boring machines, they did an explicit agreement and, as part of the agreement, the coal miners subsequently receive $20 for every ton of coal mined to finance union pension benefits.

They find that the welfare costs of the earning losses associated with the displacement of high tenure workers are substantial. Their analysis suggest that long duration unemployment insurance is likely to exacerbate this cost, and that government-financed severance payments are a more effective way of dealing with the displacement risk. In this chapter I obtain similar conclusions in the context of technological changes, which makes the point more relevant.

My work is also related to the works of Acemoglu and Shimer (2000), and Marimon and Zilibotti (1999). These authors emphasize a positive effect of unemployment insurance on the efficient use of technologies. They show that unemployment insurance affects workers' productivity by allowing better matches between workers and firms. While their analysis abstract from the effect that this system may have on the adoption of more productive technologies, and hence on its effects on technological progress, my analysis suggests that UI may have negative effects on the adoption of better technologies.

The rest of the chapter proceeds as follows: the next section presents the model. In section 3 and 4 I present some numerical examples that illustrate the results, and section 5 presents the conclusions.

2 The Model

In this section I present the structure of the model. The economy consists of workers and firms, and in the matching process between them there is friction, which causes unemployment. Workers can be either employed or unemployed, and firms can have their jobs either filled or vacant. Time is continuous and the economy is populated by a measure one of individuals who discount the future at a rate of time preferences ρ

and have utility function given by

$$\mathcal{U}(w_t) = \frac{w_t^{1-\sigma} - 1}{1-\sigma},$$

where w_t is income at time t. All unemployed workers are unskilled, but once they initiate a match they can become skilled with the technology in use at a rate π_h per unit of time. When the match is broken they lose their skill. The term "*skill*" in this context means "*experience*" or the firm specific knowledge workers can learn to increase their productivity but that cannot be transferred to other firms.

A new firm incurs initial investment cost I_c and receives a technology with productivity normalized to one. Firms can freely enter the market, and they can have at most one worker. For the latter reason I am going to refer for the rest of the chapter to a firm as a job. The output produced by an unskilled worker is θ_l while a skilled worker produces θ_h, with $0 < \theta_l < \theta_h = 1$. Firms matched with a worker receive a stochastic opportunity of adopting a new technology with productivity $\pi > 1$, and when a firm adopts the new technology it uses the new technology until it closes down. An individual who meets a firm that uses the new technology is able to operate the new technology with probability λ_a. This assumption implies that when a firm receives an opportunity of adopting the new technology, with probability $1 - \lambda_a$ the worker is not able to operate it and has to be dismissed. I can then study in a simple way workers' decisions when they face a technological change that may cause them to lose their jobs.

To study the effect that the possibility of losing skill might have on workers' decisions, I assume that with probability δ_h a skilled worker will remain skilled with the new technology and that before the change takes place he does not know whether he is going to remain skilled or not. In contrast, unskilled workers can only remain in the job as unskilled.

In addition I assume that workers have the power to block a technological change if they think it is not optimal for them. This assumption allows me to focus on the reasons workers have to block a technological change rather than on the mechanism they might use to do it. In the real world, however, successful deterring of new technologies or better work practices seems to depend on how much political power do labor unions have in the economy and on the willingness of the government to protect workers' employment. The implication of this assumption is that a technological change would be adopted only if the firm and workers agree on doing it.

Finally, there is no physical depreciation of the technology but each job faces the risk of being destroyed with probability ϕ per unit of time. This implies that in the steady state equilibrium of the model both technologies might coexist.

The remaining of this section is devoted to the description of all the necessary elements that are needed to define the steady state equilibrium of the economy. The first step is to describe the matching process between workers and firms. The second step will be to derive the value functions for firms and workers in all possible states of the economy.

2.1 Matching Process

The matching process between workers and firms is random and takes place in a pool comprising all workers and vacancies. All vacancies are alike and the search process only takes time. When a worker is unemployed he can work at home with a technology $\pi_0 < \pi$ earning $w_u = \pi_0$.[6]

Let λ_w and λ_f be the rates per unit of time at which a worker meets a vacancy and a firm meets a worker.[7] The number of matches in any moment is given by a constant return to scale matching function $m(v, u)$, where v is the total measure of vacancies and

[6] In section (3.1) I consider the inclusion of an unemployment insurance system and analyze the effect that it may have on the existence of barriers to technology adoption.

[7] Implicitly, I assume that λ_w, λ_f, ϕ and π_h are Poisson processes.

u is the total measure of unemployed workers. I also assume that $m(v,u)$ is strictly increasing in both arguments and satisfy some standard regularity conditions.[8] Let $\theta = v/u$ denotes labor market tightness. Hence,

$$\lambda_w(\theta) = m(\theta, 1) \text{ and } \lambda_f(\theta) = \frac{m(\theta,1)}{\theta}.$$

2.2 Value functions

Let γ denote the rate per unit of time at which a firms receives the opportunity of adopting the new technology. Because there is no depreciation of the technology and firms' and workers' transition among the different states follow Poisson processes, the value of a vacancy, the value of a filled job, the value of being employed and the value of being unemployed do not depend on how long a worker or a firm has been in its current state or on its prior history. This observation implies that on the steady state those values are constant over time.

For the rest of the chapter the term "*low productive firm*" will refer to a firm that has not adopted the technology π and the term "*high productive firm*" to one that has adopted it.

To define an equilibrium I need to specify the market value for a firm and for a worker in all the possible states. A firm can be low or high productive, and it can have its job ether filled or vacant. A job can be filled by a skilled or by an unskilled worker. A firm, them, can have six different market values. Individuals, instead, can be unemployed or employed ether in a low or in a high productive firm as an unskilled

[8] These conditions are:

$$\begin{aligned} m(0,u) &= m(v,0) = 0, \\ \lim_{v\to\infty} m_v(v,u) &= \lim_{u\to\infty} m_u(v,u) = 0, \\ \lim_{v\to 0} m_v(v,u) &= \lim_{u\to 0} m_u(v,u) = \infty. \end{aligned}$$

or as a skilled worker. This implies the existence of five different market values for an individual.

In section (2.2.1) I derive the market values for high productive firms and for the workers matched with those firms, and the rest of the value functions are derived in section (2.2.2).

2.2.1 Value functions for high productive firms

Let $J_{\pi,i}$ be the value of a match with a type i worker, $i \in \{l,\ h\}$, where $i = l$ means unskilled and $i = h$ means skilled, and V_π be the value of a vacancy for a high productive firm. The wage paid by a high productive firm to an unskilled worker is denoted by $w_{\pi,l}$ and to a skilled worker by $w_{\pi,h}$. I derive the present discounted value of these value functions using arbitrage as is standard in search theory, although I can also use dynamic programming. Think of $V_\pi,\ J_{\pi,l}$ and $J_{\pi,h}$ as assets priced by firms, which are risk neutral investors, with required rate of return r, where r is the interest rate. The expected return on a vacancy V_π is the probability $\lambda_f(\theta)\lambda_a$ per unit of time of finding a worker that is able to operate the technology and obtains a capital gain of $J_{\pi,l} - V_\pi$ minus the probability ϕ per unit of time of a capital loss of V_π if the firm closes down. Agents will be willing to hold the asset V_π if its expected rate of return, i.e., its dividends plus any expected capital gain or loss per unit of time, equal rV_π. Thus the arbitrage equation that determines the present discounted value of V_π is given by

$$rV_\pi = \lambda_f(\theta)\lambda_a \left(J_{\pi,l} - V_\pi\right) - \phi V_\pi. \tag{I.1}$$

If the firm is matched with an unskilled worker, the return for the firm is the dividend $\pi\theta_l - w_{\pi,l}$ per unit of time plus a capital gain $J_{\pi,h} - J_{\pi,l}$ with probability π_h per unit of time if the worker gains skill, minus the capital loss of $J_{\pi,l}$ with probability ϕ per unit of time if the firm closes down. Hence,

$$rJ_{\pi,l} = \theta_l \pi - w_{\pi,l} + \pi_h \left(J_{\pi,h} - J_{\pi,l}\right) - \phi J_{\pi,l}. \tag{I.2}$$

Similar reasoning implies

$$rJ_{\pi,h} = \pi - w_{\pi,h} - \phi J_{\pi,h}. \tag{I.3}$$

Let $W_{\pi,l}$ and $W_{\pi,h}$ be the present discounted value of being employed as an unskilled and as skilled worker in a high productive firm, and let U be the value of being unemployed. Parallel to the previous analysis, I can think of $W_{\pi,l}$ as an option value that yield utility $\mathcal{U}(w_{\pi,l})$ per unit of time, has an expected capital gain of $W_{\pi,h} - W_{\pi,l}$ with probability π_h if the worker gains skill, and an expected capital loss of $W_{\pi,l} - U$ with probability ϕ per unit of time if the match is destroyed. In order to hold this asset a worker requires that the expected rate of return equals $\rho W_{\pi,l}$. Thus,

$$\rho W_{\pi,l} = \mathcal{U}(w_{\pi,l}) + \pi_h \left(W_{\pi,h} - W_{\pi,l}\right) - \phi \left(W_{\pi,l} - U\right). \tag{I.4}$$

Finally, the expected rate of return of $W_{\pi,h}$ is the utility $\mathcal{U}(w_{\pi,h})$ per unit of time minus the expected capital loss of $W_{\pi,h} - U$ with probability ϕ per unit of time. Then,

$$\rho W_{\pi,h} = \mathcal{U}(w_{\pi,h}) - \phi \left(W_{\pi,h} - U\right). \tag{I.5}$$

To determine wages I use a Nash bargaining solution with workers' bargaining power equal to β. The Nash bargaining equation, which implicitly defines the wages $w_{\pi,h}$ and $w_{\pi,l}$, are

$$\beta\, k_\pi\, \mathcal{U}'(w_{\pi,l})(J_{\pi,l} - V_\pi) = (1-\beta)(W_{\pi,l} - U), \tag{I.6}$$

$$\beta\, k_\pi\, \mathcal{U}'(w_{\pi,h})(J_{\pi,h} - V_\pi) = (1-\beta)(W_{\pi,h} - U), \tag{I.7}$$

where $k_\pi = (r + \phi + \pi_h)/(\rho + \phi + \pi_h)$.

2.2.2 Value functions for low productive firms

I now turn to derive the market values for low productive firms and for workers matched with them. Let J_i be the value of a match with a type i worker, $i \in \{l,\ h\}$, and V be the value of a vacancy for a low productive firm. The wage paid by a low productive firm to an unskilled worker is denoted by w_l and to a skilled worker by w_h. Since only operating firms can receive the opportunity of adopting the new technology, the arbitrage equations determining the present discounted value of V can be derived in the same way that V_π was derived. The main difference is that all workers can operate this technology. This implies that with probability $\lambda_f(\theta)$ per unit of time a firm finds a worker that can operate the technology as an unskilled worker and obtain a capital gain of $J_l - V$. Thus,

$$(r + \phi)V = \lambda_f(\theta)\,(J_l - V)\,. \tag{I.8}$$

To derive the arbitrage equations for J_l and J_h, I have to take into account that with probability γ per unit of time a firm has the opportunity of switching to the technology π. Firms take as given worker's decision and decide whether to adopt the new technology or not. The arbitrage equations are as follow:

$$rJ_l = \theta_l - w_l + \pi_h\,(J_h - J_l) - \phi J_l + \gamma\,\mathcal{I}(\mathcal{W}_a^l)\max\{\lambda_a J_{\pi,l} + (1-\lambda_a)V_\pi - J_l - \epsilon I_c, 0\}, \tag{I.9}$$

$$\begin{aligned} rJ_h = {} & 1 - w_h - \phi J_h + \gamma\,\mathcal{I}(\mathcal{W}_a^h)\max\{\lambda_a(\delta_h J_{\pi,h} + (1-\delta_h)J_{\pi,l}) + (1-\lambda_a)V_\pi \\ & - J_h - \epsilon I_c, 0\}. \end{aligned} \tag{I.10}$$

Equations (I.9) and (I.10) can be derived in the same way equations (I.2) and (I.3) were derived, but now with probability γ per unit of time firms have the expected gain of changing the technology, which are the last terms in equations (I.9) and (I.10). These terms merit an explanation. First, the function $\mathcal{I}(\cdot)$ is the indicator function, which equals one if the argument is greater or equal than zero and equals zero otherwise. Second, the function $\mathcal{W}_a^i$, $i = l$ for unskilled and $i = h$ for skilled, represents workers' expected gain of accepting the technology π and will be derived later. A type i ($i = l, h$) worker will accept the technological change if and only if $\mathcal{W}_a^i \geq 0$. Conditional on workers' decision the firm will be willing to accept the technological change if and only if the value of expected gain with the new technology is greater or equal than the cost of adoption plus the value of expected gain of continuing with the current technology. That is,

$$\lambda_a J_{\pi,l} + (1 - \lambda_a)V_\pi \geq J_l + \epsilon I_c, \tag{I.11}$$

and

$$\lambda_a(\delta_h J_{\pi,h} + (1 - \delta_h)J_{\pi,l}) + (1 - \lambda_a)V_\pi \geq J_h + \epsilon I_c, \tag{I.12}$$

for a firm that is matched with an unskilled and with a skilled worker. Then equations (I.9) and (I.10) follow. I now explain expression (I.12), since (I.11) has a similar interpretation. The left hand side of (I.12) is the expected gain of adopting the technology π. Conditional on being able to operate the new technology, a skilled worker will remain skilled with the new technology with probability δ_h and will lose the skill with probability $1 - \delta_h$. If the worker is not able to operate the technology the match is broken and the firm changes its value to V_π. The right hand side of (I.12) is the cost of adoption. This cost is the sum of the value of continuing with the current technology, J_h, plus the cost of the new technology, ϵI_c, which is a fraction $\epsilon \in [0,\ 1]$ of the entry cost.

In order to study firms' decisions I define the following functions

$$\mathcal{F}_a^l = \lambda_a J_{\pi,l} + (1 - \lambda_a)V_\pi - J_l - \epsilon I_c, \tag{I.13}$$

and

$$\mathcal{F}_a^h = \lambda_a(\delta_h J_{\pi,h} + (1-\delta_h)J_{\pi,l}) + (1-\lambda_a)V_\pi - J_h - \epsilon I_c. \tag{I.14}$$

Hence, a firm matched with a type i ($i = l, h$) worker will want to adopt the new technology if and only if $\mathcal{F}_a^i \geq 0$.

For workers I proceed as follow. Let W_l and W_h denote the present discounted value of being employed in a low productive firm as unskilled and as skilled worker. The equations that determine U, W_l, and W_h are

$$\begin{aligned}
\rho\, U &= \mathcal{U}(w_u) + \lambda_w(\theta)\left(\frac{v_0}{v}(W_l - U) + \lambda_a \frac{v_1}{v}(W_{\pi,l} - U)\right), && \text{(I.15)}\\
\rho\, W_l &= \mathcal{U}(w_l) + \pi_h\,(W_h - W_l) - \phi\,(W_l - U) + \gamma\, \mathcal{I}(\mathcal{F}_a^l)\max\{\lambda_a W_{\pi,l} + (1-\lambda_a)U \\
&\quad -W_l, 0\}, && \text{(I.16)}\\
\rho\, W_h &= \mathcal{U}(w_h) - \phi\,(W_h - U) + \gamma\, \mathcal{I}(\mathcal{F}_a^h)\max\{\lambda_a(\delta_h W_{\pi,h} + (1-\delta_h)W_{\pi,l}) + (1-\lambda_a)U \\
&\quad -W_h, 0\} && \text{(I.17)}
\end{aligned}$$

where v_0 and v_1 are the number of vacancies in firms that use the low and the high productive technology, and $v = v_0 + v_1$ is the total number of vacancies in the economy. These equations have the following interpretation. According to (I.15) the flow return to an unemployed worker, $\rho\, U$, equals the utility provided by home production, $\mathcal{U}(w_u)$, plus the gain from switching from unemployed to employed as unskilled worker in a low productive firm, $W_l - U$, with probability $\lambda_w \frac{v_0}{v}$ per unit of time and in a high productive firm, $W_{\pi,l} - U$, with probability $\lambda_w \lambda_a \frac{v_1}{v}$ per unit of time. According to (I.16) the flow return to an unskilled worker employed in a low productive firm, $\rho\, W_l$, equals the sum of four terms. The first is the utility provided by this asset, $\mathcal{U}(w_l)$. The second is the rate at which an unskilled worker becomes skilled, π_h, times the gain from switching from being low productive to be high, $W_h - W_l$. The third term is the rate at which a match is destroyed because the firm closes down, ϕ, times the capital loss from switching from employed to unemployed, $-(W_l - U)$. The last term is the rate at which a firm receives the opportunity of adopting the high productive technology, γ, times the firm decision, $\mathcal{I}(\mathcal{F}_a^h)$, times the expected capital gain from accepting or rejecting the technology. Note that a worker decides whether to accept or reject the new technology taking as given the firm decision. Equation (I.17) can be derived following a similar reasoning.

A worker will accept the new technology if the expected gain of accepting it is greater or equal than zero. Since an unskilled worker will be able to operate the technology π with probability λ_a and will be dismissed with probability $1-\lambda_a$, his expected gain of accepting the new technology is

$$\mathcal{W}_a^l = \lambda_a W_{\pi,l} + (1-\lambda_a)U - W_l. \tag{I.18}$$

Similarly, a skilled worker will remain employed as skilled with probability $\lambda_a\delta_h$, as unskilled with probability $\lambda_a(1-\delta_h)$ and with probability $1-\lambda_a$ the worker will be fired. Hence, the expected gain of accepting the new technology for a skilled worker is given by

$$\mathcal{W}_a^h = \lambda_a(\delta_h W_{\pi,h} + (1-\delta_h)W_{\pi,l}) + (1-\lambda_a)U - W_h. \tag{I.19}$$

Thus, a type i worker, $i = l\ h$, will accept a technological change if and only if $\mathcal{W}_a^i \geq 0$. Finally, in equilibrium I require $V = I_c$ so that there is no profitable entry by new firms. This is the so called free entry condition.

As for the firms with the technology π, wages w_l and w_h solve first-order conditions from a Nash bargaining solution with the workers bargaining power equals to β:

$$\beta\, k_l\, \mathcal{U}'(w_l)(J_l - V) = (1-\beta)(W_l - U), \tag{I.20}$$

$$\beta\, k_h\, \mathcal{U}'(w_h)(J_h - V) = (1-\beta)(W_h - U), \tag{I.21}$$

where $k_i = (r + \phi + \pi_h + \gamma\, \mathcal{I}(\mathcal{F}_a^i)\mathcal{I}(\mathcal{W}_a^i))/(\rho + \phi + \pi_h + \gamma\, \mathcal{I}(\mathcal{F}_a^i)\mathcal{I}(\mathcal{W}_a^i))$ for $i = l, h$.

