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Macroeconomic Impact of Product and Labor Market Reforms on Informality and Unemployment in India

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Abstract

This paper investigates the implications of lowering formal regulations in labor and product markets on informality and macroeconomic outcomes in India. We estimate a DSGE model with an informal sector, and rigidities in the formal labor and product markets. Along with increasing GDP and employment, deregulation also leads to lower informality and greater product market competition. Slow reallocation of resources between the formal and informal sectors leads to some adverse impacts in the short run that can be minimized by implementing a combined package of reforms. These impacts are shown to be greater in an economy with a larger informal sector.

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Contents	Page
I. Introduction.....	1
II. Literature Review.....	4
III. Two Sector Model with Regulations	6
1. Wholesale Producers: The Labor Market	7
2. Retailers: Free Entry and the Number of Firms.....	11
3. Household	14
4. Capital Producer.....	16
5. Rest of the World.....	17
6. Government Policy	18
7. Market Clearing and Aggregation	19
8. Shock Processes	19
IV. Method of Estimation	20
1. Data.....	20
2. Calibration.....	20
3. Bayesian Estimation.....	24
V. Estimation Results.....	24
1. Posterior Estimates for India.....	24
VI. Dynamic Adjustment to Market Deregulation	25
1. Labor Market Deregulation.....	26
2. Product Market Deregulation.....	30
3. Reform Combination	32
4. Low Informality	34
VII. Conclusion.....	35
Figures	
1. Despite Improvement, Product Market Regulation Remains High	1
2. Informality in India	2
3. Deteriorating Employment Conditions for Informal Workers.....	2
4. Long Run Impact of a Fall in Formal Hiring Cost.....	27
5. Short Run Impact of a Fall in Formal Hiring Cost	28
6. Long Run Impact of a Fall in Formal Bargaining Power	29
7. Short Impact of a Fall in Formal Bargaining Power.....	30
8. Long Run Impact of a Fall in Formal Entry Cost	31
9. Short Run Impact of a Fall in Formal Entry Cost.....	32

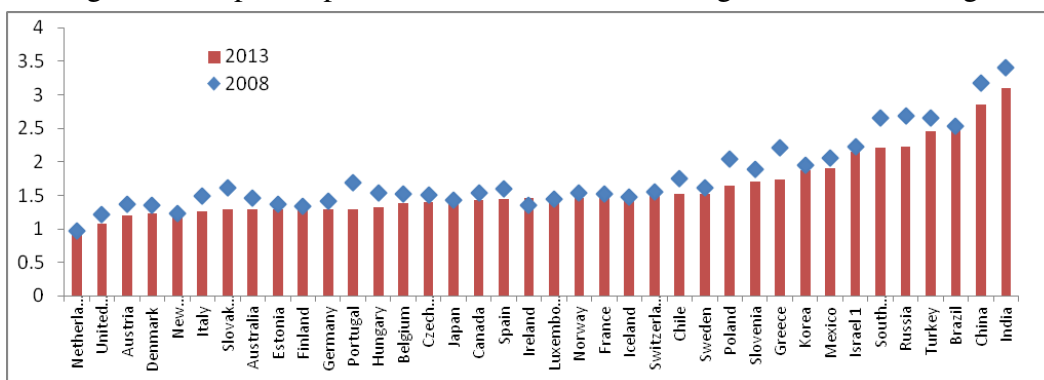
10. Long Run Impact of a Fall in Formal Hiring Cost Combined with a Fall in Formal Bargaining Power.....	33
11. Long Run Impact of a Labor and Product Market Deregulation	34
12. Short Run Impact of a Combined Package of Reforms	46
13. Impact of Deregulation Reforms with Low Informality.....	49
Table	
1. Parameter Calibration, Baseline Model for India	22
2. Prior and Posterior Distributions, Baseline Model	42
3. Robustness of Result, Alternative and Baseline Model.....	45
4. Impact of Deregulation Policies, Baseline Model	47
5. Impact of Deregulation Policies with Low Informality	48
References.....	36
Appendix.....	42
Technical Appendix	50

1. Introduction

The relationship between market regulations and growth is complex. On one hand, regulations can improve growth by removing certain market failures, and improving economic efficiency. On the other hand, however, they can have a negative impact on growth by creating undesirable compliance costs, and market distortions. Determining which effect is stronger is crucial for making informed policy decisions. This has led to an ongoing and intense debate on labor and product market reforms in India today, where market regulations are argued to be quite restrictive.

Although significant progress has been made in liberalizing product and labor markets, product market competitiveness and labor market flexibility in India remain low. The OECD's product market regulation index (2013) suggests that product markets in India are less competitive compared to other OECD (including the emerging market economies) and Non-OECD countries (Figure 1). This is mainly due to high level of state control in many industries which lowers competition, along with existence of several barriers to entrepreneurship including many administrative burdens on business start ups and other regulatory hurdles¹.

Figure 1: Despite improvement, Product Market Regulation remains high



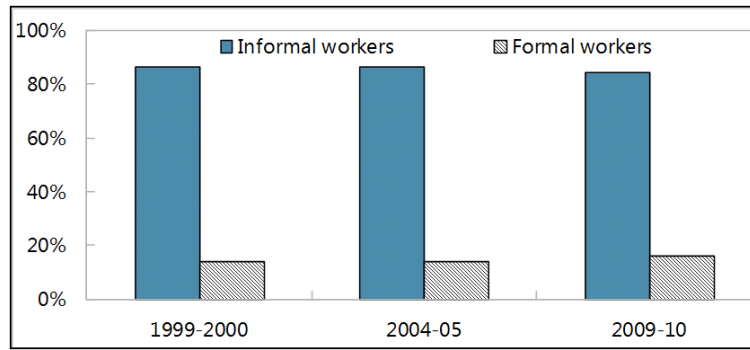
Source: OECD Product Market Regulation (2013), higher number means more restrictive.

Labor market rigidities remain high because of multiplicity of labor laws and high costs of meeting legal requirements. Though, the Industrial Disputes Act (IDA) of 1947 is the basis of industrial labor regulations in India (it requires firms employing 100 workers or more to seek government's permission to dismiss a worker or to close a plant²), firms are required to comply with numerous, complex and ambiguous laws governing different aspects of labor market (such as laws governing minimum wages, resolution of industrial disputes, conditions for hiring and firing workers, and conditions for the closure of establishments etc.).

¹These include hurdles to land acquisition, environment clearances, construction permits, getting electricity, resolving insolvency among others

²The Act was passed by the central government, and applied equally to all states. This Act has been amended by state governments, which has caused the states to differ markedly in their labor regulation.

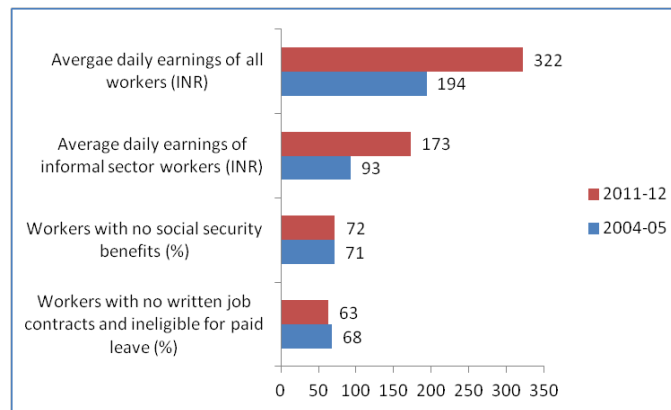
Figure 2: Informality in India



Source: Report on the Conditions of Work and Promotion of Livelihoods in the Informal Sector, National Commission for Enterprises in the Unorganized Sector (based on National Sample Survey Organization (NSSO) data)

Empirical studies find a significantly negative effect of strict regulations in the labor and product market on employment and productivity³. In addition, high labor and product market rigidities have resulted in a large informal (unorganized) sector in India which employs nearly 90 percent of the Indian workforce, and contributes almost half to India’s GDP (Figure 2)⁴. Tightly regulated formal (organized) sector forces firms to remain small and informal to avoid regulations (see, for instance, Besley and Burgess (2004), Sharma (2009); Kathuria (2013)). Although the informal sector provides useful employment opportunities, high level of informality has failed to improve labor welfare (as workers operate in an unregulated environment, are paid low wages with no job security), negating the very motive of India’s pro-worker regulations (Figure 3).