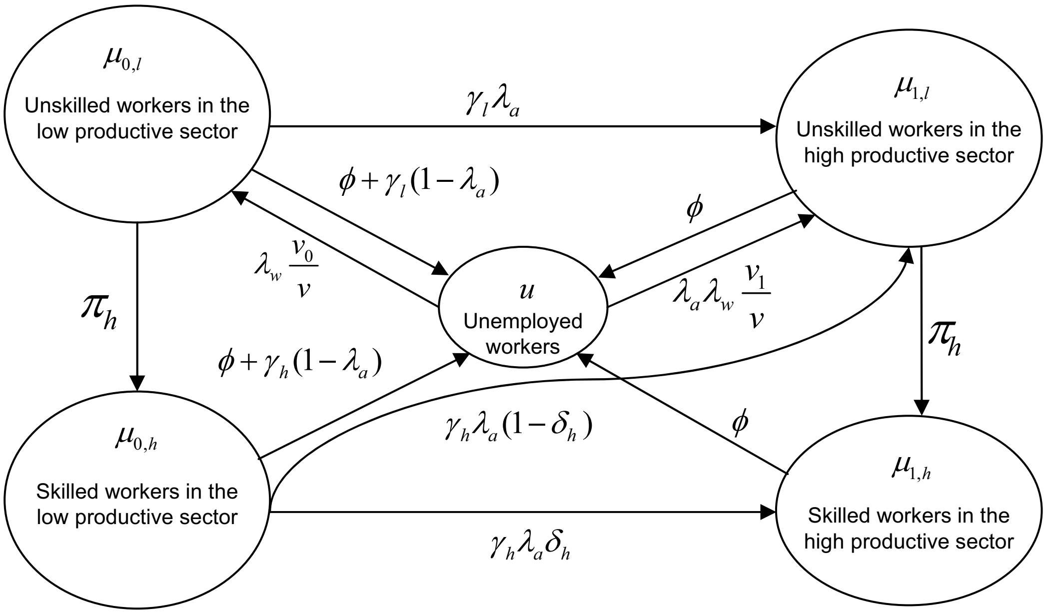

Figure I.2: Transitions

2.3 Distribution of employment

To fully solve for the equilibrium, it is necessary to derive explicit expressions for the matching probabilities in terms of the endogenous variables. To this end I need to determine the unemployment rate and the distribution of vacancies and employment across firms. Begin by letting $\mu_{i,j},\ i = 0, 1$, and $j = l,\ h$, denotes the proportion of the population who is employed in a firm with productivity i ($i = 0$ means low productive and $i = 1$ high productive) as unskilled ($j = l$) or as a skilled worker ($j = h$). The proportion of the population that is unemployed is denoted by u. The transitions between all possible states is illustrated in Figure I.2, where $\gamma_i = \gamma\ \mathcal{I}(\mathcal{F}_a^i)\ \mathcal{I}(\mathcal{W}_a^i),\ i = l, h$. To determine the steady state values of $\mu_{i,j},\ i = 0, 1$, and $j = l,\ h$, I equate the flow out of and into each of the different states:

$$(\pi_h + \phi + \gamma_l)\mu_{0,l} = \lambda_w(\theta)\frac{v_0}{v}u, \tag{I.22}$$

$$(\phi + \gamma_h)\mu_{0,h} = \pi_h\mu_{0,l}, \tag{I.23}$$

$$(\pi_h + \phi)\mu_{1,l} = \gamma_l\lambda_a\mu_{0,l} + \gamma_h\lambda_a(1-\delta_h)\mu_{0,h} + \lambda_a\lambda_w(\theta)\frac{v_1}{v}u, \tag{I.24}$$

$$\phi\mu_{1,h} = \pi_h\mu_{1,l} + \gamma_h\lambda_a\delta_h\mu_{0,h}. \tag{I.25}$$

In addition, the flow equations for the measure of vacant low productive firms, v_0, is given by

$$(\phi + \lambda_f(\theta))v_0 = \phi(\mu_{0,l} + \mu_{0,h} + \mu_{1,l} + \mu_{1,h} + v_0 + v_1). \tag{I.26}$$

The left hand side of (I.26) is the measure of low productive vacancies that are destroyed, ϕv_0, plus the number of firms that finds a match, $\lambda_f(\theta)v_0$. In the steady state it should equals the number of firms that enter the market every instant, which is equal to the number of jobs and vacancies that are destroyed $\phi(\mu_{0,l} + \mu_{0,h} + \mu_{1,l} + \mu_{1,h} + v_0 + v_1)$. Hence, equations (I.22) to (I.26) together with the facts that $v\lambda_f(\theta) = u\lambda_w(\theta)$ and that the μ's plus u sum to 1, form a system of seven equations in seven unknowns, $\mu_{0,l}$, $\mu_{0,h}$, $\mu_{1,l}$, $\mu_{1,h}$, v_0, v_1 and u, which can be solved and expressed as functions of the value of the market tightness θ. In particular, for the ratios v_0/v and v_1/v, I have

$$\frac{v_0}{v} = \frac{(\gamma_h + \phi)(\lambda_a\lambda_f(\theta) + \phi)(\gamma_l + \pi_h + \phi)}{(\gamma_h + \phi)(\lambda_a\lambda_f(\theta) + \phi)(\gamma_l + \pi_h + \phi) + \lambda_f(\theta)(1-\lambda_a)(\gamma_h(\gamma_l + \pi_h) + \gamma_l\phi)},$$

and

$$\frac{v_1}{v} = \frac{\lambda_f(\theta)(1-\lambda_a)(\gamma_h(\gamma_l + \pi_h) + \gamma_l\phi)}{(\gamma_h + \phi)(\lambda_a\lambda_f(\theta) + \phi)(\gamma_l + \pi_h + \phi) + \lambda_f(\theta)(1-\lambda_a)(\gamma_h(\gamma_l + \pi_h) + \gamma_l\phi)}.$$

2.4 Steady state equilibrium

In this section I define the equilibrium of the economy. Before proceeding I want to claim that each value function can be written as an implicit function of the value of the market tightness θ. The reason is the following. Equations (I.1)-(I.5) form a linear system of equations in the variables $V_\pi,\ J_{\pi,l},\ J_{\pi,h},\ W_{\pi,l}$ and $W_{\pi,h}$. I can solve this system and find the formulas that define each of these value functions as functions of $w_{\pi,l},\ w_{\pi,h},\ U$ and θ, which remain linear functions of U. Then, substituting these values into equations (I.8)-(I.10) and (I.15)-(I.17) I obtain another linear system of six equations in the variables $V,\ J_l,\ J_h, W_l,\ W_h$ and U. Solving this new system I can find the formulas that define these functions as functions of the wages $w_l,\ w_h,\ w_{\pi,l},\ w_{\pi,h}$ and θ. Finally, substituting all the value functions into the Nash bargaining equations (I.6), (I.7), (I.20) and (I.21) I obtain a non-linear system of four equations that implicitly define all wages as functions of θ, which, in turns, allows us to write each value function as a function of the market tightness θ.

Definition 2.1 *For a given set of parameter values $\delta,\ \phi,\ r,\ \rho,\ \beta,\ \theta_l,\ \pi_0,\ \pi,\ I_c, \lambda_h,\ \lambda_a,\ \gamma$ and ϵ such that $\delta,\ \phi,\ I,\ \gamma,\ \epsilon > 0$, $r < 0$, $\rho,\ \beta,\ \theta_l,\ \lambda_h,\ \lambda_a,\ \phi + \delta < 1$ and $0 \leq \pi_0 < 1 < \pi$, and a functional form for the matching function, a steady state equilibrium for this economy is a vector of value functions $\{V, J_l, J_h, U, W_l, W_h, V_\pi, J_{\pi,l}, J_{\pi,h}, W_{\pi,l}, W_{\pi,h}\}$, wages $\{w_l, w_h, w_{\pi,l}, w_{\pi,h}\}$ and a value of the market tightness θ such that:*

(i) *The value functions V, J_l, J_h, U, W_l, W_h, V_π, $J_{\pi,l}$, $J_{\pi,h}$, $W_{\pi,l}$, $W_{\pi,h}$ and wages w_l, w_h, $w_{\pi,l}$, $w_{\pi,h}$ satisfy equations (I.1)-(I.7), (I.8)-(I.10), (I.15)-(I.17), (I.20) and (I.21).*

(ii) *The value of the market tightness, $\theta = v/u$, satisfies the free entry condition*

$$V(\theta) = I_c. \tag{I.27}$$

3 Barriers to a technological change

The previous sections give us the necessary tools to define *a barrier to a technological change*.

Definition 3.1 *Given the values π, λ_h, λ_a and ϵ for the new technology, I say that there exist a* ***barrier to a technological change*** *in the economy if firms are willing to adopt the new technology, $\mathcal{F}_a^h \geq 0$ ($\mathcal{F}_a^l \geq 0$), but ether skilled or unskilled workers do not, i.e., $\mathcal{W}_a^h < 0$ or $\mathcal{W}_a^h < 0$.*

This definition allows the existence of a barrier to a technological change by both skilled and unskilled workers, or by only one of such groups. The next proposition states the conditions under which a barrier to a technological change depends only on skilled workers.

Proposition 3.1 *If workers are risk neutral, whenever a technological change is optimal for a firm matched with an unskilled worker. i.e., $\mathcal{F}_a^l \geq 0$, it is also optimal for unskilled workers to accept it. i.e., $\mathcal{W}_a^l \geq 0$.*[9]

Proof: Using the Nash bargaining equations (I.6) and (I.20), I can write $\mathcal{W}_a^l$ as

$$\mathcal{W}_a^l = \frac{\beta}{1-\beta}\left(\lambda_a(J_{\pi,l} - V_\pi) - (J_l - V)\right), \tag{I.28}$$

or equivalently

$$\mathcal{W}_a^l = \frac{\beta}{1-\beta}\left(\mathcal{F}_a^l - (V_\pi - V - \epsilon I_c)\right).^{10} \tag{I.29}$$

Solving for $\lambda_a(J_{\pi,l} - V_\pi)$ from equation (I.1) and for $(J_l - V)$ from equation (I.8) and substituting those values into equation (I.29) I obtain

$$\mathcal{W}_a^l = \frac{\beta}{1-\beta}\frac{r+\phi}{\lambda_f(\theta)}(V_\pi - V).$$

[9]This result seems to be true when workers are risk averse. In all numerical examples I have performed the result holds for risk averse agents.

[10]Since workers are risk neutral I assume that they have the same discount rate than firms, i.e., $\rho = r$.

Hence, a necessary and sufficient condition for an unskilled worker reject a technological change is that $V_\pi < V$. But, if $V_\pi < V$, equation (I.29) would imply that $\mathcal{F}_a^l < 0$. The proposition follows. ■

This proposition implies that in any equilibrium of the economy in which the new technology is at least optimal for a firm matched with an unskilled worker, I will have both technologies in operation. Skilled workers, however, can block the technological change even if the change is optimal for the firm.

Corollary 3.1 *In an economy with only one type of workers, whenever it is optimal for the firm the adoption of a new technology, it is also optimal for the workers to accept it.*

Proof: This is the especial case when $\pi_h = 0$. Since proposition 3.1 is valid for all values of $\pi_h \geq 0$, the proof follows. ■

This corollary says that there is no way I can generate barriers with only unemployment risk, independently of the level of unemployment, the home production wage, etc. A plausible explanation is that when there is only one type of worker the welfare losses of a displaced worker are very small. In fact, these losses consist of the reduction in wages while unemployed, since they can find similar jobs to the ones they had before displacement, and the losses can be easily offset by the possibility of getting a higher wage if the new technology is implemented. For instance, if the unemployment rate is large, workers' threat point is small and the bargaining process implies that wages should be close to the home production wage which makes workers almost indifferent between working in a firm or being unemployed. The possibility of obtaining a higher wage in the event of remaining employed using the technology π offset the risk of becoming unemployed. It does not happen when there are more than one type of workers in the economy, because for a worker who has gained a wage premium with the technology π, the losses in the event of being displaced are much higher and may not be easily offset. On the other hand, if the unemployment rate is small, the probability of finding a similar job is high, which reduces the losses in the event of being displaced.

This result does not contradict the main point of this chapter to be illustrated later, that unemployment is at the origin of barriers to technology adoption, but points out that the secondary effects of unemployment are very important.

3.1 Numerical examples I

The next examples illustrate the quantitative implications of a change in the level of unemployment on barriers to technological changes.

Example 3.1

In this example I study the existence of barriers to technological change in economies that differ only in the level of unemployment. I consider economies with the unemployment rate varying from 2.5% to 20%. In order to generate economies with different unemployment rates I adjust the job creation cost, I_c. This election is based on the fact that the relative price of investment is higher in poor countries than in rich countries (See for example Easterly (1993) and Jones (1994)), and according to Restuccia and Urrutia (2001) the relative price of investment is negatively correlated with investment rates. A lower investment rate generate fewer jobs, and a low rate of job creation leads to an increase in the level of unemployment. In the simulation 1% increase in the job creation cost increases the unemployment rate by 18%.

Before proceeding, I need a functional form for the matching function. I follow the existing literature and use a Cobb-Douglas functional form: $m(v, u) = v^{\alpha} u^{1-\alpha}$, $\alpha \in (0,\ 1)$, which implies that $\lambda_f(\theta) = \theta^{\alpha-1}$ and $\lambda_w(\theta) = \theta^{\alpha}$; $\lambda'_f(\theta) < 0$, and $\lambda'_w(\theta) > 0$.

In this example a period is a month. The model has sixteen parameters $\{\sigma$, r, ρ, β, α, ϕ, γ, I_c, b, π_0, θ_l, π_h, π, λ_a, δ_h, $\epsilon\}$. I choose then in the following way: the parameter of risk aversion is $\sigma = 1.5$; the interest rate, r, and the rate of time preferences, ρ, are equal to 5% per year; the exogenous firm destruction rate, ϕ, is set such that the probability a firm closes down before 9 years equals 0.75; γ is set such that the probability a firm receives the opportunity of adopting the new technology before 9 years equals 0.75; b equals zero, so there is not unemployment benefit in the economy; workers bargaining power β is 2/3, and the matching function parameter α is 0.6; $\pi_0 = 1/5$ and the productivity of an unskilled worker is 30% lower than the productivity of a skilled worker, i.e., $\theta_l = 0.7$; finally, π_h is chosen such that a worker gains skill in one year with probability 0.75.

The parameters of the technological change are π, λ_a, δ_h, and ϵ. The new technology is 65% more productive than the current technology, i.e., $\pi = 1.65$. Workers' probability of being displaced is 0.15, which implies that $\lambda_a = 0.85$. The probability that a skilled worker remain skilled with the new technology is $\delta_h = 0.75$. Finally, for the technological change to be optimal for all firms I take $\epsilon = 0.84$. Under these assumptions low and high productive firms are always willing to adopt the new technology. Table I.1 summarizes the parameter values of the model.

The type of equilibria I consider are pure strategy equilibria. Figure I.3 (a) presents the expected gain of accepting the new technology for a skilled worker, $\mathcal{W}_a^h$, in economies with different unemployment rates. The continuous line represents the expected gain of accepting the new technology if everybody else accept it, and the dashed line when everybody else reject it. Note that in all cases the adoption of the new technology is optimal for firms and also for unskilled workers. In what follows I restrict the analysis only to skilled workers.

When the unemployment rate is less or equal than 7% both lines are above the horizontal axis, which means that workers are always willing to accept the new technology, and an equilibrium where there is always adoption of the new technology exists. If the

Parameters	u = 2.5%	u = 20%
σ	1.5	1.5
r, ρ	0.0042	0.0042
β	2/3	2/3
α	0.6	0.6
ϕ	0.012	0.012
γ	0.012	0.012
I_c	27.7	38.3
π_0	0.2	0.2
θ_l	0.7	0.7
π_h	0.02	0.02
π	1.65	1.65
λ_a	0.85	0.85
δ_h	0.75	0.75
ϵ	0.84	0.84

Table I.1: Parameters of the model. (Period 1 month)

unemployment rate is greater or equal than 15% both lines are below the horizontal axis. In this case it is optimal for a skilled worker to reject the technology when everybody else is rejecting it, and an equilibrium with *a barrier to the technological change* exits since workers will reject a technology that is optimal for firms. For unemployment rates between 7% and 15%, it is optimal for workers neither to accept the new technology when everybody is accepting nor to reject the new technology when everybody is rejecting. In this case there should be a mix strategy equilibrium with an intermediate level of adoption. The main conclusion from this example is that barriers to a technological change are stronger the higher is the unemployment rate and that they disappear when the unemployment rate is sufficiently low. This result indicates that labor market frictions can play an important role in explaining the existence of barriers to technology adoption.

Part (b) of figure I.3 presents a measure of aggregate welfare for the economies where technological changes are always implemented and where the changes are always rejected. The measure of aggregate welfare is $W = uU + \mu_{0,l}W_l + \mu_{0,h}W_h + \mu_{1,l}W_{\pi,l} +$

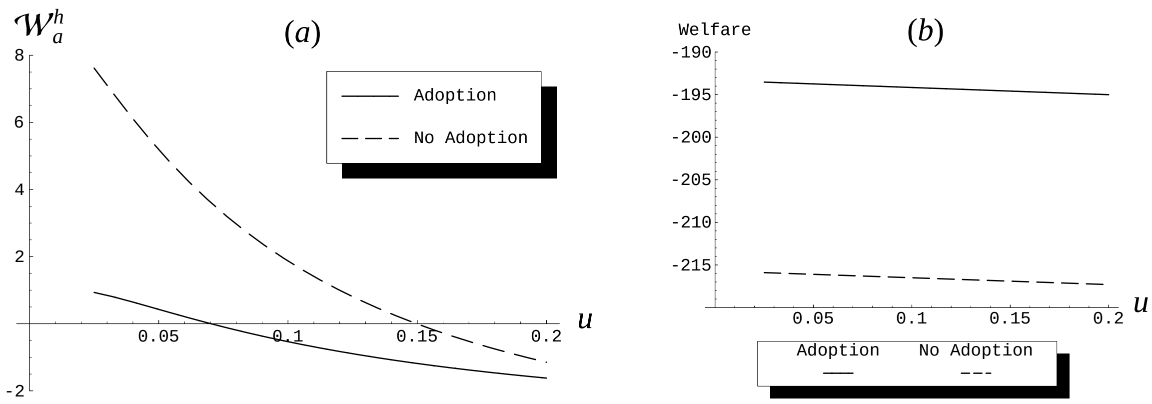

Figure I.3:
(a) Skilled workers' expected gain of adoption for u changing from 2.5% to 20%.
(b) Social welfare for economies where there is adoption or rejection of the new technology.

$\mu_{1,h}W_{\pi,h}$. This figure shows that the whole economy is better off when the new technology is implemented than when it is rejected. The rejection of the new technology represents a welfare loss for the whole economy.

In figure I.4 I perform the same experiment but increasing the probability of being displaced to 30% if the new technology is implemented, i.e., $\lambda_a = 0.7$. In this case barriers become stronger. This result suggests that new technologies are more likely to be rejected the higher is the labor substitutability of the technology, which in this case is modeled as the inability to operate the new technology.

Example 3.2

In this example I consider economies with the same cost of creating jobs but different levels of unemployment benefit b. All unemployed workers receive a transfers b in addition to the home production π_0, i.e., the income of an unemployed worker is $w_u = \pi_0 + b$. The unemployment benefit is financed by a lump sum tax to all employed workers. The economy with $b = 0$ has an unemployment rate equals to 15.75%, and the rest of parameters are like in the previous example. Note that for this level of

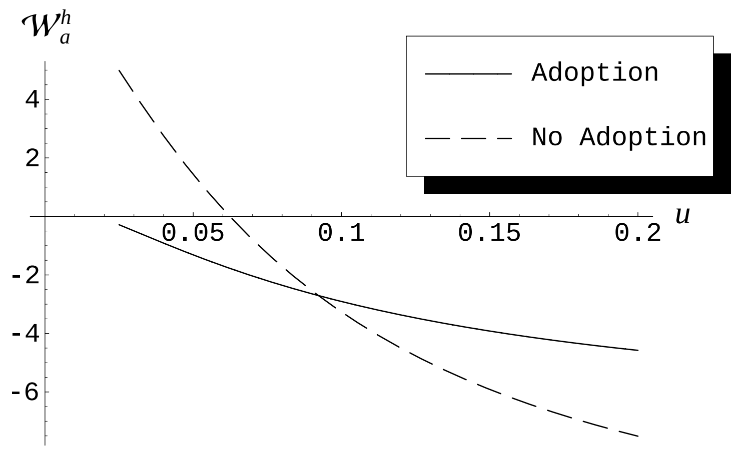

Figure I.4: Skilled workers' expected gain of adoption for u changing from 2.5% to 20% and $\lambda_a = 0.7$.

unemployment, $u = 15.75\%$, there is already a barrier to the adoption of the new technology. The experiment consists in increasing b and observes how workers decision change in economies with higher b. Figure I.5 shows how $\mathcal{W}_a^h$ changes for the different economies. Note that $\mathcal{W}_a^h$ decreases as b increases, which implies that barriers to technological change are more severe in economies with high unemployment benefit. This surprising result was unexpected. In principle one could expect the insurance effect that the UI provides to offset the risk of becoming unemployed. In a general equilibrium context, however, economies with high unemployment benefit and the same cost of creating jobs exhibit higher unemployment rates. The higher unemployment rate offsets the insurance effect of the UI and leads to higher barriers. In the present example the unemployment rate increases from 15.75% when $b = 0$ to 22% when $b = 0.012$.

This result does not imply that for two economies with the same unemployment rate but with different level of unemployment benefits, the economy with the higher unemployment benefit should exhibit higher barriers. The economy with the higher unemployment benefit is certain to exhibit weaker barriers because the unemployment

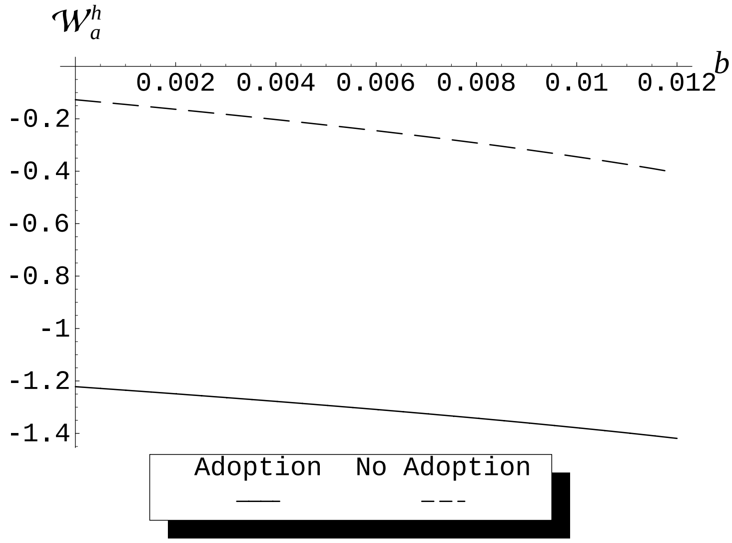

Figure I.5: Skilled workers' expected gain of adoption $\mathcal{W}_a^h$ for economies that differ only in the value of b.

risk is smaller. But, in order to have the same unemployment rate, the economy with the higher unemployment benefit requires a lower cost of creating jobs.