Figure 3: Deteriorating employment conditions for informal workers



Source: Informal Sector and Conditions of Employment in India , NSS 68th Round (June 2011-June 2012), National Sample Survey Office (NSSO)

³These include Besley and Burgess (2004), Aghion et al. (2005), Arnold et al. (2008a), and Jha and Golder (2008) which are studies based on India; Alesina et al. (2005), Conway et al. (2006), Fiori et al. (2007), Arnold et al.(2008), Bassanini and Duval (2009), Barone and Congano (2012) and Bourles et al. (2013) focus on OECD countries.

⁴Note that informality is a complex, multi-faceted issue that may not just reflect regulations.

Indeed, researchers have attempted to build theoretical frameworks to study the macroeconomic effects of easing regulation, i.e. a deregulation reform⁵. These frameworks model rigidities in the labor and product markets within a standard New Keynesian setting, where market deregulation leads to a fall in rigidities. However, these studies are restricted to developed economies, where the impact of deregulation reforms on the flows between formal employment and unemployment captures most of the labor market fluctuations. In most emerging economies (particularly India), on the other hand, capturing the impact of market reforms on the flows between the formal and informal sector becomes more relevant.

Motivated by these observations, the objective of this paper is to estimate the short run and long run impact of deregulation reforms in the presence of informality for India. To this end, we develop a small open economy dynamic stochastic general equilibrium (DSGE) model with a formal and informal sector, combined with rigidities (i.e. regulations) in the labor market following Blanchard and Gali (2006), as well as rigidities in the product market following Bilbie et al. (2012). Our contribution adds to the existing literature along two dimensions. First, our paper incorporates informality and openness within a unified framework, both features largely ignored in the market regulation literature. Second, existing studies in the literature apply calibration techniques to assign values for the relevant parameters using reference studies from developed countries. For India, due to scarce empirical studies, relying on calibration of parameters could potentially lead to biased results. Hence, we estimate the parameters in our model using Bayesian techniques and quarterly data for India.

To capture empirical evidence, we model informality in both the product and in labor market. In the product market, formal and informal firms co-exist. They combine labor with rented capital in order to produce formal and informal goods, and sell these at different prices, respectively. They hire labor from the same pool of unemployed workers, which integrates the two sectors. Formal firms employ labor on formal contracts, whereas informal firms employ labor informally. Number of firms operating in each sector is determined endogenously by a sunk-entry cost that firms pay when starting a new business, relating to product market rigidities. Unemployment results from labor market rigidities, which are modeled as labor hiring costs. Wages, on the other hand, are determined through Nash bargaining between workers and firms. Profitability of firm entry depends on the costs of hiring workers and wage bargaining power of workers, while barriers to firm entry, in turn, affect the evolution of employment by determining the size and number of producers in each sector. Thus, firm and employment dynamics in each sector is determined by the interaction between the product and labor market regulations, which together determine the extent of informality in the economy.

Using this framework, we study the effects of policies that lower product and labor market regulations, on output, informality, unemployment, and wages. Impact on informality is considered along two dimensions: (i) informality in the labor market, given by the share of formal workers among the employed; and (ii) informality in the product market, which is captured by both, the number of firms in the formal sector among the total number of firms, and the share of formal output in aggregate output. Labor market deregulation is considered as a fall in

⁵See, for instance, Blanchard and Giavazzi (2003), Alessandria and Delacroix (2008), Ebelle and Haefke (2009), and Cacciatore et al. (2012, 2015).

formal firms' labor hiring costs, or a fall in formal workers' wage bargaining power⁶. Product market deregulation, on the other hand, is a reduction in entry barriers, i.e. lower entry costs for firms in the formal sector⁷.

Our main findings in this paper are summarized as follows. First, gross domestic product (GDP) increases and unemployment decreases with lower regulations in the long run. At the same time, deregulation lowers informality in both labor and goods markets. Quantitatively, for the same size of shocks, these gains are significantly larger with labor market deregulation, relative to product market deregulation. Second, regarding wages, labor market deregulation raises informal sector wages and lowers formal sector wages, reducing wage inequality. On the other hand, product market deregulation increases wages in both sectors, with a larger increase in formal sector wages, resulting in higher wage inequality. Third, both product and labor market deregulation entail short run adjustment costs as follows. GDP (real output) falls, unemployment increases, and informality in the goods market increases with a labor market deregulation. On the other hand, informality in the labor market is higher with a product market reform. These adverse impacts are the result of a slow reallocation of resources between the formal and informal sectors, and last up to four to five quarters post reform. We find that implementing a package of labor and product market reforms helps mitigate (and even overturn) these short run costs, while also leading to higher long run gains in GDP, employment, and formality, along with reducing wage inequality. Lastly, a comparative analysis reveals that both the direction and magnitude of impact is sensitive to the extent of informality, where long run gains as well as the short run adjustment costs are found to increase with higher informality.

The remainder of this paper is structured as follows. Section 2 presents a description of the previous literature. In Section 3 we lay out the theoretical model. Section 4 describes the data, calibration and estimation of our model for India. In Section 5 we present the estimation results and Section 6 discusses the dynamic impacts of deregulation reforms. Section 7 provides concluding remarks.

2. Literature Review

This section presents a brief overview of the related theoretical studies. Our study integrates the two strands of literature - policy literature on market regulations and policy literature on informality - within a unified theoretical framework.

The work on market deregulation reforms are broadly categorized into three different groups: (i) Studies focusing only on regulations in the product market without any labor market regulations, or solely on the latter without considering the former⁸. However, as they ignore any

⁶These mainly refer to lower labor unionization, and changes to unproductive employment protection legislations.

⁷It represents changes such as simplifying procedures, and getting rid of corrupt bureaucratic activities involved in setting up a new business.

⁸Campolmi and Faia (2006), Thomas and Zanetti (2008), and Christofell et al. (2009) study the impact of labor

interplay between the product and labor market, which is found to be of significance importance, these studies do not fully capture the impact of these reforms⁹. (ii) Studies that model both product and labor market regulations in a static framework to study the long run effects of deregulation (Blanchard and Giavazzi (2003)¹⁰, Alessandria and Delacroix (2008), Ebelle and Haefke (2009)¹¹). In sum, results in this group of literature suggest that in the long run output and employment increases with both product and labor market deregulation. They also find significant interaction between the two reforms. However, short run outcomes are not captured in these static frameworks. (iii) Recent studies that use a DSGE framework to capture the dynamic impacts of both product and labor market reforms (Cacciatore and Fiori (2012), Cacciatore et al. (2012, 2013, 2015)). Our paper is closely related to this third group of studies.

Cacciatore and Fiori (2012) build a small open economy model with nominal rigidities, search and matching frictions, and endogenous firm entry. The model is calibrated to OECD countries. In the long run, both labor and product market deregulation increase output and decrease unemployment. There are short term costs in terms of increased unemployment and a fall in consumption, and they conclude that implementation of a package of reforms might help mitigate the short term costs. Cacciatore et al. (2015) build on this framework but calibrate it to the Euro area instead, where their analysis generates similar results. Cacciatore et al. (2013), on the other hand, build a two-country model but focus on the optimal monetary policy in the presence of regulation and not on the effects of deregulations itself.

This existing literature focuses on developed economies and employs one-sector models, where the presence of informality is not considered. In order to fully capture the impact of deregulation policies in emerging economies, we find that it is crucial to model the interplay between the formal and informal sector. For example, if formal labor hiring costs are lowered, it has a direct impact on informal employment, as more workers will now be able to find formal jobs, which indirectly affects the number of informal firms through changes in the relative profitability of firms in the two sectors. Hence, applying these models created for developed countries to the study of market reforms in emerging countries may result in inaccurate analysis.

A notable exception is Charlot et al. (2011), who distinguish between formality and infor-

market deregulation with no role of regulations in the product market; whereas Spector (2004), Felbemayr and Prat (2011), Bilbie et al. (2012), and Bertinelli et al. (2012) analyse the impact of product market deregulation abstracting from the role of labor market regulations.

⁹The interaction between product and labor market regulations is an important issue; for instance, empirical evidence suggests that the gains from product market deregulation are more if labor market regulation is less restrictive (Besley and Burgess (2004), Aghion et al. (2005), Fiori et al. (2007)).