4 Severance Payment System

Example (3.2) shows that economies with generous unemployment benefit exhibit higher barriers to the adoption of new technologies than similar economies with less generous unemployment benefit when they face the same cost of creating jobs. In this section I consider the inclusion of a severance payment system and study how barriers to the adoption of new technologies change. The motivation of this experiment is the following. Severance payment system does not discourage employment, as the unemployment insurance system does, since it does not depend on the unemployment spell, and the increase in unemployment was the main reason why the UI performed badly in the previous section. In addition, according to Rogerson and Schindler (2002), a severance payment system seems to be appropriate to reduce the losses of displaced workers, which in this model is a key factor in the determination of barriers to technological changes.

The mechanism through which a severance payment helps displaced workers to reduce their losses is saving. When a worker is displaced he receives a severance payment and distributes it in an optimal way in order to smooth his future consumption. The possibility of distributing the severance payment throughout the future is essential when workers are risk averse since for them consumption smoothing is very important. Unfortunately, I do not have saving in my model. A simple approach to this problem, which allows me to use the same framework, is to assume that workers are risk neutral. Risk neutral workers are indifferent in the way the severance payment is distributed throughout the future, which makes saving unnecessary.[11] This simplification, however, makes more difficult the existence of barriers since the risk of becoming unemployed or losing skill have less importance.

Note that the risk neutrality assumption rules out any insurance aspect of the system. In addition, the effect of a pure transfer from employer to worker is neutral under bilateral bargaining because the worker would compensate the employer for the expected transfer ex-ante in the form of lower initial wages.[12] Although severance payments do not have any effect on labor market outcomes, it can still have interesting redistributive consequences that can help to reduce barriers to technological changes.

The severance payment policy considered entitles all workers who are displace either because the firm closes down or because of a technological change to receive a payment T at the moment of separation, and the system is financed by a lump sum tax, τ, to all employed workers.[13] Since this payment is a one-time shock and because only

[11]The results obtain in this section would be undoubtedly stronger if workers were risk averse. When workers are risk averse the barriers to a technological change are higher and the possibility of saving plays a more relevant role.

[12]Lazear (1986, 1990) notes that if contract were perfect, severance payments would be neutral. Burda (1992) also derives the Lazear result in a search environment with exogenous job destruction.

[13]This way of modelling the system does not increase workers bargaining power and, therefore, has

workers who are displace either because the firm closes down or because of a technological change can receive the payment, the policy does not affect workers' bargaining power and has not direct effect on unemployment.

All value functions for the firm and the value of being unemployed remain unchange. The transition dynamics of the model also hold. The new value function for workers are:

$$r\, W_{\pi,l} = w_{\pi,l} - \tau + \pi_h \left(W_{\pi,h} - W_{\pi,l}\right) - \phi \left(W_{\pi,l} - (U + T)\right), \tag{I.30}$$

$$r\, W_{\pi,h} = w_{\pi,h} - \tau - \phi \left(W_{\pi,h} - (U + T)\right), \tag{I.31}$$

$$\begin{aligned} r\, W_l &= w_l - \tau + \pi_h \left(W_h - W_l\right) - \phi \left(W_l - (U + T)\right) + \gamma\, \mathcal{I}(\mathcal{F}_a^l) \max\{\lambda_a W_{\pi,l} \\ &\quad + (1 - \lambda_a)(U + T) - W_l, 0\}, \end{aligned} \tag{I.32}$$

$$\begin{aligned} r\, W_h &= w_h - \tau - \phi \left(W_h - (U + T)\right) + \gamma\, \mathcal{I}(\mathcal{F}_a^h) \max\{\lambda_a(\delta_h W_{\pi,h} + (1 - \delta_h) W_{\pi,l}) \\ &\quad + (1 - \lambda_a)(U + T) - W_h, 0\}, \end{aligned} \tag{I.33}$$

where upon separation the insider worker receives the severance payment T. Since workers are risk neutral I assume that they have the same discount rate than firms, i.e., $\rho = r$. An equilibrium also requires that $V = I_c$, so that there is not profitable entry by new firms. The Nash bargaining solution for wages are now

$$\beta \left(J_{\pi,l} - V_\pi\right) = (1 - \beta)(W_{\pi,l} - U),$$

$$\beta \left(J_{\pi,h} - V_\pi\right) = (1 - \beta)(W_{\pi,h} - U),$$

$$\beta \left(J_l - V\right) = (1 - \beta)(W_l - U),$$

$$\beta \left(J_h - V\right) = (1 - \beta)(W_h - U),$$

neutral effects on real variables as the effects of a direct transfer from the firm to the worker.

and workers decision are studied by the functions:

$$\mathcal{W}_a^l = \lambda_a W_{\pi,l} + (1-\lambda_a)(U+T) - W_l, \tag{I.34}$$

$$\mathcal{W}_a^h = \lambda_a(\delta_h W_{\pi,h} + (1-\delta_h)W_{\pi,l}) + (1-\lambda_a)(U+T) - W_h. \tag{I.35}$$

As before, a skilled (unskilled) worker will accept a technological change only if $\mathcal{W}_a^h \geq 0$ ($\mathcal{W}_a^l \geq 0$, respectively). It can be observe from equations (I.34) and (I.35) that an increase in T increases the net gain of adopting the new technology for both unskilled, $\mathcal{W}_a^l$, and skilled, $\mathcal{W}_a^h$, workers. Since a high T does dot increase the bargaining power of workers the result of having a high T would be weaker barriers by workers.

4.1 Numerical examples II

In this section I study numerically the effect of a severance payment system on barriers to technological changes.

Example 4.1

This example considers the same parametrization used in example (3.1), except for the technological change. The parameters of the technological change are as follow. The new technology is 40% more productive than the current technology, so $\pi = 1.4$. Workers' probability of being displaced is 0.30, which implies that $\lambda_a = 0.7$. The probability that a skilled worker remain skilled with the new technology is $\delta_h = 0.7$. Finally, for the technological change to be optimal for all firms I take $\epsilon = 0.4$. Under these assumptions low and high productive firms are always willing to adopt the new technology, and low skilled workers do not reject the technological change. Figure I.6 shows the expected gain of accepting the new technology for a skilled worker, $\mathcal{W}_a^h$, in economies with different unemployment rates. For economies with unemployment rate less or equal than 7.5% it is neither optimal for workers to accept the new technology when everybody is accepting nor it is optimal for them to reject the new technology when everybody is rejecting. These economies should exhibit an intermediate level of adoption. Workers, however, are more reluctant to the change the higher is the unemployment rate, and when the unemployment rate is greater or equal than 7.5% there exits *a barrier to the technological change*.

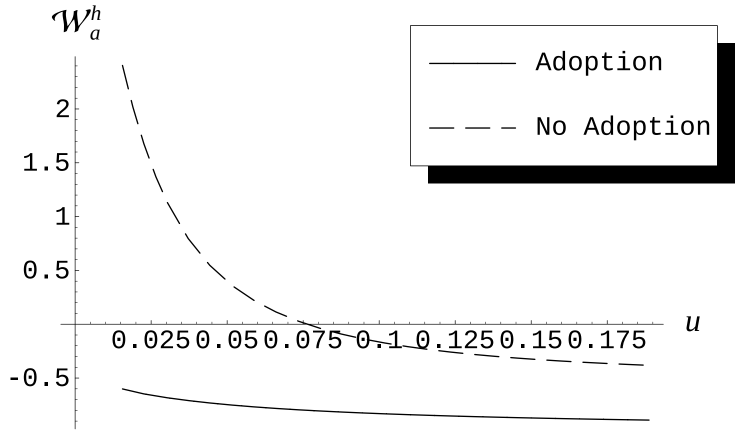

Figure I.6: Skilled workers' expected gain of adoption for u changing from 2.5% to 20%.

I consider now economies with the same cost of creating jobs but with different severance payments T. The economy with $T = 0$ has an unemployment rate equals to 15%, and the rest of parameters are like in the previous example. Note that for this level of unemployment, $u = 15\%$, there is already a barrier to the adoption of the new technology. The experiment consists in increasing T and observe how workers decision change.

Figure I.7(a) shows the change in $\mathcal{W}_a^h$ for the different economies. Observe from this figure that $\mathcal{W}_a^h$ increases as T increases. This implies that barriers to technological change are weaker in economies with high values of T, and the barriers disappear in economies with T large enough. In the present example the barriers vanish for val-

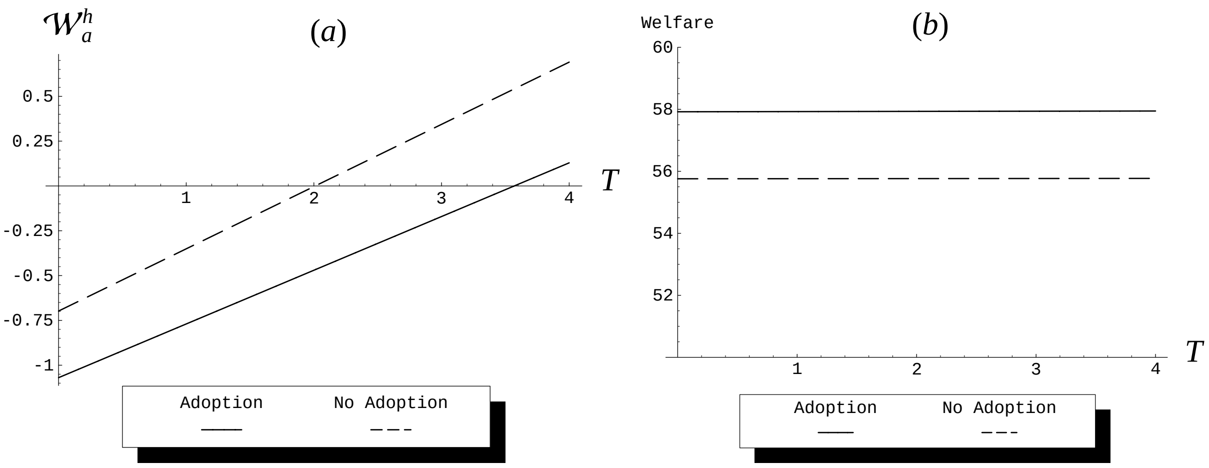

Figure I.7:
(a) Skilled workers' expected gain of adoption for T changing from 0 to 4.
(b) Social welfare for economies where there is adoption or rejection of the new technology.

ues of T greater or equal than 3.6. Since the system plays only a redistributive role, social welfare is independent of the transfer T as figure I.7(b) indicates. Nonetheless, an equilibrium with adoption exists in economics with transfers greater or equal than 3.6. Thus, those economies are better-off than economies with no transfer since the equilibrium with adoption exhibit a higher level of welfare than the equilibrium with no adoption. This result indicates that a severance payment system can help to eliminate barriers to technological change, and that the elimination of such barriers may be desirable for the whole society as it implies an increase in the level of welfare.

Figure I.8 shows that under this new set of parameters the unemployment insurance system continues performing badly. These observations indicate that a severance payment system financed by a lump sum tax seems to be more effective in eliminating barriers to technology adoption than an unemployment insurance system. the previous exercises suggest that policymakers should be very careful when designing welfare policies because they can have negative effects of technological progress.

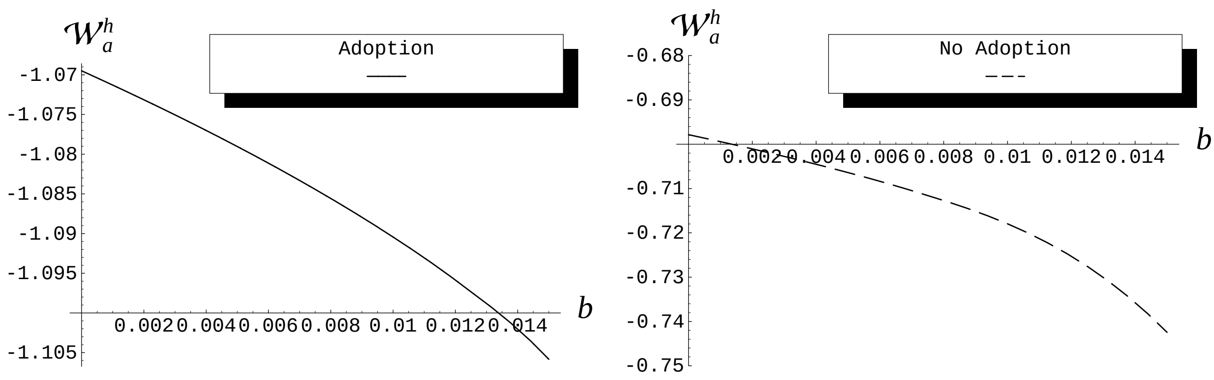

Figure I.8: Skilled workers' expected gain of adoption $\mathcal{W}_a^h$ for economies that differ only in the value of *b*.

5 Conclusions

This chapter presents a model that includes labor market frictions, capital market imperfections and heterogeneity in workers' skills in order to study the existence of barriers to the adoption of new technologies or implementation of better work practices.

I analyze numerically the effects of labor market frictions on barriers to technological changes by studying the circumstances under which workers may be willing to reject a new technology. I find that when the unemployment rate is large and workers have the possibility of losing skills if fired, new technologies are more likely to be rejected.

This work suggests that the design of social policies to deal efficiently with these barriers is not trivial. I consider two different social policies: an unemployment insurance system and a severance payment system. With respect to the unemployment insurance system I find that for economies differing only on the level of unemployment benefit, the one with the higher level of unemployment benefit has stronger barriers to technological changes than the one with the lower level of unemployment benefit. The explanation is that economies with high unemployment benefit and the same cost of creating jobs exhibit higher unemployment rates. The higher unemployment rate offsets the insurance effect of the UI and leads to higher barriers. This suggests that welfare policies have to be careful designed since no well designed policies can have negative effects on technological progress.

Then I consider a severance payment system. Under this system all workers who are displace either because the firm closes down or because of a technological change are entitled to receive a lump sum payment at the moment of separation. The experiments show that barriers to technological change are weaker in economies with high transfers. In practice this policy requires the identification of those workers who are displace because of a technological change which represent a limitation of the policy.

Chapter II

Low TFP in the Investment Sector, the Informal Economy, and International Income Differences

1 Introduction

The existence of a large informal sector has always been considered as a bad indicator of an economy's performance. This is confirmed by the strongly negative correlation between the size of the informal sector and per capita GDP as shown in figure II.1. The correlation between the log of per capita GDP and the share of output produced in the informal sector for the sample is -0.86.[1] There may be many plausible explanations for the existence of such large informal sectors in many poor and developing countries. One potential explanation, connected with De Soto's (1989) work, is related to a form of implicit taxation, due to obstacles to production, prohibitions, corruption, and bureaucratic regulations, among others, which lead to a high entry costs in the formal sector and low investment rates.

Low income countries are not only plagued by high entry costs but they also face

[1] Loayza (1996) derives a similar finding using a multiple-cause-multiple-indicator (MIMIC) method for a sample of 14 Latin American countries. He obtains a strong negative correlation (-0.7) between the size of the informal sector and real per capita GDP.

higher relative price of investment than rich countries (see, Easterly (1993) and Jones (1994)). A higher relative price of investment discourage investment and reduces the creation of formal jobs which, in turns, provides incentives to unemployed workers to engage in informal business.[2] According to Hsieh and Klenow (2003), low PPP investment rates in poor countries are not due to low savings rates or to high tax or tariff rates on investment but to low efficiency in producing investment goods. These observations suggest that high entry costs and low efficiency in the investment sector are likely to play an important role in explaining the large observed international income disparities and the size of the informal sector.

In this chapter I study the extent to which one can account for international disparities on income and on the size of the informal sector with differences in policies that either increase the entry cost in the formal sector or distort the efficiency of the investment sector and, as a consequence, distort the accumulation of capital. To this end, I introduces an informal sector into an otherwise standard neoclassical growth model with monopolistic competition in the formal sector. The informal sector uses a labor intensive technology to produce one good that is an imperfect substitute of the goods produced in the industrial sector.

The main result of this chapter is to show that the model constructed is able to generate income differences consistent with the observed international patterns for differences in the productivity of the investment good sector that generate reasonable differences in the relative price of investment. The aggregate income of an economy where the low productivity of the investment sector raises the relative price of investment with respect to consumption by a factor of 4 is 14% of the benchmark economy, and the share of employment in the informal sector is 73%. The capital to output ratio

[2] Restuccia and Urrutia (2001) show that the relative price of investment is negatively correlated with investment rates in a cross section of countries, and Hsieh and Klenow (2003) show that the positive correlation between PPP investment rates and PPP income levels across countries is almost entirely driven by differences in the price of investment relative to output across countries.

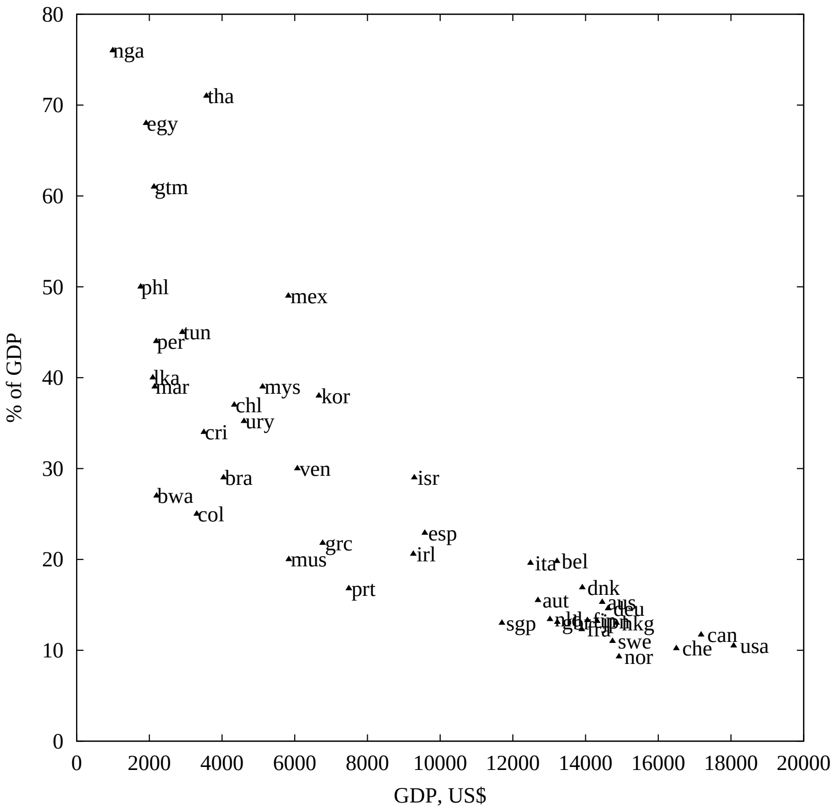

Figure II.1: Estimates of the underground economy as a percentage of measured GDP. Country codes as in the Summers and Heston data set. The data from the informal sector is as reported in Schneider and Enste (2000). This figure is from Koreshkova (2003).

is 3.12 times smaller than in the benchmark economy. These income differences generated by the model are larger than in a standard one-sector growth model with similar capital share, which implies that a country with low TFP in the investment sector that increases the price of the investment good relative to the consumption good by a factor of 4 has an aggregate income of 50% of the benchmark economy, and larger than two sector-models with technology choice, like the one presented by Restuccia (2004), which implies that a country with a relative price of investment of 4 has an aggregate income of 41% of the benchmark economy.

The intuition for this result is the following: a reduction in the productivity of the investment sector increases the rental price of capital and discourages the creation of firms in the formal sector causing a reduction in competition. The fall in competition allows monopolies to operate old technologies more intensively by allocating more labor and less capital to old vintages which, in turns, causes a sharp decrease in output per worker in the formal sector. This reallocation effect is similar to mechanism present in the home production model of Parente, Rogerson and Wright (2000) or the multi-sectoral models of Restuccia (2004) which generate differences in output per worker, mainly through the reallocation of inputs from high productive sectors to low productive ones.