¹⁰Blanchard and Giavazzi (2003) is one of the earliest works in this literature, which models imperfectly competitive firms for whom labor is the only factor of production, and both product and labor markets are non-competitive. Product market deregulation is modeled as a fall in firm entry costs, whereas labor market deregulation is a fall in workers' bargaining power. Following studies have consequently built around this framework.

¹¹Note that even though the framework in Ebelle and Haefke (2009) incorporates rigidities in both product and labor markets, they only analyse the effects of product market deregulation, abstracting from any analysis on deregulation in the labor market.

mality in the goods and labor market in a simple closed economy static model setting. Both the formal and the informal sectors are subject to search and matching frictions in the labor market, and endogenous firm entry. Data for Brazil serves as the basis for the model's calibration. Similar to our findings, their analysis suggests that both reforms lower informality and unemployment in the long run. Our results also match theirs regarding increase in wage inequality associated with a product market deregulation, however, with labor market deregulation we find that reduction in wage inequality stems from an increase in informal sector wages and a fall in formal sector wages, as opposed to a fall in both in Charlot et al. (2011). In terms of quantities, they find significantly smaller impacts on informality and unemployment, in comparison to our findings.

Their work makes a significant contribution, as it is the first and only study among the existing market regulation literature that models informality and is suited and applied to a developing economy. However, short run outcomes are not captured in their static frameworks. In addition, their framework is not detailed enough to capture all the channels through which reforms impact the economy. In particular, their framework abstracts from modeling a comprehensive demand side of the economy; for instance, it does not capture the full impact of policies on GDP as they do not model investment, government and the export sector, hence making their framework inadequate for quantitative policy analysis.

Our study is also related to the growing literature that incorporates informality and unemployment in a general equilibrium setting (see, for instance, Conesa et al. (2002), Zenou (2008), Castillo and Montoro (2008), and Satchi and Temple (2010)). However, these studies abstract from the role of product market rigidities and hence its interplay with rigidities in the labor market. Moreover, they focus on the interaction between informality and monetary policy, and not on the effects of deregulation policies.

3. Two Sector Model with Regulations

This section presents the Baseline model and the Technical Appendix describes the derivation of optimality conditions¹².

The small open economy is populated by households, wholesale producers, retailers, capital producers, and a government. There are three consumption goods: formal tradable goods (F , sold both domestically and in the rest of the world), informal non-tradable goods (I), and imported goods (f^*). The first two are produced domestically by formal and informal retailers in each sector $s \in \{F, I\}$, respectively, while the latter is produced in the foreign economy and sold domestically by import retailers in the formal sector.

Formal and informal wholesale firms hire workers supplied by domestic households, and rent capital from domestic capital producers, to produce formal and informal wholesale goods,

¹²Magnus Saxegaard at the IMF and Zsuzsa Munkacsi at the European University Institute (EUI) were closely involved in the development stages of this model. They employ a similar model to look at the impact of deregulation reforms in South Africa in their forthcoming IMF Working Paper titled 'Structural Reforms, Openness and the Informal Economy'.

respectively. They sell these to retailers in their respective sectors in a competitive manner. Unemployment exists as wholesalers in each sector pay a hiring cost when hiring new labor, which is an increasing function of the vacancy to unemployment ratio *a la* Blanchard and Gali (2006). Wages in each sector are determined through Nash bargaining between workers and firms.

Formal and informal retailers purchase wholesale goods from wholesalers in their respective sectors, differentiate these into different varieties, and set the retail price for each individual variety in an environment of monopolistic competition and price adjustment costs *a la* Rotemberg (1982). The number of retailers operating in each sector is determined endogenously by a sunk entry cost that retailers pay when starting a new business *a la* Bilbie et al. (2012), where the price elasticity of demand for each individual variety of retail good, is positively related to the number of competitors in each sector. Formal retailers sell the final formal tradable good to households, capital producers, and government in the domestic economy, while also exporting it to the foreign economy. Informal retailers on the other hand, sell the informal final good to domestic households only.

Households consume domestic and imported goods (subject to habit formation), purchase domestic and foreign bonds, supply labor to wholesalers, finance entry of new firms in each sector, collect profits from domestic firms, and pay taxes on formal sector wage income to the government. A group of competitive capital producers combine final formal goods and imported goods to produce final investment goods, which is then combined with the used capital goods rented from wholesalers to produce new capital. Government consumes an exogenous stream of final goods consisting of domestically produced formal goods and imported goods, and provide unemployment benefits to unemployed workers, which is financed by taxing wage income in the formal sector. They also set the nominal interest rate on domestic bonds using a Taylor-type rule.

Details regarding each agent's behaviour are described below.

3.1. Wholesale Producers: The Labor Market

Wholesale firms operating in each sector $s \in (F, I)$ differ along two dimensions: available technology and labor market regulations. We have a continuum of wholesalers $(0, 1)$ in each sector s producing different intermediate goods, $Y_{F,t}^W$ and $Y_{I,t}^W$, with access to different technologies, $\theta_{F,t}$ and $\theta_{I,t}$. By the beginning of period t , they are assumed to acquire capital, $K_{F,t-1}$ and $K_{I,t-1}$, from capital producers, which is combined with labor hired from households, $L_{F,t}$ and $L_{I,t}$, to produce these goods over period t , using a Cobb-Douglas function¹³:

$$Y_{F,t}^W = \theta_{F,t} (K_{F,t-1})^{\psi_F} (L_{F,t})^{1-\psi_F} \quad (3.1)$$

$$Y_{I,t}^W = \theta_{I,t} (K_{I,t-1})^{\psi_I} (L_{I,t})^{1-\psi_I} \quad (3.2)$$

¹³Wholesale firms are assumed to be perfectly competitive and use a constant returns to scale (CRS) technology function. This allows us to treat these firms as a whole, and hence we write aggregate production function without firm specific constraints.

where ψ_s is the capital intensity related to capital income share in sector s . They sell their goods to retailers in their respective sectors at a price of $P_{F,t}^W$ and $P_{I,t}^W$.

Hiring Cost

Wholesalers in each sector s face real hiring costs, $HC_{s,t}$, when hiring new labor, $H_{s,t}$, and the real wage, $W_{s,t}$, is decided by the generalized Nash bargaining solution. Per period real profit is equal to the revenue net costs spent on renting capital and employing labor, where the latter includes both wages and labor hiring costs:

$$\Pi_{F,t}^W = \frac{P_{F,t}^W}{P_t} Y_{F,t}^W - W_{F,t} L_{F,t} - R_t^K K_{F,t-1} - HC_{F,t} H_{F,t} \quad (3.3)$$

$$\Pi_{I,t}^W = \frac{P_{I,t}^W}{P_t} Y_{I,t}^W - W_{I,t} L_{I,t} - R_t^K K_{I,t-1} - HC_{I,t} H_{I,t} \quad (3.4)$$

P_t is the aggregate price level of the final goods, and R_t^K is the real rental rate of capital.

The stock of employed labor in each sector s varies because of the endogenous variation in hiring, and an exogenous probability of getting fired $\sigma_{s,t}$ every period. Wholesalers in each sector s fire workers, $F_{s,t}$, at the beginning of period t from the pool of employed workers at the end of the previous period. During period t , wholesalers hire new labor from the pool of unemployed workers, which consists of the unemployed workers in $t-1$, plus the ones that are fired: $U_{t-1} + \sigma_{F,t} L_{F,t-1} + \sigma_{I,t} L_{I,t-1}$. After firing and hiring takes place, the labor employed at the end of period t is given by $L_{s,t}$ as follows:

$$L_{F,t} = L_{F,t-1} - F_{F,t} + H_{F,t} = (1 - \sigma_{F,t}) L_{F,t-1} + H_{F,t} \quad (3.5)$$

$$L_{I,t} = L_{I,t-1} - F_{I,t} + H_{I,t} = (1 - \sigma_{I,t}) L_{I,t-1} + H_{I,t} \quad (3.6)$$

Probability of getting hired, $p(H_{s,t})$, is then given by the ratio of new hires to the pool of unemployed:

$$p(H_{F,t}) = \frac{H_{F,t}}{U_{t-1} + \sigma_{F,t} L_{F,t-1} + \sigma_{I,t} L_{I,t-1}} \quad (3.7)$$

$$p(H_{I,t}) = \frac{H_{I,t}}{U_{t-1} + \sigma_{F,t} L_{F,t-1} + \sigma_{I,t} L_{I,t-1}} \quad (3.8)$$