A second important result is that to generate a relative price of investment of a factor of 4 with respect to the benchmark economy, the model only requires a reduction in the productivity of the investment sector of a factor of 3.11, which is smaller than the distortions required by the home production model of Parente et al. (2000) or the multi-sectoral models of Restuccia (2004). This result comes from the assumption that the good produced in the informal sector can not be used in the production process of the investment good. The implication of this assumption is that the price of the investment good differs from the price of the consumption good, which is a composite good of both formal and informal goods. Given that the informal sector uses a labor intensive technology, any distortion that reduces the productivity of the investment sector raises the price of capital making the goods produced by the formal sector more expensive, because the formal sector uses capital more intensively than the informal sector. A reduction of the productivity of the investment sector raises the price of the investment good by more than the price of consumption. The low price of consumption goods in poor countries, therefore, might be due to the existence of large informal sectors that generally produce their goods with labor intensive technologies.

De Soto (1989) reports examples of the type of economic policy and institutions that have affected economic development in Peru, and argues that obstacles to production account for a large fraction of the low returns to capital investment during the period. He describes a simulation performed by his researchers' team to quantify the time necessary to legally open a small business in Peru in 1983, without reverting bribes. They spent six hours a day at it and finally registered the business 289 days later. Although the garment workshop was supposed to be operated by only one worker, the cost of legal registration was $\$1,231$ - thirty-one times the monthly minimum wage. These kind of regulations affect the creation of firms by substantially increasing the startup cost of business.

To assess the quantitative effect of the De Soto's (1989) argument that the size of the informal sector is mainly determined by entry barriers, I perform a "De Soto experiment". In this experiment I analyze how much of the differences in the size of the informal sector and in per capita income can be accounted for by policies that increase the entry cost in the formal sector. The quantitative exercises suggest that a higher entry cost is associated with both a larger informal sector size and a lower per capita income level. The magnitude of this effect, however, is modest. To generate an aggregate income of 50% of the benchmark and a share of employment in the informal sector of 34%, the required entry cost should be 7.6 times higher than the entry cost of the benchmark, which seems a bit higher. I see this result as complementary to Antunes and Cavalcanti (2006) who examine how much of the difference in the size of the informal sector and in per capita income across countries can be accounted for by regulation costs and enforcement of financial contracts. They find that for developing countries contract enforcement and regulation costs are equally important in accounting for the size of the informal sector, but they do not account for most of the income differences observed among countries. My findings also point to the importance of the combination of distortions to the efficiency of the investment sector and costly barriers to entry. These two distortions are likely to coexist in poor countries and they have the potential to explain a large part of the observed international income differences.

The rest of the chapter proceeds as follows. In section 2 the details of model and define the equilibrium are presented. The calibration procedure is discussed in section 3, and in section 4 I perform some numerical simulations to assess quantitatively the effect of policies that distort the productivity of the investment sector on the size of the informal sector and income differences. The "De Soto experiment" is presented in section 5. Section 6 offers a sensitivity analysis of an important parameter of the models, and section 7 concludes.

2 The economy

I consider an infinite-horizon model of infinitely lived heterogeneous agents. The economy consists of a household sector, an industrial sector, and an informal or extralegal sector. In the industrial sector there is a positive measure of differentiated goods, each of which is produced by a monopoly. The informal sector produces only one good, and the household sector is composed of a measure one of risk adverse individuals, who are endowed with one unit of time every period. The utility function of each individual is

$$E_0\left(\sum_{t=0}^{\infty}\beta^t \frac{c_t^{1-\sigma}}{1-\sigma}\right),$$

where c_t is a consumption good, β is the discount factor, and $\sigma > 0$. The consumption good is a composite good defined over the good $x_{IS}(t)$ produced in the informal sector and a good $x_{fs}(t)$ produce in the formal sector, both indexed by date $t \in \{0, 1, 2, ...\}$. It is given by,

$$c_t = \left(\mu\ x_{fs}(t)^{\gamma_s} + (1-\mu)\ x_{is}(t)^{\gamma_s}\right)^{\frac{1}{\gamma_s}}. \tag{II.1}$$

The parameter $0 < \gamma_s < 1$ is the elasticity of substitution between the formal and the informal good. Large values of γ_s are associated with a higher substitutability between formal and informal goods. The composite good produced in the formal sector is given by

$$x_{fs}(t) = \left(\int_0^v x_i(t)^\gamma di \right)^{\frac{1}{\gamma}},$$

where $x_i(t)$ are differentiated goods produced in the industrial sector, index by type $i \in [0, v]$ and by date t, and $v > 0$ is the measure of differentiated goods that is endogenously determined in equilibrium. The parameter $0 < \gamma < 1$ measures the degree of competition in the formal sector.

Given prices p_{it} for the differentiated goods i, this preference specification implies the household's demand for good i is

$$x_i(p_{it},\ c_t,\ t) = \left(\frac{\mu\ P_t}{p_{ft}}\right)^{1/(1-\gamma_s)} \left(\frac{p_{it}}{p_{ft}}\right)^{\frac{1}{\gamma-1}}\ c_t, \tag{II.2}$$

and the demand for the informal good is

$$x_{is}(c_t,\ t) = ((1-\mu)P_t)^{1/(1-\gamma_s)}\, c_t,$$

where the price of the informal good has been normalized to one, $p_{ft} = \left(\int_0^v p_{jt}^{\gamma/(\gamma-1)} dj\right)^{(\gamma-1)/\gamma}$, and P_t is the aggregate price of the composite good given by

$$P_t = \left(\left(\frac{1}{\mu}\right)^{\frac{1}{\gamma_s-1}} p_{ft}^{\frac{\gamma_s}{\gamma_s-1}} + \left(\frac{1}{1-\mu}\right)^{\frac{1}{\gamma_s-1}} \right)^{\frac{\gamma_s-1}{\gamma_s}}.$$

The informal sector in the model is an alternative to unemployment. To generate unemployment I introduce search friction in the economy as in Alvarez and Veracierto (2001). The search friction takes place only in the formal sector and unemployed individuals must divide their time between searching for a job in the formal sector and working in informal activities. To simplify the exposition of the model I abstract from search friction in the informal sector, although it is argued that employment in the informal sector is also very volatile. Firms in the formal sector must hire agents at a common labor market, which changes location randomly over time, and the probability that an unemployed individual finds the labor market depends on the individual's search intensity level according to a matching function. The matching function $m(\eta)$ depends positively on the time devoted to search the labor market η. Thus, the probability of finding the labor market increases with the individual search intensity.

Each differentiated good is produced by a monopoly that uses capital and labor as factors of production. A new technology appears in every period and grows at a constant rate g. Once a firm enters the market it can not update the technology, which implies that its technology depreciate over time relative to the newest technology. Accordingly, firms with different productivities will coexist in the economy and will use factors of production with different intensity levels. As we will see later, economies with low TFP in the investment sector are going to use old technologies more intensively and, as a consequence, will exhibit low levels of output per worker. The production function of a firm that uses a technology that appears in period t_0 is

$$y_t = {k_t}^{\alpha}(A_{t_0} n_t)^{1-\alpha},$$

where $A_{t_0} = A_f(1+g)^{t_0}$ is a technology parameter, k_t is capital, and n_t is labor.

Firms producing new differentiated goods can be created if $I_c(t)$ units of the consumption good are allocated to it. This cost includes the technology cost and the entry cost, and it grows at the same rate than the technology. Firms in the formal sector face a constant risk of being destroyed every period, and when a firm closes down all workers in that firm becomes unemployed. Unemployed individuals can freely use a linear technology that uses labor as the only factor of production. This technology is less productive than the one used in the formal sector and can be used to produce the informal good. The measure of individuals that uses this technology constitute the informal sector. The productivity of the technology used in the informal sector equals

$$B_t = A_i(1 + g)^t.$$

The good produced in the formal sector can be used for consumption purposes or to accumulate physical capital. The informal good can only be consumed. It can not be used in the accumulation of capital. I consider the modification of the capital accumulation equation used by Parente and Prescott (1994). This modification has become standard in the cross-country income level analysis and states that the aggregate capital stock k_t satisfies the law of motion

$$K_{t+1} = (1 - \delta)K_t + x_t/\pi,$$

where δ is the depreciation rate, x_t is gross investment in physical capital, and π is a technology parameter that determines the rate at which the formal good is transform into capita. Notice that π also determines the price of capital since in order to obtain one unit of capital we need to invest π units of the formal good. This implies that the price of one unit of capital equals πp_f, where p_f is the price of one unit of the formal good.

Finally, a competitive banking sector accepts deposits from agents at the interest rate i and holds physical capital and firms as counterparts. Firms rent capital at the rental price r, and in equilibrium there is no arbitrage between the different type of investments. i.e., $r = i + \delta$.

Before defining equilibrium for this economy, I normalize all variables and define output relative to the newest vintage. That is:

$$k_t = K_t/(1+g)^t$$

and the same for c, y, and I_c. I also transform the consumers discount factor to $\tilde{\beta} = \beta(1+g)^{1-\sigma}$ and the financial intermediary discount factor to $\tilde{i} = (1+g)/(1+i)$.

In what follows I focus on the steady-state of the normalized economy, which corresponds to the balance growth path of the economy. The steady-state competitive equilibrium I consider is characterized by a complete lack of private insurance markets. Agents have no access to private insurance markets and they are not allow to borrow. The only way they can privately smooth consumption across employment states is by saving in an interest-bearing asset.

As in Alvarez and Veracierto (2001), I assume that agents cannot verify the state of a particular firm when they join it. This assumption guarantees that all hiring firms will offer the same wage rate in equilibrium which grows at the rate g. Once an agent joins a firm, the firm's individual state is revealed to the agent, but the wage rate cannot be renegotiate. Under these assumptions, agents are identical from the hiring firms' point of view and the hiring firms are ex-ante identical from the agents' point of view, which imply that the market for new hires will be perfectly competitive. The labor contracts I consider specify that the market wage per unit of labor supply should be paid as long as the employment relationship last.

The objective of the remaining of this section is to define an equilibrium of the economy. To define the equilibrium I need to specify how firms and workers take their decisions in the economy. The individual state of a firm is given by the age s of the vintage it uses. The problem of a firm with current vintage s is to maximize the current period profit, taking as given the wage rate per unit of labor supply, w, the rental price of capital r, the aggregate price level P, and the demand for the differentiated good

$x_i(p,\ Y)$ given by equation II.2, where Y is the aggregate demand of the composite good. This maximization problem is stated as follows:

$$\Pi(s) = \max_{k_s,\ n_s} \left\{ p_s(y_s, Y)\, y_s - w\, n_s - r\, \pi\, p_f\, k_s \right\} \tag{II.3}$$

subject to (II.4)

$$y_s = {k_s}^{\alpha} (A_f (1+g)^{-s}\, n_s)^{1-\alpha},$$

where πp_f is the price of one unit of capital and $p_s(y_s, Y)$ is the inverse demand function given by

$$p_s(y_s) = \left(\frac{y_s}{C_1}\right)^{\gamma-1},$$

where

$$C_1 = \left(\left(\frac{p_f}{\mu\, P}\right)^{\frac{1}{\gamma_s - 1}} C + X \right) p_f^{\frac{1}{1-\gamma_s}}, \tag{II.5}$$

C is aggregate consumption, and X is aggregate investment in capital.

In equilibrium, since banks can create new firms by allocating I_c units of the consumption good to it and their discount factor is $1/R = (1+g)/(1+i)$, the following free entry condition must be satisfied:

$$P\, I_c = \sum_{s=0}^{\infty} \left(\frac{1-\phi}{R}\right)^s \Pi(s), \tag{II.6}$$

where ϕ is the probability of being destroyed faced by each firm every period. The free entry condition (II.6) states that the expected discounted value of a newly created firm must be equal to the fixed entry cost.

I now proceed to define the agents' problem. At any point in time an agent is either employed or unemployed. Unemployed agents divide their unit of time between searching for a job in the industrial sector and working in the informal sector. The individual state of an agent is given by the agent's employment status and by her current assets level a. Let $W(a)$ and $U(a)$ represent the value of being employed in a formal firm and the value of being unemployed, and working in the informal sector, for an agent with current assets level a. An employed worker with current assets level a maximize

$$W(a) = \max_c \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \tilde{\beta} \left[(1-\phi)\, W(a') + \phi\, U(a') \right] \right\} \tag{II.7}$$

subject to

$$(1+g)\, a' = (1+i)\, a + w - P\, c,$$

$$a' \geq 0.$$

In the next period, with probability $(1-\phi)$ a worker will remain employed in the firm and obtains a value of $W(a')$, and with probability ϕ the firm closes down and workers becomes unemployed. Displaced workers obtain the value $U(a')$. Unemployed agents find the labor market with probability $m(\eta) = \eta^l$, where η denotes individual search intensity and $l > 0$, and when they find it they join some randomly determined firm among those that hire obtaining a value of $W(a')$.[3] With probability $(1-m(\eta))$ the agent continues being unemployed. The income of an unemployed agent is determined by the asset holding and by the income earn in informal activities $(1-\eta)w_i$, where w_i is the wage paid in the informal sector per unit of labor supply.

The value of being unemployed for an agent with current assets a satisfies the

[3] This matching function is similar to the one used by Alvarez and Veracierto (2001).

following functional equation:

$$U(a) = \max_{c,\,\eta} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \tilde{\beta} \left[m(\eta)\, W(a') + (1 - m(\eta))\, U(a') \right] \right\} \tag{II.8}$$

subject to

$$(1+g)\, a' = (1+i)\, a + (1-\eta)\, w_i - Pc,$$

$$a' \geq 0.$$

An important observation is that the lower the wage gap between the formal and the informal sector, the smaller the difference between the value of been employed in the formal sector and the value of been unemployed and working in the informal sector. A small premium for formalization decreases agents' incentive to look for a job in the informal sector, η, and, as a consequence, increases the size of the informal sector. This makes the model consistent with the empirical finding documented by Lemieux, Fortin and Fréchette (1994) that after-tax wages in the formal sector are negatively correlated with hours worked in the informal sector.

2.1 Distributions

The second step to define an equilibrium is to determine how firms and workers are distributed across the different states of the economy. In the steady state the measure of firms using the different vintages are described by a time invariant measure χ. This measure is defined by

$$\begin{cases} \chi(0) &= \phi\, v, \\ \chi(s) &= (1-\phi)\chi(s-1), \text{ for } s = 1, 2, 3, \ldots. \end{cases} \tag{II.9}$$

Let $g(a,\ j)$ be the optimal saving decision rule for a type (a, j) individual, where $j = u$ means that the individual is unemployed and $j = e$ means that she is employed.

Let $\eta(a)$ be the optimal search decision rule for unemployed agents. The distribution of agents is characterized by time invariant measures $\Phi(a,\ j)$ describing the number of employed and unemployed agents across individual states. These measures are implied by the optimal search rule $\eta(a)$ and the optimal saving rules $g(a,\ j)$. In particular, the measure Φ satisfies

$$\Phi(A_0,\ e) = \int\limits_{\{a:g(a,u)\in A_0\}} m(\eta(a), S_u)\, d\Phi(a,\ u) + \int\limits_{\{a:g(a,e)\in A_0\}} (1-\phi)\, d\Phi(a,e), \qquad \text{(II.10)}$$

for all $A_0 \in B(\mathbb{R}_+)$, where $B(\mathbb{R}_+)$ is the borel σ-algebra of $\mathbb{R}_+$. The first term in this equation is all those unemployed agents who find a job in the formal sector and save an amount that belongs to A_0. The second term is all those employed agents whose net saving is in A_0, and remain employed. The measure of unemployed agents with asset levels in A_0 is given by all those unemployed agents who do not find a job plus those employed workers who become unemployed because of the shutting down of firms which savings are in A_0. That is,

$$\Phi(A_0, u) = \int\limits_{\{a:g(a,u)\in A_0\}} (1 - m(\eta(a),\ S_u))\, d\Phi(a,\ u) + \int\limits_{\{a:g(a,e)\in A_0\}} \phi\, d\Phi(a,\ e). \qquad \text{(II.11)}$$

Finally, the units of work allocated to informal activities is:

$$\Phi_i = \int\limits_{\mathbb{R}_+} (1-\eta(a))\, d\Phi(a,u). \qquad \text{(II.12)}$$

2.2 The aggregate production function in the formal sector

An important question I wanted to address in this chapter was whether the introduction of monopolistic competition in the formal sector together with the low TFP in the investment sector were able to generate endogenous TFP differences in the formal sector. The answer to this question turns out to be no. TFP in the formal sector depends only on some parameters of the model. To illustrate this point I compute the average TFP of the formal sector which is given by

$$\text{Average TFP} = \frac{1}{v}\sum_{s=0}^{\infty}\left[A_f(1+g)\right]^{1-\alpha}\chi(s) = \frac{\phi A_f^{1-\alpha}}{(1+g)^{1-\alpha}-1+\phi}.$$

This average TFP depends positively on the job destruction rate ϕ, which is an exogenous parameter in my model. Economies with large destruction rates will update their technologies faster and, as a consequence, will exhibit a higher productivity. Properly modelling the job destruction decision is a potential extension that could help us to better understand the effects on TFP of the interaction between monopolistic firms and labor market frictions. This extension is in line with Lagos's (2006) work. He shows how aggregate TFP depends on all the characteristics of the labor market as summarized by the job-destruction decision, and used his model to study the effects of labor-market policies on the level of measured TFP. In his model labor-market policies can make an economy exhibit a low level of TFP by distorting the way in which firms react to the economic environment. As a result, two economies may exhibit different levels of TFP even if production units in both have access to the same technology.

2.3 Equilibrium

In this section I define the steady state equilibrium of the economy, which corresponds to the balance growth path. Let $c(a, j)$ be the optimal consumption rule for a type (a, j) individual. The aggregate demand of the consumption good equals household consumption plus investment in the creation of new firms. It is given by

$$C = \sum_{s\in\{e,u\}}\int_{\mathbb{R}_+} c(a,s)\, d\Phi(a,s) + \phi\, v\, I_c.$$

Total production of the i differentiated good y_i, $i \in [0,\ v]$, and production of the informal good y_{is} are given by

$$y_i = k(s_i)^{\alpha} \left(A_f (1+g)^{-s_i}\ n(s_i)\right)^{1-\alpha},\quad \forall i \in [0, v], \tag{II.13}$$

and

$$y_{is} = A_i\ \Phi_i. \tag{II.14}$$

Definition 1 *A stationary equilibrium for this economy is: a set of prices* $\{r,\ w,\ P\}$*, a set of functions for the firms* $\{\Pi,\ p_s,\ n_s,\ k\}$*, and for workers* $\{W, U, g, \eta, c\}$*, and a set of time invariant measures* $\{\Phi,\ \chi\}$ *such that the following conditions hold:*

(i) Given i, r, and w, the functions k and n solve the firm's problem given by (II.3).

(ii) Given i, w, and P, the functions W, U, g, η, and c solve the agent's problem (II.7) and (II.8).

(iii) The measure χ satisfy the condition given by (II.9).

(iv) The measures Φ, and Φ_i are consistent with the individual decisions of agents as given in equations (II.10), (II.11) and (II.12).

(v) Given the aggregate price p_f and the interest rate i the function Π satisfies the free entry condition (II.6).

(vi) Markets clears:

Good's market:

$$x_i(p_i, C) + (\delta + g)\pi\ K \left(\frac{p_i}{p_f}\right)^{\frac{1}{\gamma-1}} = y_i,\quad \forall i \in [0, v] \tag{II.15}$$

$$x_{is}(C) = y_{is}, \tag{II.16}$$

$$C = \left(\mu \left(\int_0^v x_i(p_i, C)^{\gamma} di\right)^{\gamma_s/\gamma} + (1-\mu)\ x_{is}(C)^{\gamma_s}\right)^{1/\gamma_s},$$

where (II.15) is the equilibrium condition in the formal sector, (II.16) is the equilibrium condition in the informal sector.

Labor Market: *The number of unemployed agents who find the labor market must equal total hiring by firms.*

$$\int_{\mathbb{R}_+} m(\eta(a))\, d\Phi(a,u) = \phi \int_{\mathbb{R}_+} d\Phi(a,e). \tag{II.17}$$

Financial Market: *The total amount of savings by agents must equal the total value of assets owned by the banking sector.*

$$\sum_{s\in\{e,u\}} \int_{\mathbb{R}_+} a\, d\Phi(a,s) = \pi\, p_f K + \Big(\int_0^v \big(p_i\, y_i - w\, n(s_i) - r\, \pi\, p_f\, k(s_i)\big)\chi(s_i)\, di - \phi\, v\, PI_c \Big)/i, \tag{II.18}$$

where $K = \int_0^v k_{s_i}\, \chi(s_i)\, di.$

(vii) The no-arbitrage condition $r = i + \delta$ *is satisfied.*

3 Calibration

The quantitative exercise is based on the following strategy. First, choose a base country and find a set of parameters such that the informal sector size, along with other characteristics of the base country, are delivered by the competitive equilibrium in the model economy. Second, consider a world populated by a continuum of closed economies, all of them being replicas of the benchmark economy at time 0 and differing only in the the size of the investment sector's TFP. By comparing equilibria across the economies, one can learn about the relationship between policies that distort the efficiency of the production process of the investment sector, the size of the informal sector, and their effect on income differences across countries.

In this section I calibrate the model to the U.S. data. In the calibration I treat the

U.S. as an economy with no distortions to the TFP of the investment sector. In this economy one unit of the formal good is transformed into one unit of capital, which implies that $\pi = 1$. The period in the model correspond to a quarter of a year in the data.

I follow standard procedures for choosing the parameters that are presented in the standard growth model: g, β, δ, α, and σ. The growth rate of the technology, g, is chosen to match long-run post-ward U.S. productivity growth. I target an annual interest rate of 6.18%, implying a value for β of 0.9918 and a capital income share of 0.3, which is consistent with U.S. capital income share. The physical capital depreciation rate and the technology parameter α are chosen to match the investment to output ratio and the capital to output ratio. The relative risk aversion parameter σ is 1.5.

With respect to the technology parameters the formal sector productivity A_f is chosen to generate a normalized annual aggregate output in the formal sector of 1 in the benchmark economy and the informal sector productivity A_i is chosen to generate an informal output to aggregate formal output of 0.07. This values is between the smallest estimates of the informal production as a percentage of GDP in the U.S. Different estimates of the size of the informal economy, or underground economy, as a percentage of GDP in the U.S. range from 6.7 to 13.9%, with an average of 10% (Schneider and Enste (2000) and Schneider (2005)).

Labor market functioning is determined by the firms' destruction parameter ϕ, which coincides with the job separation rate, and by the search technology parameter l. I assigned a value of 0.035 to ϕ, which is consistent with Shimer (2005) finding that the U.S. separation probability averaged 3.5 percentage points during the period 1948 to 2004, and the search technology parameter l is chosen to match the employment share in the informal sector.

Relative to the standard growth model, what is new are the share parameter between

Parameter	Value	Target
g	0.02	growth rate of the technology 2% per annun
β	0.9918	capital income share of 0.3
δ	0.014553	investment to output ratio of 0.275
α	0.33	capital to output ratio of 2.5
σ	1.5	relative risk aversion parameter 1.5
A_f	0.01137	annual aggregate output in the formal sector of 1
A_i	0.16324	informal output to aggregate formal output of 0.07
ϕ	0.035	job separation probability 3.5% per quarter
l	0.85	employment share in the informal sector 13%
μ	0.5	share parameter between formal and informal goods of 0.5
I_c	0.057063	normalization of differentiated goods $v = 1$
γ	10/11	steady-state markup of 1.1 in the formal sector
γ_s	0.8	substitution between the formal and the informal good of 0.8

Table II.1: Calibration of Benchmark Economy

formal and informal goods, μ, the firms' creation cost, I_c, the elasticities of substitution between formal goods, γ, and the elasticity of substitution between the formal and the informal good, γ_s. The share parameter μ is 0.5, and the firms' creation cost I_c is chosen to generate a normalize measure of differentiated goods in the formal sector v of 1. The the elasticity of substitution for the differentiated goods in the formal sector γ determines the markup for individual goods. The steady-state markup is set equal to 1.1, corresponding to $\gamma = 10/11$. The last parameter γ_s is especially relevant in determining the impact of the distortion of capital accumulation on the size of the informal sector. This parameter may vary a lot across countries and is likely to be larger in countries with large informal sectors. I set this parameter equal to 0.8, which represent a lower substitution between the formal and the informal good than between the formal differentiated goods alone. In section 6 I analyze the sensitivity of the result to variations of this key parameter. Table II.1 reports a summary of all parameter values and targets.

4 Effect of policies that distort the productivity of the investment sector on informal employment and income

In this section, I examine to what extent policies that distort the efficiency of the investment sector account for differences in income and in the size of the informal sector across countries. The way I approach this issue here is by shutting down technological differences in the formal and the informal sector and asking how much income inequality can be explained by differences in distortions alone, i.e., by differences in the productivity parameter π. The experiment therefore is to consider the whole world as having access to the same technology, and quantify the impact of bad economic policies (or other institutional differences) that raise the cost of capital by affecting the productivity of the investment sector. The empirical counterpart of the distortions to the investment sector in the data is the relative price of investment. According to Restuccia and Urrutia (2001) and Jones (1994) reasonable factor differences in the relative price of investment across countries lies between 4 and 6. Table II.2 presents the variations in output in both sectors, formal and informal, the size of the informal sector, and capital to output ratios for different values of the distortion parameter π that generates reasonable differences in the relative price of investment. To be consistent with the way the data is reported in Summers and Heston (1991), I use the price of the composite consumption good and the price of the investment good of the benchmark economy to compute aggregate income in all other economies.

The first important observation from this simulation exercise is that the model is capable of delivering the negative correlation between the size of the informal sector and output per capita presented in figure II.1. The second important finding is that the model is able to generate income differences consistent with the observed international patterns for reasonable values of π. From table II.2 can be observed that the aggregate

π	p_i/p_c	y_f	$y_f + y_i$	Φ_i	K/Y	$\frac{0.5\,y_i}{0.5\,y_i + y_f}$	$\frac{y_i}{y_f + y_i}$
1	1	1	1	0.107	2.50	0.0338	0.0653
1.5	1.54	0.669	0.714	0.231	1.66	0.0873	0.161
2	2.16	0.438	0.562	0.387	1.25	0.174	0.297
2.5	2.88	0.271	0.469	0.551	0.997	0.297	0.458
2.7	3.22	0.218	0.442	0.614	0.923	0.356	0.525
3.11	4.0	0.135	0.400	0.727	0.801	0.484	0.652
3.36	4.56	0.100	0.382	0.782	0.741	0.561	0.719
3.8	5.69	0.0579	0.360	0.857	0.655	0.682	0.811

Table II.2: Effect of changes in the distortion parameter π on income and the size of the informal sector. Columns 2 and 3 are formal output and total output relative to the benchmark case.

income of an economy where the low productivity of the investment sector raises the relative price of investment with respect to consumption by a factor of 4 is 14% of the benchmark economy, and the share of employment in the informal sector is 73%. The capital to output ratio is 3.12 times smaller than in the benchmark economy.

An important implication of this result is that aggregate income differences across countries in this model are larger than in a standard one-sector growth model with similar capital share, which implies that a country with low TFP in the investment sector that increases the price of the investment good relative to the consumption good by a factor of 4 has an aggregate income of 50% of the benchmark economy, and larger than two sector-models with technology choice, like the one presented by Restuccia (2004), which implies that a country with a relative price of investment of 4 has an aggregate income of 41% of the benchmark economy.

More relevant than generating large income differences across distinctive economies is to understand the sources of these differences. The aggregate income differences across countries generated by two sector models that incorporate a non-market sector, like a home production sector in Parente et al. (2000), or a low productive sector, like the agricultural sector in Restuccia (2004), are mainly driven by the reallocation of inputs, labor and capital, from high productive sectors to low productive ones. This is also the main channel through which distortions to the productivity of the investment sector affect output and employment in this model, since labor is reallocated from the formal sector to the informal one. The theory, therefore, is consistent with the existing literature that emphasize the negative effect of barriers to capital accumulation on the inefficient reallocation of resources across low productive sectors.

The intuition for the amplification effect of these kind of distortions on income and the size of the informal sector is the following: a reduction in the productivity of the investment sector increases the relative price of investment as column 2 of table II.2 shows. An increase in the relative price of investment increases the rental price of capital and, as a consequence, reduces the net present discounted value of a newly created firm in the formal sector. This decrease of the present discounted value of a new firm discourages entry in the formal sector and reduces competition, as shown in figure II.2(b) by the reduction in v. The reduction in competition allows monopolies to operate old technologies more intensively by allocating more labor and less capital to old vintages, as figure II.2 (d) and (e) illustrate, which causes a large fall in output per worker in the formal sector. A higher rental price of capital encourage firms to substitute capital for labor causing a decrease on the marginal product of labor and a decrease on wages. The drop in wages in the formal sector reduces the wage gap between the formal and the informal sector, as shown in figure II.2(c), which makes more attractive the work in the informal sector and causes a rise of informal activities.This feature makes the model consistent with Lemieux et al. (1994) finding that net wages in the formal sector are negatively correlated with hours worked in the informal sector.

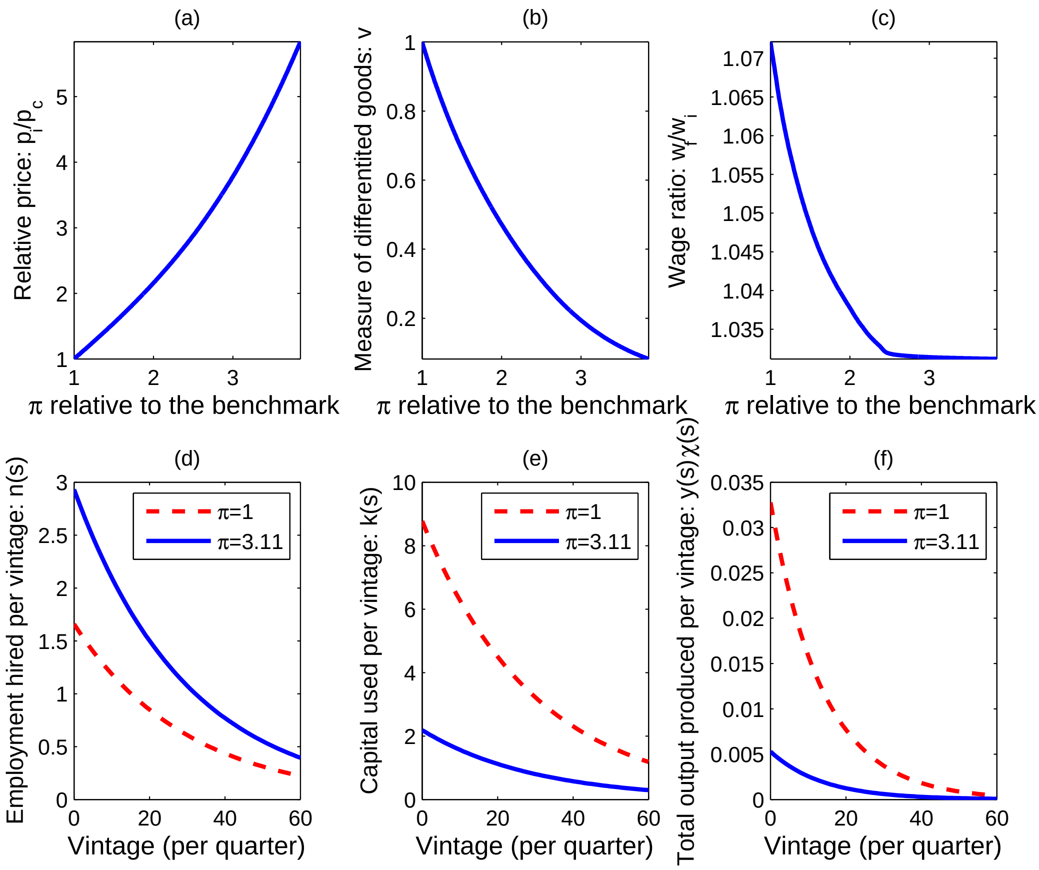

Figure II.2: Relative price of investment, measure of firms v, wage gap, and inputs used by vintages in the formal sector for different values of π.

Table II.2 also reports how national incomes would compare if we measured both formal and informal output. The ratio of total output across the undistorted and the distorted economies is presented in column 4. The true output ratio is greater than the ratio of formal output because of the relatively more important role played by informal production in the distorted economy. The aggregate income, measuring both formal and informal output, of the distorted economy with a relative price of investment of 4 is 40% of the benchmark economy. These differences are still larger than the differences generated by the standard one-sector growth model and by the model presented by

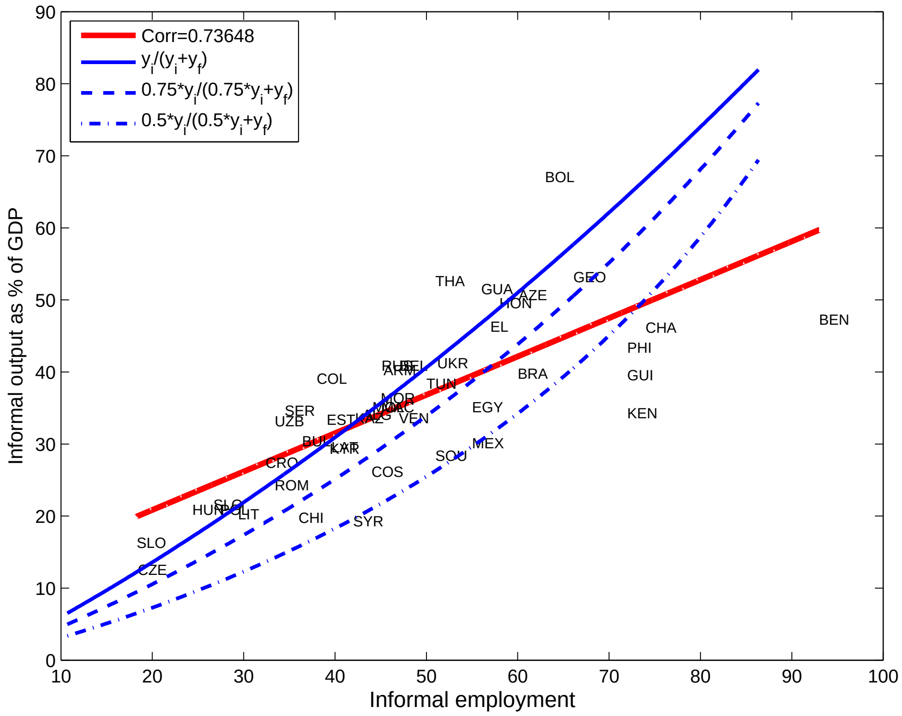

Figure II.3: Estimates of the underground economy as a percentage of measured GDP vs. informal employment. Source: The data from informal employment is from ILO (2002) and the data from the informal sector is as reported in Schneider (2005). The data is in appendix 8.

Restuccia (2004) for the same relative price of investment.

The model predicts a strong positive correlation between the share of informal employment and the relative income of the informal economy with respect to total income. Figures II.3 shows how the data generated by the model compares to the available data on informal employment and relative income for some developing and transition countries. I graph the values of informal employment and output generated by the model for three different situations. The first one refers to the case in which all informal output is measured properly. The other two cases refer to the situations in which only part of the informal output is measured. The factor allocation implication of the theory is therefore consistent with the available cross-country data.

A second important result is that to generate a relative price of investment of a factor of 4 with respect to the benchmark economy, the model only requires a reduction in the productivity of the investment sector of a factor of 3.11, which is smaller than the distortions required by the home production model of Parente et al. (2000) or the multi-sectoral models of Restuccia (2004). This result comes from the assumption that the good produced in the informal sector can not be used in the production process of the investment good. The implication of this assumption is that the price of the investment good differs from the price of the consumption good, which is a composite good of both formal and informal goods. Given that the informal sector uses a labor intensive technology, any distortion that reduces the productivity of the investment sector raises the price of capital making the goods produced by the formal sector more expensive, because the formal sector uses capital more intensively than the informal sector. A reduction of the productivity of the investment sector raises the price of the investment good by more than the price of consumption. The low price of consumption goods in poor countries, therefore, might be due to the existence of large informal sectors that generally produce their goods with labor intensive technologies.

5 Entry cost and the size of the informal sector

In this section I perform an experiment to asses the quantitative effect of De Soto's (1989) argument that the size of the informal sector is mainly determined by entry barriers. The experiment consist in examining to what extent the size of the informal sector is affected by entry barriers, and whether high entry costs have a quantitatively important effect on income. The results support the De Soto hypothesis that the size of the informal sector is positively correlated with the entry cost in the formal sector. Columns 3 and 5 of table II.3 show the change in formal output and the size of the informal sector for different values of the entry cost parameter I_c. To reduce output in

I_c	p_i/p_c	y_f	$y_f + y_i$	Φ_i	K/Y	v	w_f/w_i
1	1	1	1	0.10702	2.4999	1.0003	1.0721
3	1.0220	0.72783	0.79609	0.20116	2.4971	0.24792	1.0519
5	1.0401	0.60260	0.70952	0.26846	2.4958	0.12531	1.0449
7.6	1.0613	0.50043	0.64208	0.33754	2.4952	0.069854	1.0403
10	1.0794	0.43455	0.59998	0.38979	2.4946	0.046886	1.0376
16	1.1217	0.32575	0.53237	0.49110	2.4926	0.022820	1.0334
20	1.1484	0.27660	0.50235	0.54367	2.4913	0.015868	1.0319

Table II.3: Effect of changes in the entry cost I_c on income and the size of the informal sector. Columns 2 and 3 are formal output and total output relative to the benchmark case.

the formal sector by a factor of 2, the entry cost has to be 7.6 times larger than the entry cost of the benchmark economy. The size of the informal sector increases to 34% of total employment.

The explanation for this result is that higher entry costs discourage competition in the formal sector but do not distort the capital accumulation decision in the formal sector as seen in column 6 of table II.3. A smaller number of firms in the formal sector reduces the marginal product of labor and, as a consequence, lowers wages. The reduction in competition and the wage gap are shown in columns 7 and 8 of table II.3. The lower wages in the formal sector encourage workers in the informal sector to allocate more time in informal activities and to reduce the time devoted lo look for a formal job. The result is an increase in the size of the informal sector and a decrease in formal output.

To determine how much of the international income differences can be accounted by the model I need to know how large are barriers to entry in poor countries compared with those of rich countries. Djankov et al. (2002) present data on the regulation of entry of start-up firms in 85 countries, which includes most of the top and bottom ten percent countries of the Penn World Tables in 96 (PWT96). The data cover the number of procedures, official time, and official cost that a start-up must bear before it can operate legally. They find that countries with heavier regulation of entry have higher corruption and larger unofficial economies. Taking averages over the countries of the top and bottom ten percent of the PWT96 for which they have data, their estimates imply an average cost of setting up a legal business of 7.5% of one annual per capita GDP in the top ten percent and 120% of one annual per capita GDP in the bottom ten percent. In other words, expressed as a percentage of an annual per capita GDP the official entry costs were 16 times larger in the bottom ten percent than in the top ten percent countries. It is important to realize that such large differences in entry costs do not include unofficial costs such as bribes and the like, which are much harder to measure than the official ones.

Table II.3 shows the change in formal output and the size of the informal sector for an entry cost of 16 times the entry cost of the benchmark economy. The size of the informal sector increases to 49% of total employment, which makes the model consistent with Djankov et al.'s (2002) results, and formal output is reduced to 33% of the benchmark economy. High entry costs, therefore, are able to explain a large part of the observed international income differences.

Although large entry costs alone are unable to explain all the observed international income differences across countries, when these costs are combined with distortions to the efficiency of the investment sector, they have the potential to explain an even larger part of the observed international income differences. This is a relevant exercise because these two distortions are likely to coexist in poor countries. Table II.4 displays the change in formal output, the size of the informal sector for different values of I_c for an economy where the investment sector is half as productive as the investment sector of the benchmark economy. e.i., $\pi = 2$. The value of I_c that is required to decrease output in the formal sector by a factor of 10 relative to the undistorted economy is only 5.4 times larger than the cost of the benchmark economy. The mechanism that is behind this result is a combination of the effects created by the increase in π from 1 to 2, the increase in the relative price of investment that distort the accumulation of capital, and the effects produced by the increase in the entry cost, mainly the reduction in the measure of firms in the formal sector.

I_c	p_i/p_c	y_f	$y_f + y_i$	Φ_i	K/Y	v	w_f/w_i
1	2.1567	0.43815	0.56231	0.38676	1.2473	0.47226	1.0378
3	2.4210	0.19680	0.43629	0.64071	1.2454	0.079328	1.0315
5.4	2.6997	0.10319	0.38768	0.77716	1.2451	0.025766	1.0313

Table II.4: Effect of changes in the entry cost I_c on income and the size of the informal sector starting at $\pi = 2$.