The formal and informal labor markets are integrated, as they hire from the same pool of unemployed workers. Following Blanchard and Gali (2006), hiring costs depend positively on the total number of new hires, and negatively on the pool of unemployed at the beginning of period t ¹⁴:

$$HC_{F,t} = (\beta_{HC_{F,t}}) p(H_{F,t})^{\alpha_{HC_{F,t}}} \quad (3.9)$$

¹⁴Blanchard-Gali (2006) show that the presence of hiring costs creates a friction in the labor market similar to the cost of posting a vacancy and the time needed to fill in the standard Diamond-Mortensen-Pissaridis (DMP) model.

$$HC_{I,t} = (\beta_{HC_{I,t}}) p(H_{I,t})^{\alpha_{HC_I}} \quad (3.10)$$

$\alpha_{HC_s} > 0$ is the elasticity of hiring cost with respect to the hiring probability in sector s , and exogenously given $\beta_{HC_{s,t}} > 0$ determines the intensity of hiring costs in each sector s .

Capital and Labor Demand

Wholesalers in sector s choose $L_{s,t}$, $H_{s,t}$, and $K_{s,t-1}$ by maximising their expected discounted value of future profits:

$$\max_{L_{s,t}, K_{s,t-1}, H_{s,t}} E_t \sum_{k=0}^{\infty} \rho_{t,t+k} \Pi_{s,t+k}^W \quad (3.11)$$

subject to the law of motion of employment, given by Eq. 3.5 for the formal sector and Eq. 3.6 for the informal sector. $\rho_{t,t+k}$ is the stochastic discount rate obtained from the households' optimization problem derived below.

We obtain the following capital and labor demand functions from the first order conditions:

$$R_t^K = \psi_F \frac{P_{F,t}^W Y_{F,t}^W}{P_t K_{F,t-1}} \quad (3.12)$$

$$(1 - \psi_F) \frac{P_{F,t}^W Y_{F,t}^W}{P_t L_{F,t}} = W_{F,t} + HC_{F,t} - E_t (\rho_{t,t+1} HC_{F,t+1} (1 - \sigma_{F,t+1})) \quad (3.13)$$

Similarly for the informal sector ($s = I$), we obtain:

$$R_t^K = \psi_I \frac{P_{I,t}^W Y_{I,t}^W}{P_t K_{I,t-1}} \quad (3.14)$$

$$(1 - \psi_I) \frac{P_{I,t}^W Y_{I,t}^W}{P_t L_{I,t}} = W_{I,t} + HC_{I,t} - E_t (\rho_{t,t+1} HC_{I,t+1} (1 - \sigma_{I,t+1})) \quad (3.15)$$

The equation for capital demand in each sector (Eq. 3.12 and Eq. 3.14) is standard in the literature, where the marginal product of capital is equal to its cost. The labor demand, on the other hand, is now determined by equating its marginal product to the cost of employing labor, which includes the real wage plus the cost of hiring.

Wage Determination

Wage setting follows a Nash bargaining process between workers and wholesalers where exogenously determined wage bargaining power of the worker in the two sectors is given by $\lambda_F \varepsilon(0, 1)$ and $\lambda_I \varepsilon(0, 1)$, respectively. This captures the level of unionization in each sector.

Let $V_{F,t}$, $V_{I,t}$, and $V_{U,t}$ be the marginal value to a worker of being employed formally, employed informally, and of being unemployed. A formally employed worker in period t receives current

wage income of $(1 - \tau_F)W_{F,t}$, where τ_F is the marginal tax rate on wage income. In period $t + 1$, this worker either remains employed with the same firm with probability $(1 - \sigma_{F,t+1})$, or gets fired with probability $\sigma_{F,t+1}$. If fired, there is a probability $p(H_{F,t+1})$ of getting rehired in the same sector, a probability $p(H_{I,t+1})$ of getting hired in the informal sector, and a probability $1 - \sum_{s=F,I} p(H_{s,t+1}) ds$ of staying unemployed. Hence, we obtain the following expression for $V_{F,t}$:

$$V_{F,t} = (1 - \tau_F)W_{F,t} + E_t \left\{ \rho_{t,t+1} [1 - \sigma_{F,t+1}(1 - p(H_{F,t+1}))] V_{F,t+1} \right\} \quad (3.16)$$

$$+ E_t \left\{ \rho_{t,t+1} (\sigma_{F,t+1}) [p(H_{I,t+1})V_{I,t+1} + (1 - p(H_{I,t+1}) - p(H_{F,t+1}))V_{U,t+1}] \right\}$$