6 Sensitivity analysis

Table II.5 displays the value of π that is required to decrease output in the formal sector by a factor of 10 relative to the undistorted economy, $\pi = 1$. Several values of the key parameter γ_s are considered. It is important to observe the negative correlation

γ_s	π	Φ_i
0.85	2.17	0.823
0.8	3.36	0.782
0.75	5.08	0.734

Table II.5: Value of π that is required to decrease output in the formal sector by a factor of 10 relative to $\pi = 1$ for several values of γ_s.

between γ_s, the degree of substitutability of formal and informal goods, and the level of distortions needed to decrease output in the formal sector by a factor of 10 relative to the benchmark economy. The sign of the correlation, however, could be expected since it capture the willingness of individuals to substitute formal goods by informal. The more indifferent agents are about formal and informal goods the higher is the effect of the distortions on the allocation of labor in the informal sector. For large values of γ_s small changes in the distortion parameter π causes large reallocation of labor from the formal to the informal sector as shown in the last column of table II.5. This inefficient reallocation of labor has a huge negative impact on the production of goods in the formal sector.

This exercise also illustrate that the results are very sensitive to changes in the parameter γ_s, which is one of the features that distinguish this model from previous ones. As far as I know there is no empirical estimation of this parameter in the literature. One can expect, however, that this parameter should display a large variation across countries. It is reasonable to postulate that the willingness to substitute formal by informal goods is larger in poor countries where more than 50% of the total employment is provided in the informal sector. This hypothesis is supported by the findings of Fortin, Lacroix and Montmarquette (2000). Using a recent survey on underground activities conducted in the Province of Quebec (Canada), they find that hours work in the underground or informal sector have a strong positive effect on the probability of purchasing underground commodities and on the level of expenditure. They emphasize three reasons why working in the underground sector stimulates the demand for irregular commodities. First, individuals working in the underground sector may have better access to the sector's output. They may benefit from better information on the availability of goods and services produced in the sector. This network effect is likely to lower search costs and induce workers to increase their expenditures on underground commodities. Second, preferences over goods and services in the underground sector may be non-separable from labor supply in that sector. An example is the demand for irregular housework services or home improvement for underground workers who have little time available to spend on these activities. Third, the income effect of working in the underground sector may increase the demand for irregular goods and services (e.g., renovation services).

π	p_i/p_c	y_f	$y_f + y_i$	Φ_i	K/Y	y_i/y_f	$y_i/(y_f + y_i)$
1	1	1	1	0.107	2.50	0.0338	0.0653
1.5	1.53	0.717	0.745	0.206	1.66	0.0764	0.142
2	2.11	0.517	0.606	0.325	1.25	0.138	0.243
2.5	2.76	0.366	0.517	0.452	0.997	0.220	0.361
3	3.50	0.249	0.455	0.576	0.830	0.322	0.487
3.3	4.01	0.193	0.427	0.646	0.755	0.391	0.563
4.01	5.43	0.101	0.382	0.781	0.621	0.561	0.719

Table II.6: Effect of changes in the distortion parameter π on income and the size of the informal sector. Columns 2 and 3 are formal output and total output relative to the benchmark case. In this simulation the entry cost only require time input of people dealing with bureaucratic regulations. The free entry condition is $w\,I_c = \sum_{s=0}^{\infty}\left(\frac{1-\phi}{R}\right)^s \Pi(s)$.

There is one implicit assumption in the model that might seem to be important. I am modelling the entry costs as a good cost. Because countries with low productivity in the investment sector have a higher cost of producing goods, this implies that they effectively face higher costs of creating businesses. To determine how sensitive are my results to this implicit assumption I consider the following modification. I assume that the entry cost only require time inputs, time inputs of people dealing with bureaucrats. In this case, low productivity of investment sector and low capital accumulation imply low wages which, in turn, reduce the cost of creating businesses. Table II.6 shows the results of this simulation. The results are very similar to the ones presented in table II.2. The value of π that is required to decrease output in the formal sector by a factor of 10 relative to the undistorted economy is 4.01 instead of 3.36, which represent a reduction in productivity of the investment sector of only 20%. The effect on the other variables are almost the same. The results of the chapter , therefore, do not depend significantly on this assumption.

7 Conclusions

In this chapter I present a theory that considers explicitly two sources of inefficiencies at reallocating inputs across sectors: the existence of a low productive sector which is an alternative to unemployment, the informal sector, and the presence of monopolistic competition in the industrial or formal sector. With this theory I study the extent to which one can account for international income differences with differences in policies that distort the efficiency of the investment sector, represented by a low TFP in the investment sector, and with policies that increases the cost of creating a firm in the formal sector. The model developed is able to generate income differences consistent with the observed international patterns for reasonable differences in the TFP of the informal sector even when ignoring the role of differences in technology in both the formal and the informal sector.

In a recent article Robert Solow (2001) stresses the importance of the non-technological sources of differences in TFP, which may be more important than the technological ones, especially in developing countries. In particular, he points out that

> "It is certainly unwise to suggest that all economies are equally efficient at reallocating inputs across sectors. This difference will be reflected in $A(t)$, and maybe not only there [...] there are other non-technological factors that could influence the level and growth of TFP. They would include the intensity of competition - domestic or foreign - ..., the alacrity with which the national economy adopts new technologies, and thus the level and growth of TFP. You can just as easily imaging that the amount and nature of regulation in a country can affect the efficiency of resource allocation, and thus the "effective" level of TFP and quite possible its growth rate."

This chapter provides some support to Solow's comment by showing that policies or regulations that increases the relative price of investment can affect the efficiency of resource allocation and the intensity of competition in an economy causing large negative effects on aggregate income.

8 Appendix

Table II.7: Informal employment and output.

Region/country	Informal employment as % of non-agricultural employment, 1994/2000.[4]	Shadow Economy in % of GDP, 1990/2000.[5]
North Africa	48	35.9
Algeria	43	34.1
Morocco	45	36.4
Tunisia	50	38.4
Egypt	55	35.1
Sub-Saharan Africa	72	37.16
Benin	93	47.3
Chad	74	46.2
Guinea	72	39.6
Kenya	72	34.3
South Africa	51	28.4
Latin America	51	40.29
Bolivia	63	67.1
Brazil	60	39.8
Chile	36	19.8
Colombia	38	39.1
Costa Rica	44	26.2
El Salvador	57	46.3
Guatemala	56	51.5
Honduras	58	49.6
Mexico	55	30.1
Rep Dominicana	48	-
Venezuela, RB	47	33.6
Asia	65	31.56
India	83	23.1
Indonesia	78	19.4
Philippines	72	43.4
Thailand	51	52.6
Syria	42	19.3
Transition Economies	38.22	32.17
Armenia	45.3	40.3
Azerbaijan	60.1	50.7

[5] The data from informal employment is from ILO (2002).

[5] Shadow Economy (in % of off. GDP) using the DYMIMIC and Currency Demand Method. The data is as reported in Schneider (2005).

(Continued)

Region/country	Informal employment as % of non-agricultural employment, 1994/2000.	Shadow Economy in % of GDP, 1990/2000.
Belarus	47.1	40.9
Bulgaria	36.4	30.4
Croatia	32.4	27.4
Czech Republic	18.4	12.6
Estonia	39.1	33.4
Georgia	66.1	53.2
Hungary	24.4	20.9
Kazakhstan	42.2	33.6
Kyrgyzstan	39.4	29.4
Latvia	39.6	29.6
Lithuania	29.4	20.3
Macedonia	45.1	35.1
Moldavia	44.1	35.1
Poland	27.4	20.9
Romania	33.4	24.3
Russia	45.1	40.9

Chapter III

Monetary policy and the informal economy[1]

1 Introduction

Few would deny that unregistered economic activity is a fact in every country although there is a general disagreement about its size. Diversity of opinion is nevertheless understandable as it is clear that obtaining information about unregistered economic activity is very difficult due to the unwillingness of those engaged to admit it. Arguably, knowing more about shadow sectors of the economy, is of great importance to policy makers for various reasons:

(i) Large informal sectors imply that the statistics on which policy decisions are made are wrong or, at least incomplete, thus rendering ineffectiveness and unwanted side-effects that may question the usefulness of such policies.

(ii) There is interaction between the formal and informal sectors that is at least twofold. The informal sector withdraws resources from the formal economy and enjoys certain public goods without paying for them. At the same time, as

[1]This chapter is a joint work with Atanas Kolev.

Schneider and Enste (2000) point out, nearly two-thirds of the income earned in the informal sector is spent on goods and services provided by formal economic activity.

(iii) In the absence of information about the informal sector policy makers do not have feedback on the policies implemented. In other words, since the effects of policies on the informal sector are generally unobserved it might be the case in many situations that despite observed desired effects in the formal sector, the overall economy is worse off. An example can be the design of social security systems. Previous studies have found that social security and unemployment insurance are desirable, however these can be designed in such a way that give people incentives to look for jobs in the informal sector while receiving unemployment benefits and at the same time can provoke lower net job creation in the formal sector due to high social security contributions. Thus, ill designed social welfare system may increase the share of the informal sector in the economy.

In the literature on informal economic activities there exist different definitions of the informal sector of an economy. We find the most relevant for our purposes the definition given by Schneider and Enste (2000). In particular, *we call informal sector all legal value-added activities that avoid taxation and remain unregistered by official statistics.* In this chapter we argue that the effects of monetary policy on informal economic activity can be very different from those on the officially reported one. To this point, we consider a two-sector monetary business cycle model in which one of the sectors, which we call the formal sector, is affected positively by the liquidity effects generated by monetary policy actions. The other sector, which we call the informal sector, shrinks from expansionary monetary policy since the pickup of inflation acts as a tax on the transactions of this sector's participants.

There is a general agreement among economists that changes in monetary conditions influence aggregate economic variables. In particular, after a monetary contraction output, employment, and inflation decrease. See, for example, Christiano, Eichenbaum and Evans (1996), Leeper, Sims and Zha (1996) for studies of the US economy, and Kim (1999), Canova and de Nicoló (2003) for studies of G-7 economies. Of course, all studies analyze the effects of money on officially measured variables such as GDP, industrial production, employment, etc. According to various studies, however, in most economies around the world there might be a fairly large informal sector, i.e. unregistered economic activity. Estimates vary a lot across studies and countries but all reveal that a non-trivial portion of the economy is not included in the officially reported statistics. For example, in a comprehensive recent study Schneider and Klinglmair (2004) find that the informal sector (IS) in 21 OECD countries is on average about 18 per cent of the officially estimated GNP and that this share has been growing for the past 20 years. The estimates for individual countries range from 8.6 percent in US to 28.3 percent in Greece. These values are much higher for developing and transition countries, averaging 41 percent and 38 percent respectively. It is, of course, difficult to imagine government policies that affect only the officially registered economic activity and this motivates us to pursue a better understanding of the effects of monetary policy on the informal sector.

The idea that policy has effects on the informal sector is not new. Various authors analyze such problems from different perspectives. Loayza (1996) constructs a simple endogenous growth model with a production function that uses congestible public services as inputs and in which the government cannot enforce compliance with the tax code. This model is used to study the determinants and the effects of taxes and regulation on the informal sector. Its analysis shows that changes in policy and quality of government institutions that increase the size of the informal sector affect negatively the rate of economic growth. Johnson, Kaufman and Shleifer (1997) analyze a model of allocation of labor between the official and the informal sectors of the economy. The government levies taxes on the official sector to provide public goods that increase productivity. The informal sector neither pays taxes nor has access to public goods. Instead, it pays fees to private agencies to provide them. The quality of these goods depends on the revenue these agencies raise. The key prediction of this model is that economies can be in either of two distinct equilibria. In one, the government offers a sufficiently attractive combination of tax rates, regulation, and public goods and most firms choose to stay in the official sector. In the other equilibrium private agencies out-compete the government in providing public goods and hence many firms stay in the informal sector. Antunes and Cavalcanti (2006) construct a general equilibrium model with credit-constrained heterogeneous agents that make occupational choices over formal and informal businesses, contractual imperfections and a government that imposes taxes and regulations on formal-sector firms. In this model the return from being in the formal sector is better access to outside finance. The numerical results suggest that regulation costs rather than financial market imperfections account for the difference in the sizes of the informal sectors of US and the Mediterranean Europe, but this is exactly the opposite for countries with very weak enforcement systems. In summary, excessive taxes, social security contributions, bad institutions and regulations, especially on the labor market, tend to stimulate the unreported economic activity.

Unlike fiscal policy and regulation, effects of monetary policy are not well studied. Koreshkova (2003) documents a strong positive relationship between the size of the informal sector and inflation. Using a quantitative general equilibrium monetary model she shows that a theory of optimal taxation can rationalize government incentives to inflate in the presence of an informal (tax-evading) sector. Our work, however, has somewhat different perspective than ours since it justifies certain types of monetary policy in the presence of informal sector but does not analyze what are the effects of such a policy on it. Caballé and Panadés (2004) analyze the effects of inflation on tax compliance and government revenues in a monetary economy where households face cash-in-advance constraints on consumption purchases and are exposed to random audits by the tax enforcement agency. One of their findings is that higher inflation stimulates tax evasion.

As a first step in tackling our problem we estimate a time series index of the informal sector in UK. We report some evidence suggesting that monetary policy affects the informal sector quite differently from the formal one. Based on this observation we build an equilibrium monetary business cycle model that attempts to explain why this might be so.

The rest of the chapter is organized in six sections. Section 2 describes our empirical study of the British informal sector. Sections 3 and 4 describe a model that accounts for the observations in the previous section. The following two sections, Section 5 and Section 6, discuss the calibration, numerical solution and results for the model in Section 3. Section 7 concludes.

2 Estimating the informal sector in UK

In general it is very difficult to estimate the informal sector as pointed out by Schneider and Enste (2000) who review the existing methods of estimation. The authors suggest that an approach called Multiple-Indicator Multiple-Cause (MIMIC) modeling is the least prone to the critiques directed to existing estimation strategies. We follow this advice and use a dynamic version of this approach (DYMIMIC) to estimate the informal sector in UK. Using the time series index resulting from this estimation we then analyze the statistical relationships between this estimate and aggregate variables such as GDP, the interest rate set by the monetary authority, various monetary aggregates, etc. with the intention to infer the effects that changes in monetary conditions exert on the informal sector.

The empirical method that we use is based on the statistical theory of unobserved variables, which considers various causes and various indicators of the phenomenon of interest. For the estimation, a factor-analytic approach is used to measure an index of the unobservable variable over time. The coefficients are estimated in a system of structural equations in which the unobserved variable cannot be measured directly. The DYMIMIC model consists of two general parts, the measurement model and the structural equations model. The structural model specifies the relationship between the unobserved variable, in our case the informal sector, and the set of variables that are assumed to influence it, see equation (III.1a). The measurement model links the unobserved variable with another set of variables that are assumed to be indicators for the shadow economy's development, thus capturing the structural dependence of the informal sector on variables that may be useful in predicting its size and movements over time, see equation (III.1b). Nowadays, there is a large literature on the causes and indicators of informal activity. Summarizing, causes can be among the following types,

(i) The tax burden is pointed out in almost all studies, both empirical and based on theoretical models, as the main cause for the existence of an informal sector. The argument is that increasing tax payments and social security contributions give incentives both to workers and employers to avoid stating the (full scale) economic activity they are engaged in. Thus we expect estimated coefficients for variables representing tax burden in the structural equation to have positive signs. As proxies of the tax burden we use the ratio of total direct and indirect taxes to GDP, the ratio of social security contributions received by the government to

GDP, and total government receipts to GDP. A note of caution should be added. In some cases this positive correlation is reversed as in Italy where relatively low tax burden co-exists with high informal sector and the Scandinavian countries, where the tax burden is high but the informal sector is relatively small.

(ii) Generous social welfare systems give incentives for people to work in the informal sector since by accepting a formal-sector job they lose their (potentially large) welfare benefits and in addition pay income taxes on newly earned incomes. Thus the alternative of working in the informal sector and keeping the benefits plus non-taxed earnings can easily have a higher payoff. To account for this we use the amount of social benefits paid by the government as a fraction of GDP. As with the tax burden we expect the estimated coefficients on these variables in the state equation to have positive sign.

(iii) Koreshkova (2003) points out that larger informal sectors co-exist normally with higher inflation. At the same time since price inflation acts as a tax on cash holdings it can decrease the motivation of people to participate in the informal sector or at least to use cash transactions. In the presence of these two counterbalancing effects the expected sign on inflation-related variables is ambiguous. We include CPI as one of the causes in our estimation.

A change in the size of the informal sector over time may be reflected in the following indicators:

(i) Developments of the product market. Changes in size of the informal sector mean that inputs, particularly labor, are redirected from or to the formal sector which most likely has effects on formal GDP size and fluctuations. Other, complementarity effects are also likely. For example, a considerable part of the income earned in the informal sector is spent on goods and services produced by the formal sector. As production market indicator we use real GDP and as noted above it is difficult to determine the expected sign of the estimated coefficient.

(ii) Developments of money markets. Informal sector transactions are paid mostly in cash in order to avoid being registered by tax authorities and thus changes in the informal sector introduce changes in the demand for cash, other things equal. Therefore we expect positive sign of the estimated coefficient on IS in the measurement equation that represents developments on money markets. Our indicators are currency in circulation or currency in circulation divided by M2.

(iii) Developments of labor markets. Increases in informal sector activity requires more labor input and therefore leads to decreases in the participation in registered economically active population. We use as an indicator on this market the rate of economically inactive male population. We choose to work only with male population since female labor force participation in the last forty years has been predominantly driven by factors unrelated to shadow economic activity. To achieve identification of the model we fix to unity the coefficient on IS in this measurement equation.

Table III.1 reports the variables used in the present study.

2.1 The econometric model

Let the latent variable x_t denote the time-t index of the informal-sector output. Let $Z_t = [z_{1,t}, z_{2,t}, \ldots, z_{k,t}]'$ denote a vector of k time-t causal variables, and $Y_t = [y_{1,t}, y_{2,t}, \ldots, y_{p,t}]'$ denote a vector of time-t observations of p indicator variables. We consider the fol-

Name	Description
CPI	CPI, Harmonized Consumer Price Index
GDP	Real GDP, chained volume measures, 2001 prices
CURR	Currency outside banks
Taxb1	Government receipts
Taxb2	Total direct taxes
Taxb3	Total indirect taxes
Taxb3	Social security contributions to Government
URATE	Unemployment rate, registered
RUWC	Real unit wage costs
EIAM	Economic inactivity rate, males 16 years and more
Sben	Social security benefits paid by Government
BR	The interest rate set by the Bank of England
M2	M2 monetary aggregate

Table III.1: Variables used in the estimation. Data sources: OECD Economic Outlook, OECD Paris; International Financial Statistics, IMF Washington, D.C.; Office of National Statistics, London UK.

lowing state space model,

$$x_t = Fx_{t-1} + GZ_t + v_t, \tag{III.1a}$$

$$Y_t = H'x_t + A'Z_t + w_t, \tag{III.1b}$$

for $t = 1, \ldots, T$ and with independently, normally distributed, mean zero errors,

$$\begin{pmatrix} v_t \\ w_t \end{pmatrix} \sim \mathbf{N}\left[\mathbf{0}, \begin{pmatrix} \sigma_v^2 & \mathbf{0} \\ \mathbf{0} & R \end{pmatrix}\right] \tag{III.2}$$

where F, G, H, and A are conformable matrices of coefficients. We estimate the model using a combination of the EM algorithm and scoring as discussed by Watson and Engle (1983). The unobserved component is handled via the Kalman filter. We have tested all variables for non-stationarity starting with the hypothesis of I(3) against the alternative of I(2) and going down to I(1) against I(0). Those variables for which tests do not reject I(1) are transformed into percent growth rates. Table III.2 reports the results from the Augmented Dickey-Fuller tests for non-stationarity.

Variable	I(3) vs. I(2)	I(2) vs. I(1)	I(1) vs. I(0)
CPI	Reject I(3)	Reject I(2)	I(1)
GDP	Reject I(3)	Reject I(2)	I(1)
CURR/M2 (CM2)	Reject I(3)	Reject I(2)	I(1)
Taxb1/GDP	Reject I(3)	Reject I(2)	I(1)
URATE	Reject I(3)	Reject I(2)	I(1)
RUWC	Reject I(3)	Reject I(2)	I(1)
EIAM	Reject I(3)	Reject I(2)	I(1)

Table III.2: Results from Augmented Dickey-Fuller tests. All variables are transformed in logarithms and tested down for stationarity starting with H_0 : Integration of third order.

We should underline that the estimation method allows us to recover only a unit-free index of the informal sector. This is, however, sufficient for our purposes since we are interested only in the co-movements with other variables over the business cycle and not in the particular size of the informal sector.

2.2 Estimation results

After trying various specifications for the state variable (informal sector) process and using different causal variables we pick a model with an AR(2) process for the informal sector and five causes: the unemployment rate, the consumer price index, the share of government receipts in GDP, the social benefit payments by the Government as a fraction of GDP, and real wages. Table III.3 contains the estimates of the coefficients of the model in (III.1). All causal variables, except the unemployment rate, are statistically significant and have the expected sign. According to our estimation increases of inflation, the tax burden, and social benefits all influence positively the size of the informal sector. High wages in the official sector, however, tend to reduce the size of the informal sector, i.e. as the opportunity cost to working in the informal sector rises, perhaps more workers decide to look for job in the formal sector.

State equation			
Parameter	Estimate	St. error	p-value
Informal Sector(-1)	0.1654	0.1394	0.2382
Informal Sector(-2)	0.5489	0.1496	0.0004
URATE	-0.0212	0.0254	0.4057
CPI	0.1534	0.0673	0.0249
Taxb1/GDP	0.0622	0.0371	0.0969
Sben/GDP	0.1897	0.0823	0.0232
RUWC	-0.1808	0.1088	0.0997

Table III.3: Parameter estimates of the state equation (matrices F and G) of the DYMIMIC model defined by (III.1) and (III.2). The coefficient of the informal sector in the first measurement equation is normalized to one to achieve identification.

For the purpose of comparison with other studies Figure III.1 presents our estimate of the informal sector as percentage of the official GDP estimate. To obtain this graph, however, we need an estimate not only of an index of the informal sector but, in addition, we need an estimate of the *actual size*. To this point we take the estimate of Schneider and Klinglmair (2004) of the *size* of the British informal sector in 1990 and use it to calibrate our index. Our estimate proves to be roughly consistent with the liter-

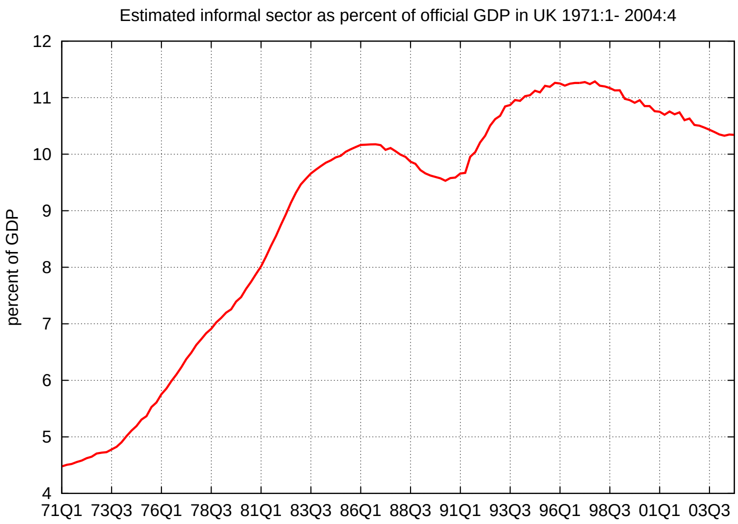

Figure III.1: Estimate of the UK informal sector as percentage of GDP.

ature. Using the currency demand approach, Bhattacharyya (1990), estimates that the share of the informal sector in official GDP has risen from 6.4 percent in 1971:1 to 8.18 percent in 1984:4 whereas our estimate for the period is an increase from 4.48 to 9.78 percent. Table III.4 compares our estimate with those of Schneider and Klinglmair (2004) who pursue the same estimation approach as we do.

Study	Average 1989/90	Average 1994/95	Average 1997/98	Average 1999/00	Average 2001/02	Average 2002/03
SK (2004)	9.6	12.5	13.0	12.7	12.5	12.3
This study	9.5	11.1	11.2	10.9	10.6	10.5

Table III.4: Comparison between our estimates and those reported by Schneider and Kliglmair (2004).

To get an idea about the statistical relationship between our informal sector estimate and various monetary variables we estimate a five variable VAR using quarterly observations from the first quarter of 1971 to the fourth quarter of 2004 for the following variables: our estimate of the informal sector, real GDP, CPI, the interest rate set by the Bank of England, and M2. Table III.5 reports results from the 15 step-ahead

Period	IS	GDP	CPI	BR	M2
5	68.32	20.49	6.31	2.98	1.90
10	41.30	29.59	14.06	14.12	0.93
15	30.61	28.67	19.64	19.51	1.58

Table III.5: Variance decomposition of 15 step-ahead forecast error of the growth rate of the informal sector resulting from a 5 variable VAR containing besides the estimate of the index of the informal sector, GDP, CPI, the policy rate set by the Bank of England, and M2.

forecast error variance decomposition, computed with Choleski decomposition and variables in the order above. A brief inspection of this table confirms that the policy-set interest rate plays an important role for our estimate of the British IS. As long as the Bank of England's policy rate reflects its monetary policy stance we cannot deny that there is an interesting statistical relationship between our estimate of IS and monetary policy. Figure III.2 gives us further information about this relationship. We estimate that a one standard-deviation (orthogonalized) positive shock in the interest rate causes a statistically significant increase in our informal-sector estimate and this is exactly the opposite to the estimated response of official output. These two results are present in VARs estimated with variables both in levels and percent growth rates. According to

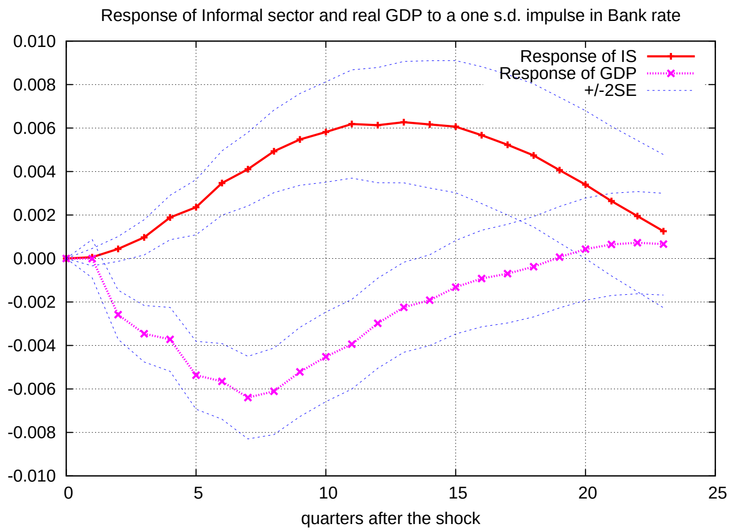

Figure III.2: Impulse responses of the estimate of the index of UK informal sector and real GDP to a shock in the Bank of England policy rate resulting from a 5 variable VAR containing besides the estimate of the index of the informal sector, GDP, CPI, the policy rate set by the Bank of England, and M2.

our estimates an increase in the interest rate causes an expansion of informal sector activity while the official sector contracts. How could one justify such a finding? We think that a possible explanation could be the following. It is widely accepted that informal economic activity is not financed by banks and other official credit institutions and financial transactions are made mostly in cash. Thus a liquidity effect created by a monetary policy action does not have the direct consequences that it has on formal business activity, rather the effects can be indirectly passed through the official sector. For example, if a monetary contraction decreases output, employment, and inflation there would be more workers that in the face of unemployment would choose to work in the informal sector. Further, since inflation acts as a tax on cash transactions, such a policy action reduces this tax and this spurs the economic activity in the informal sector.

3 A Theoretical Model

To study the effect of monetary policy on informal economic activities, we incorporate an informal sector into a monetary general equilibrium business cycle model proposed by Cooley and Quadrini (1999). In the model there are two types of frictions. Labor market frictions that generate unemployment, and a cash-in-advance constraint that generates demand for money. Business cycle fluctuations are driven by a monetary policy shock. The labor market frictions allow us to study the effect of monetary policy on the creation and destruction of jobs, as well as on the allocation of time between formal and informal activities.

There are three sectors in the economy: a household's sector, a production sector, and a banking sector. There is also a monetary authority that controls the supply of liquidity (money) available for transactions in the economy. In the production sector there are two types of firms: industrial or formal firms and informal or extralegal firms. Both types of firms produce the same good, but they use different technologies. Households own two types of assets, liquid and illiquid, and are the ultimate owners of firms. Households enjoy leisure and the consumption of a single-type good produced in both sectors. Due to frictions on the labor markets, an individual works only if he or she is matched currently with a formal-sector firm. Otherwise such an individual divides his or her time between job-search and informal economic activity.

In the beginning of the period households observe their current employment status, employed in the formal sector or unemployed, and buy deposits from the banking sector. The monetary authority trades government bonds with the financial intermediaries, which determines the amount of liquidity available for formal firms' loans, L = Deposits − Bonds. Formal firms use these loans to advance wages to their employees. When workers receive their wages in the formal sector, production begins, the labor market opens, and firms post vacancies. Unemployed individuals divide their time between searching for a job in the formal sector and working in informal activities. Once production have taken place the labor market closes, new matches are formed and firms carry their production to the goods market. Formal employees carry their cash and current period wages to the goods market, and unemployed individuals carry only their cash, since proceeds from production in the informal sector are not available for consumption until next period. This last assumption gives expected inflation a role in determining the allocation of hours to informal activities since inflation acts as a tax on informal production. At this stage consumption takes place.

In the end of the period firms repay the loans to the financial intermediaries, the government collects taxes to pay for the interests on bonds, and workers receive the return of their deposits and the profits of formal firms. In the remaining of this section we explain in detail the problem faced by each of the participants of the economy.

3.1 The monetary authority and the intermediation sector

The monetary authority controls the supply of liquidity (money) available for transactions by conducting open market operations, that is, by purchasing and selling government bonds. We assume that the total nominal stock of public debt is constant. What changes is the fraction of it that is in the hands of financial intermediaries, i.e. part of this stock is owned by the monetary authority and part is owned by the banking sector. The nominal value of public debt or government bonds owned by the banks is denoted by B. Transactions in government bonds take place between the monetary authority and the banks. For simplicity we assume that the interest paid on bonds owned by the private sector (banks) is financed with non-distorting taxes.

The quantity of liquid funds, M, available in the economy is constant. Part of these funds are held by households for transactions and the remainder is deposited with banks. Banks collect these deposits from households and use them to buy government bonds and to make loans to firms. Consequently, in each period, an amount $M - D$ of money, where D denotes the aggregate stock of nominal deposits, is available to the households for transaction and an amount $D - B$ is available to the firms. The sum of these two stocks gives the total amount of money used for transactions, that is, $M - B$.

Although we assume that M is constant, the monetary authority is able to modify the stock of money used for transactions by changing the stock of public debt outstanding with open market operations. When the monetary authority purchases public bonds from the banks, the quantity of loanable funds $D - B$ available to the intermediation sector increases (for a given stock of deposits D), and this increase in the supply of loanable funds has the potential to drive the interest rate down.

To insure that open market operations change the supply of loanable funds, we need to impose some rigidity in the ability of the individuals to adjust their stock of deposits. We assume that individuals are able to change their stock of deposits at any moment but there is a readjustment cost associated with doing so. We denote this cost by $\tau(d, d')$ where d is the current holding and d' the new chosen stock. The adjustment cost function is continuously differentiable in both arguments and convex in the absolute change of the initial stock. We also assume that $\tau(d, d) = \tau_1(d, d) = \tau_2(d, d) = 0$, that is, the cost and the partial derivatives are zero when the $d = d'$.[2] The advantage of this approach over the standard limited participation model is that liquidity effects of

[2] As Cooley and Quadrini (1999) note this cost can be justified by penalties that banks charge on earlier withdrawals and by lower interest rates earned in the first period in which a new deposit is made. Such penalties are justified by the costs that banks incur for readjusting their loan portfolio. Of course, in this model, deposits should not be understood as checking deposits but rather as less liquid assets that earn higher interest.

monetary shocks are more persistent even though they may be smaller in the current period.[3]

The monetary authority controls the growth rate of the aggregate stock of money $M - B$ with open market operations. Monetary policy shocks are innovations to the targeted growth rate g. We formalize the monetary policy rule with the AR process $\log(1+g') = \rho_g \log(1+g) + \epsilon'_g$, where the prime denotes the next period values and ϵ'_g is the monetary policy shock.

3.2 Households

In the household's sector there is a continuum of individuals in the interval $[0, 1]$. Households maximize the expected present discounted value of the sum of per period utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(c_t - \chi_t \frac{l_{f,t}^{\gamma}}{\gamma} - (1-\chi_t) \frac{l_{i,t}^{\gamma}}{\gamma} \right), \tag{III.3}$$

where c is consumption of market produced goods, l_f is the time spent working in the formal sector, l_i is the time spent working in the informal sector if the individual is unemployed, and χ is an indicator function taking the value of one if the individual is employed in the formal sector and zero otherwise. Only unemployed individuals can work in the informal sector. In order to work in the formal sector, an unemployed individual needs to search for a job. However, there is no direct cost of searching and the probability of finding a job in the formal sector depends positively on the time allocated to search. The opportunity cost of searching for a job in the formal sector is the forgone gain from working in the informal sector.

Households are the owners of all firms in the economy and besides own two types

[3] Under the assumptions of the standard limited participation model, even if the transfers from the monetary authority are persistent, the greater availability of funds in subsequent periods will be mostly compensated for by a reduction in the stock of deposits owned by households. With adjustment costs, households do not completely adjust their nominal stock of deposits in the following period either, and this induces a more persistent effect of monetary policy shocks.

of assets: cash and nominal deposits. Households maximize expected utility subject to two constraints. First, they face a cash-in-advance constraint that takes the form:

$$p(c + \tau(d, d')) \leq m - d' + \chi \; p \; w_f \tag{III.4}$$

where primes denote the next period value, m is the household's nominal holdings of money, $\tau(d, d')$ is the cost of readjusting the nominal portfolio of deposits, p is the nominal price level, and w_f is the wage received at the beginning of the period in cash if the individual is employed in the formal sector. Nominal deposits receive a nominal interest rate r at the end of the period. The second constraint households face is the budget constraint, which can be written as

$$p(c + \tau(d, d')) + m' = m + rd' + \chi \; p \; w_f + (1 - \chi)p \; w_i + p\overline{\pi} - rB, \tag{III.5}$$

where w_i is the real labor income from informal activities, $\overline{\pi}$ is it share of aggregate profits from firms, and rB are the taxes that the household pays. Note that the income earned in the formal sector is available for purchasing current market consumption, while the income earned in the informal sector is received at the end of the period and is available for consumption in the next period. As pointed out before, this feature affects workers incentives to work in the informal sector when expected inflation is high since inflation acts as a tax on informal activities.

3.3 The production sector

In the production sector there are formal and informal firms. The production technologies in both sectors take labor as the only input. These technologies differ across sectors. The technology in the formal sector exhibits constant returns to scale, and the technology in the informal sector is assumed to exhibit decreasing returns to scale. In particular the production of an unemployed individual who allocate l_i units of time operating an informal business is $y_i(l_i) = \delta_p A l_i^{\gamma}$, where A is the technology in the formal sector and δ_p represents the relative productivity of the informal sector with respect to the formal. We assume that $\delta_p < 1$ which guarantees that in equilibrium the informal sector size is well defined: a positive amount of labor is allocated to informal businesses since $\lim_{l_i \to 0} y_i'(l_i) = \infty$. The assumption of a decreasing marginal product of labor in the informal sector is motivated by the empirical finding of Lemieux et al. (1994) that after-tax wages earned in the formal sector are negatively correlated with the hours worked in the informal sector.

The production in the formal sector requires firms and workers to be matched. The current aggregate state of the economy is $s = (g, B, D, N)$, where N is the number of workers that at the beginning of the period are matched with a firm. The production of a match in the formal sector is $y_f = Al_f - \varphi$, where φ is the non-labor cost of production. The cost φ is idiosyncratic to the firm and is assumed to be independently and identically distributed across firms and time with distribution function $F : [0, \infty] \to [0, 1]$. Both the firm and the worker observe the cost shock at the beginning of the period and decide whether to continue the match. If the realization of the cost shock is high enough, it would be unprofitable for the match to continue. The value of φ above which the firm decides to shut down is denoted by $\bar{\varphi}(s)$ and it is a function of the state of the economy s. The aggregate technology level is assumed constant $A = \bar{A}$.

3.4 Matching process and the dynamics of employment

At the beginning of the period there are N matches in the formal sector, and the measure of workers employed in the formal sector that produce in the current period is equal to $F(\bar{\varphi}(s))N$. Thus, a total of

$$u(s) = 1 - F(\bar{\varphi}(s))N, \tag{III.6}$$

workers will not produce in the formal sector during the period. Individuals who do not produce in the formal sector during the period allocate l_i hours of their time operating an informal business and the rest in searching for a job in the formal sector. The measure of hours allocated to informal activities is then $l_i u(s)$ and the measure of hours devoted to search is $(1 - l_i)u(s)$.

The number of matches in any period is given by a constant return to scale matching function $\Psi(v_p, u_h)$, where v_p is the total measure of vacancies posted by formal firms during the period and u_h is the total measure of hours devoted to search. In the present case $u_h = (1 - l_i)u(s)$. We also assume that $\Psi(v_p, u_h)$ is strictly increasing in both arguments and satisfy some standard regularity conditions.[4] The probability that a searching firm finds a worker is denoted by $\lambda_f(s)$ and it is equal to $\Psi(v_p, u_p)/v_p$, while the probability that an unemployed worker who allocates one unit of time seeking for a job in the formal sector finds a job is denoted by $\lambda_w(s)$ and it is given by $\Psi(v_p, u_p)/u_h$.

The total number of matches, therefore, evolves according to

$$N(s') = F(\overline{\varphi}(s))N + \Psi(v_p, (1 - l_i)u(s)). \tag{III.7}$$

3.5 Wage and labor supply determination

To determine wages and working hours firms and workers solve a Nash bargaining problem in which workers bargaining power equals η. The Nash bargaining problem is defined as

$$\max_{w(s,\phi)} J(s, \phi)^{1-\eta}(W(s, \phi) - U(s))^{\eta}. \tag{III.8}$$

[4]These conditions are:

$$\begin{aligned} \Psi(0, u_h) &= \Psi(v_p, 0) = 0, \\ \lim_{v_p \to \infty} \Psi_{v_p}(v_p, u_h) &= \lim_{u_h \to \infty} \Psi_{u_h}(v_p, u_h) = 0, \\ \lim_{v_p \to 0} \Psi_{v_p}(v_p, u_h) &= \lim_{u_h \to 0} \Psi_{u_h}(v_p, u_h) = \infty. \end{aligned}$$

where $J(s, \varphi)$ denotes the value of a match for the firm, $W(s, \varphi)$ the value of a match for a worker, and $U(s)$ the value of being unemployed.

Firms implement optimal production plans to maximize the welfare of their owners. They have to pay wages in advance in cash, and they finance these advance payments by borrowing from a financial intermediary at the nominal interest rate r. Since dividends are paid at the end of the period, individuals need to wait until the next period to transform this cash into consumption. This implies that the current value in terms of consumption of one unit of cash received at the end of the period is $\delta(s) = \beta E(p(s)/p(s'))$. The value of a match for the firm measured in terms of current consumption is given by

$$J(s, \varphi) = \delta(s)\pi(s, \varphi) + \beta E \int_{0}^{\bar{\varphi}(s)} J(s', \varphi')dF(\varphi'), \qquad \text{(III.9)}$$

where $\pi(s, \varphi) = Al_f - \varphi - (1 + r)w(s, \varphi)$ is the profit of a type (s, φ) firm at the end of the period. This profit equals the output produced by the firm minus the non-labor cost φ and the labor cost $(1 + r)w(s, \varphi)$, which consist of the wage $w(s, \varphi)$ plus the interest paid by the loan used to financed the advanced payment of the wage.

Unmatched firms, or firms whose matches terminated, may choose to enter the labor matching market and post vacancies. The cost of posting a vacancy is k per period. If $\lambda_f(s)$ is the probability that a vacancy is filled, free entry ensures that firms post vacancies until the expected return of posting a vacancy equals k. That is until

$$\beta\lambda_f(s)E \int_{0}^{\bar{\varphi}(s')} J(s', \varphi')dF(\varphi') = k. \qquad \text{(III.10)}$$

With respect to workers we have that the value of a match and the value of being unemployed in terms of current consumption are defined as

$$W(s,\varphi) = w(s,\varphi) - \frac{l_f^\gamma}{\gamma} + \Gamma\left[\bar{\varphi}(s')\right] + \beta EU(s'), \tag{III.11}$$

$$U(s) = \max_{l_i}\left\{\delta(s)y_i(l_i) - \frac{l_i^\gamma}{\gamma} + (1-l_i)\lambda_w(s)\Gamma\left[\bar{\varphi}(s')\right] + \beta EU(s')\right\}, \tag{III.12}$$

where the function Γ is defined as,

$$\Gamma\left[\bar{\varphi}(s')\right] = \beta E\left\{\int_0^{\bar{\varphi}(s')}[W(s',\varphi') - U(s')]dF(\varphi')\right\}.$$

First, notice that the values $W(s,\varphi)$ and $U(s)$ are defined in terms of consumption net of the disutility from working. Having in mind that these two functions represent the value of being employed in the formal sector and the value of being unemployed, one can interpret Γ as the expected discounted surplus of a worker from working in the formal sector in the next period. The first two terms on the right-hand side of equation (III.11) represent the net value for a worker from working in the current period, while the last term denotes the expected discounted value of being unemployed from next period on. Equation (III.12) represents the value of being unemployed as the sum of the net gain from working in the informal sector (the first two terms on the right-hand side), the expected surplus from working next period conditional on devoting $(1-l_i)$ units of his or her time on searching (the third term), and finally the expected discounted value of being unemployed from next period on.

The first order condition of the Nash bargaining problem (III.8) can then be written as

$$\eta J(s,\phi) = (1-\eta)(1+r)\delta(s)\left[W(s,\phi) - U(s)\right]. \tag{III.13}$$

Using equations (III.9) to (III.13) we derive the wage $w(s,\phi)$ as a function of the labor inputs l_i and l_f. This is given by

$$w(s,\varphi) = \frac{\eta}{1+r(s)}(Al_f - \varphi) + (1-\eta)\left(\delta(s)y_i(l_i) - \frac{l_i^\gamma}{\gamma} + \frac{l_f^\gamma}{\gamma}\right) \tag{III.14}$$
$$+ \frac{k\,\eta}{\lambda_f(s)}\left\{\frac{1}{[1+r(s)]\,\delta(s)} - [1-(1-l_i)\lambda_w(s)]\,E\left[\frac{1}{\delta(s')\,[1+r(s')]}\right]\right\}.$$

The solution of problem (III.12) implies that the optimal input of labor allocated to informal activities, l_i, is implicitly defined by the equation

$$\delta(s)y_i'(l_i) - l_i^{\gamma-1} = \frac{k\,\eta}{1-\eta}\frac{\lambda_w}{\lambda_f}E\left\{\frac{1}{\delta(s')\,[1+r(s')]}\right\}. \tag{III.15}$$

To determine the optimal input of labor in the formal sector workers maximize the surplus $W(s,\phi) - U(s)$ with respect to l_f, which implies that

$$l_f(s) = \left(\frac{A}{1+r}\right)^{1/(\gamma-1)}. \tag{III.16}$$

This equation implies that the labor input, and therefore, firm's output, is decreasing in the nominal interest rate r. This is because the interest rate increases the marginal cost of labor. This has important implications for the impact of monetary policy shocks on real activities.

A successful match is endogenously discontinued when the realization of the shock makes the value of workers' surplus zero or negative, i.e., $W(s,\phi) - U(s) \leq 0$. This condition implicitly defines the upper bound shock $\overline{\varphi}(s)$ as the solution of $W(s,\overline{\varphi}(s)) - U(s) = 0$. By equation (III.13) the value of a firm at $\overline{\varphi}(s)$ equals zero. This means that workers and firms allways agree on wheather to form or maintain a relationship.

3.6 The household's problem and general equilibrium

In this section we describe the household problem written in recursive form after normalizing all nominal variables, (B, D, m, d, p), by M. To keep notation relatively simple we do not change the names of these variables. Recall that the aggregate state of the economy was: the growth rate of money g, the normalized stock of government bonds B owned by the intermediaries, the normalized stock of nominal deposits D, and the number of workers N that at the beginning of the period are matched with a firm. The individual states are the occupational status χ, the stock of liquid assets m, and the stock of nominal deposits d. We will denote the set of individual states with $\hat{s} = (\chi, m, d)$.

Let $\bar{\pi}$ denote the share of aggregate profits of the formal sector that is equally distributed at the end of the period to households and let the function $H(s)$ define the law of motion for the aggregate state vector, s. Then denoting with $\Omega(s, \hat{s})$ the household's value function, the household's problem becomes:

$$\Omega(s, \hat{s}) = \max_{c,m',d'} \left\{ c - \chi \frac{l_f^{\gamma}}{\gamma} - (1-\chi)\frac{l_i^{\gamma}}{\gamma} + \beta E \Omega(s', \hat{s}') \right\} \tag{III.17}$$

subject to

$$c = \frac{m - d'}{p} + \chi w - \tau(d, d'), \tag{III.18}$$

$$m' = (1+r)d' + p\bar{\pi} + p(1-\chi)y_i(l_i) - rB, \tag{III.19}$$

$$\bar{\pi} = \int_0^{\bar{\varphi}} \pi(s, \varphi) dF(\varphi), \tag{III.20}$$

$$s' = H(s), \tag{III.21}$$

After substituting the cash-in-advance constraint, equation (III.18), and the budget constraint, equation (III.19), in the household's utility, the household's problem reduces to the choice of the variable d'. Differentiating with respect to d' we get

$$\beta(1+r)E\left(\frac{p}{p'}\right) - p[\tau_2(d,d') + \beta E(\tau_1(d',d''))] = 1. \qquad \text{(III.22)}$$

Without the presence of the adjustment cost the equation would reduce to the usual Euler equation $1 = \beta(1+r)E(p/p')$.

4 Equilibrium and the steady state

A recursive competitive equilibrium is defined as a set of functions for (i) household decisions $c(s,\hat{s})$, $m'(s,\hat{s})$ and $d'(s,\hat{s})$; (ii) labor inputs $l_f(s)$ and $l_i(s)$, wage in the formal sector $w(s,\varphi)$ and exit decision $\bar{\varphi}(s)$; (iii) aggregate deposits $D(s)$, banks' holding of government bonds $B(s)$, loans $L(s)$ and employment N; (iv) interest rate $r(s)$ and nominal price $p(s)$; (v) law of motion $H(s)$ for the aggregate state. Such that: (i) the household's decisions are the optimal solutions to the household's problem (III.17); (ii) the labor input in the informal sector satisfies equation (III.15), the labor input in the formal sector satisfies equation (III.16), and the exit condition maximizes the surplus of the match; (iii) the market for loans clears, that is $D(s) - B(s) = L(s)$, and $r(s)$ is the equilibrium interest rate; (iv) the law of motion of aggregate states $H(s)$ is consistent with the individual decisions of households and firms.

In a steady-state equilibrium all variables are constant. The steady-state interest rate can be derived from equation (III.22) and it is given by $r = 1/\beta - 1$. Once we know the interest rate r, we are able to determine the steady state labor input in the formal sector l_f from equation (III.16). Then the steady state equilibrium can easily be characterized using the following system of six equations in the six unknowns v_p, l_i, u,

N, D, p, and $\bar{\varphi}$. All nominal variables are normalized by M.

$$\beta^2 \int_0^{\bar{\varphi}} \pi(\varphi) dF(\varphi) + \beta \frac{kF(\bar{\varphi})}{\lambda_f(v_p, (1-l_i)u)} = \frac{k}{\lambda_f(v_p, (1-l_i)u)}, \tag{III.23}$$

$$\nu \delta_p A l_i^{\nu-1} - l_i^{\gamma-1} = \frac{k\,\eta}{1-\eta} \frac{v_p}{(1-l_i)u}, \tag{III.24}$$

$$\beta(A l_f - \bar{\varphi}) + \frac{l_i^{\gamma}}{\gamma} - \frac{l_f^{\gamma}}{\gamma} + \frac{k\,(1-\eta(1-l_i)\lambda_w(v_p, (1-l_i)u))}{(1-\eta)\lambda_f(v_p, (1-l_i)u)} = \beta y_i(l_i), \tag{III.25}$$

$$N \int_0^{\bar{\varphi}} (A_f l_f - \varphi) dF(\varphi) - k v_p + u\, y_i(l_i) = \frac{(1-D)}{p} + N \int_0^{\bar{\varphi}} w(\varphi) dF(\varphi), \tag{III.26}$$

$$p\, N \int_0^{\bar{\varphi}} w(\varphi) dF(\varphi) = D - B, \tag{III.27}$$

$$(1-l_i)\lambda_w(v_p, (1-l_i)u)u = (1 - F(\bar{\varphi}))N, \tag{III.28}$$

$$u = 1 - F(\bar{\varphi})N. \tag{III.29}$$

Equation (III.23) is the free entry condition for firms. Equation (III.24) is the first order condition for the supply of labor in the informal sector, and equation (III.25) is the exit condition. Equation (III.26) is the aggregate cash-in-advance constraint for the households and equation (III.27) is the equilibrium condition in the market for loans. Equation (III.28) is the flow of workers in and out of employment, and equation (III.29) is the measure of workers that do not produce in the formal sector.

5 Calibration

The parameters that describe household preferences are the discount factor β and the disutility parameter γ. Choosing the time period to correspond to a quarter of a year, β is set to 0.98, implying a steady state interest rate of approximately 2% per quarter. Since in the economy there is no growth in nominal variables, the steady state nominal interest rate is equal to the steady state real interest rate. As in Cooley and Quadrini (1999), we assume that the disutility function is quadratic and, therefore, we set $\gamma = 2$.

We follow Cooley and Quadrini in choosing a Cobb-Douglas matching function of the form $\Psi(v_p, u_h) = \mu v_p^{\alpha} u_h^{\zeta}$. We set $\alpha = 0.4$ and $\zeta = 0.6$ based on the estimates of Blanchard and Diamond (1989). Cooley and Quadrini (1999), Walsh (2003), and den Haan, Ramey and Watson (2000), fix $\lambda_f = 0.7$. Based on Cole and Rogerson (1996) , we set the average duration of unemployment at 1.67 quarters, which implies $\lambda_w = 0.6$. With the values of λ_f and λ_w we are able to determine the last parameter of the matching function μ. We set the sharing parameter $\eta = 0.5$. The value of this parameter is important for the volatility of employment but not for the shape of the response of employment to shocks.

The production functions are characterized by the stochastic properties of the idiosyncratic shock and by three parameters: the aggregate technology level $\bar{A}$, the return to scale parameter of the informal sector ν, and the relative productivity of the informal sector with respect to the formal sector δ_p. Given the steady state interest rate r and using equation (III.16), the parameter $\bar{A}$ is determined by imposing the condition that each employed worker in the formal sector spends, on average, one third of the available time working. Lemieux et al. (1994) estimated the return to scale parameter of the informal sector for Canada to be 0.74, with standard error 0.1. Based on the survey by Schneider and Enste (2000), which argues that the U.S. and Canada have similar informal sector size, we consider this estimate of the degrees of scale is reasonable to be used as our benchmark parameter ν. The relative productivity between informal and formal firms δ_p is the one that matter most for the allocation of time between the sectors. This parameter controls the size of the informal sector. Alternative estimates of the size of the underground economy in the U.S. range from 6.7% to 13.9%, with an average of 10% of GDP (Schneider and Enste (2000)). Based on this observation we determine δ_p by imposing that the production of the informal sector equals 10% of the production in the formal sector.

For analytical simplicity, we assume that the non-labor cost φ is distributed exponentially with distribution function $\varphi \sim e^{-\varphi/\theta}/\theta$. The parameter θ is determined jointly with the parameter k by imposing that the steady state measure of individuals that do not produce in the formal sector equals 18%, and that the arbitrage condition for the creation of new vacancies is satisfied. Notice that we define the measure of individuals that do not produce in the formal sector as the sum of unemployed individuals, which is assumed to be 6%, plus the informal labor.

The ratio of the stock of public debt to aggregate final output is assumed to be 0.5. This value, however, does not affect the properties of the economy.

The growth rate of money follows the process $\log(1 + g') = \rho_g \log(1 + g) + \epsilon'_g$, with $\epsilon_g \sim N(0, \sigma_g^2)$. The parameter values are $\rho_g = 0.49$ and $\sigma_g = 0.00623$, which are those used by Cooley and Hansen (1989).

Finally, the adjustment cost function is specified as $\tau(d, d') = \phi((d' - d)/d)^2$ and the value of the parameter ϕ is determined to obtain the desired volatility of the nominal interest rate: the higher ϕ is, the higher the volatility of the interest rate. The value chosen for the baseline model is $\phi = 3$.

6 Results

Figure III.3 illustrates the impact of a negative monetary shock, a decrease in the growth rate of money g. Since M is constant, a decrease in the growth rate of money increases the nominal amount of the public debt B owned by the banks. An increase in B reduces the liquidity available for transactions in the economy and causes a persistent increase in the nominal interest rate as observed in Figure III.3(g). An increase

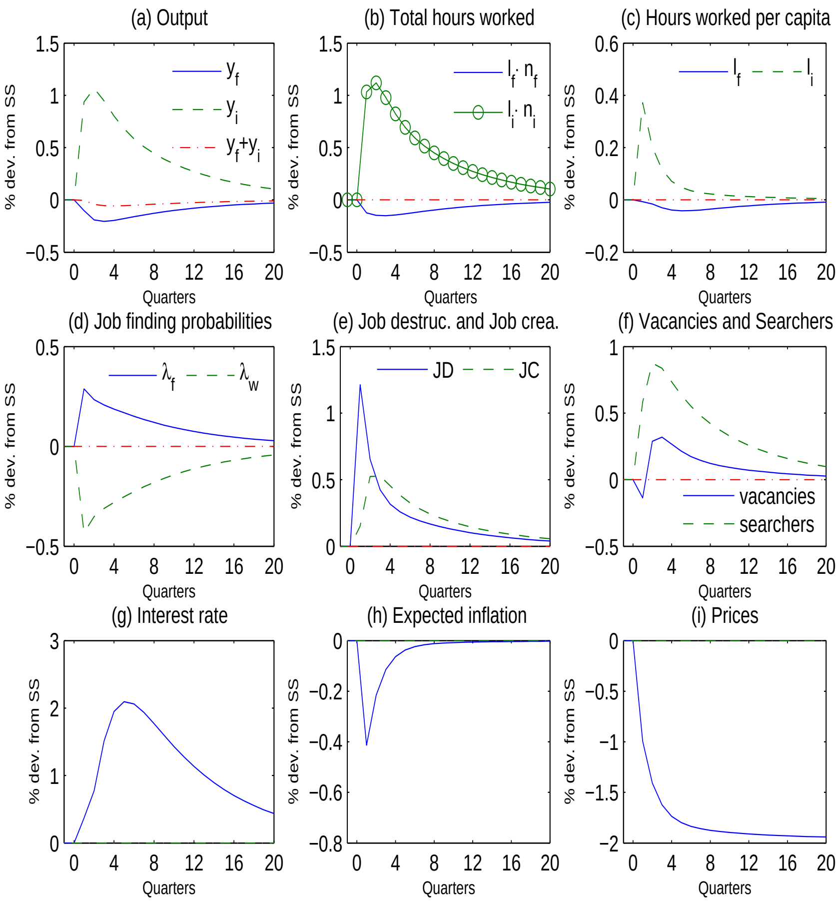

Figure III.3: Percentage deviation from the steady-state caused by a contractionary monetary shock.

in the nominal interest rate reduces the present value of production and increases the production cost of formal firms by making loans more costly. These effects generate an increase in the job destruction rate causing a fall in formal employment and hours and, as a consequence, a decline in the output produced by the formal sector.

The increase in the job destruction rate causes an increase in the measure of job searchers and reduces the probability of finding a job in the formal sector thus creating a substitution effect for unemployed workers from searching for a job in the formal sector towards working in the informal sector. This effect induces a rise in the amount of hours per individual allocated to informal activities. Apart from this substitution effect, changes in expected inflation also affect individuals' incentives to work in the informal sector, since expected inflation acts as a tax on informal activities. The reduction in expected inflation increases the present value of informal production and makes more appealing the work in the informal sector. This effect together with the substitution effect explain the increase in hours worked in the informal sector after the first year. Both the increase in the number of hours worked in the informal sector and the increase of informal labor supply caused by the fall in formal employment lead to an increase in the output produced in the informal sector as shown in Figure III.3(a).

These results are consistent with the stylized facts of monetary policy mentioned in the introduction that after a negative monetary shock output and employment observed decrease, which in our model corresponds to output and employment of the formal sector. More relevant in our case is that these results are also consistent with the empirical evidence we have presented that output in the informal sector increases after a contractionary monetary shock, which suggests that a contractionary monetary shock induces a switching of activities from the formal towards the informal sector. Since firms in the informal sector use a less productive technology than formal firms, this switching of activities still has a modest negative effect on output, but much smaller than the observed in the formal sector.

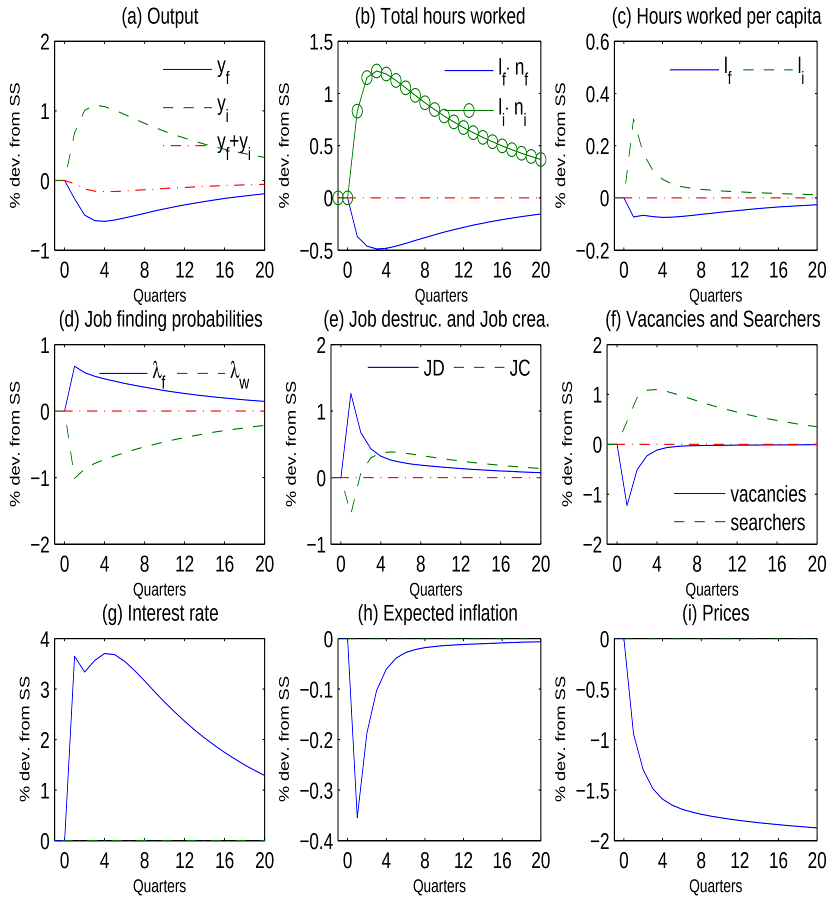

Figure III.4: Percentage deviation from the steady-state caused by a contractionary monetary shock. Large informal sector.

Figure III.4 shows the response of an economy with a large informal sector, 25% of formal output, to a negative monetary shock. To generate this economy we increase the productivity of informal firms with respect to formal firms from $\delta_p = 0.4665$ to $\delta_p = 0.5131$. The response of the economy is qualitatively similar for almost all variables. The main observation is that the responses are larger and more persistent than before. The effect on total output, however, continues to be very small.

7 Conclusions

Many studies have found that informal economic activity is a fact in market economies. Some claim that its share in measured GDP has been increasing in for the last 20 years to make the informal economic sector a significant phenomenon in many countries. For this reason, it is important that policy makers have a better understanding of both the causes of informal sector activity and its reaction to economic policy measures. While there exist studies on the effects of fiscal policy, social welfare, and institutions' quality on the informal sector we lack understanding of how, if at all, informal sector activity is affected by monetary policy. This paper makes a step towards estimating potential effects of monetary policy on informal sector activity and understanding the mechanism behind these effects. Our first findings are that informal sector activity reacts very different to monetary policy than that in the formal sector. In order to get some insight of this somewhat surprising result we begin by examining the differences between the two sectors. In our opinion, two important differences have the potential to explain this result. First, informal sector activity typically does not have access to external financing and therefore is not directly influenced by liquidity effects. Second, informal sector activity makes its transactions mainly in cash, so that inflation acts as a tax on these transactions. Based on these two observations, we build a two-sector monetary business cycle model that captures quite well what we have found in our estimation. Our next step is to repeat the estimation for various countries with significant informal sector, such as Spain, Italy, and Greece, and to calibrate the model to these economies incorporating aggregate uncertainty. This will allow us to study the business cycle properties and bring us better understanding of how the mechanism works.

As noted earlier, our model accounts for the part of the informal sector that is due to the decisions of the labor force, both official and unofficial. We keep out of our model fiscal causes and the decision of production firms to keep (part of) their activity unreported to fiscal authorities. It is relatively straightforward to incorporate distorting taxes in the model and it is left as future work.

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