Similarly, we get the value of being employed in the informal sector, the only difference being that the worker does not pay wage income tax, $\tau_I = 0$:

$$V_{I,t} = W_{I,t} + E_t \left\{ \rho_{t,t+1} [1 - \sigma_{I,t+1}(1 - p(H_{I,t+1}))] V_{I,t+1} \right\} \quad (3.17)$$

$$+ E_t \left\{ \rho_{t,t+1} (\sigma_{I,t+1}) [p(H_{F,t+1})V_{F,t+1} + (1 - p(H_{I,t+1}) - p(H_{F,t+1}))V_{U,t+1}] \right\}$$

A worker currently unemployed, receives unemployment benefits from the government, $W_{U,t}$. In the next period, he can get hired in the formal sector with probability $p(H_{F,t+1})$, hired in the informal sector with probability $p(H_{I,t+1})$, or remain unemployed with probability $1 - \sum_{s=F,I} p(H_{s,t+1}) ds$. This gives us the worker's value of being unemployed V_t^U as:

$$V_{U,t} = W_{U,t} + E_t \left\{ \rho_{t,t+1} (1 - p(H_{I,t+1}) - p(H_{F,t+1})) V_{U,t+1} \right\} \quad (3.18)$$

$$+ E_t \left\{ \rho_{t,t+1} [p(H_{F,t+1})V_{F,t+1} + p(H_{I,t+1})V_{I,t+1}] \right\}$$

An unemployed worker has a utility gain of $(V_{F,t} - V_{U,t})$ if he gets hired in the formal sector, and similarly $(V_{I,t} - V_{U,t})$ with informal employment.

Following the derivations in Blanchard and Gali (2006), sector s wholesalers' value of hiring an additional worker h in period t , $J_{s,t}$, is simply given by the hiring cost in the same period, i.e $J_{s,t} = HC_{s,t}$. This is because in our framework there is no search time for hiring new worker (i.e. instant hiring assumption), and so a firm can always replace a worker who is fired at this cost.

Generalized Nash bargaining over the wage rate determines the division of rent between the worker and firm in sector s :

$$\max_{W_{s,t}} (V_{s,t} - V_{U,t})^{\lambda_{s,t}} J_{s,t}^{(1-\lambda_{s,t})}$$

and the equation determining wages, $W_{s,t}$, in sector s is:

$$V_{s,t} - V_{U,t} = \frac{\lambda_{s,t}}{1 - \lambda_{s,t}} (1 - \tau_{s,t}) J_{s,t} \quad (3.19)$$

The evolution of formal and informal sector wage rate is derived in the Technical Appendix:

$$\begin{aligned}
W_{F,t}(1 - \tau_F) &= \frac{\lambda_{F,t}}{1 - \lambda_{F,t}}(1 - \tau_F)HC_{F,t} + W_{U,t} \\
&- (1 - \tau_F)E_t \left\{ \rho_{t,t+1} \left[\frac{\lambda_{F,t+1}}{1 - \lambda_{F,t+1}}(1 - \sigma_{F,t+1})(1 - p(H_{F,t+1}))HC_{F,t+1} \right] \right\} \\
&+ E_t \left\{ \rho_{t,t+1} \left[\frac{\lambda_{I,t+1}}{1 - \lambda_{I,t+1}}(1 - \sigma_{F,t+1})p(H_{I,t+1})HC_{I,t+1} \right] \right\}
\end{aligned} \tag{3.20}$$

$$\begin{aligned}
W_{I,t} &= \frac{\lambda_{I,t}}{1 - \lambda_{I,t}}HC_{I,t} + W_{U,t} \\
&- E_t \left\{ \rho_{t,t+1} \left[\frac{\lambda_{I,t+1}}{1 - \lambda_{I,t+1}}(1 - \sigma_{I,t+1})(1 - p(H_{I,t+1}))HC_{I,t+1} \right] \right\} \\
&+ (1 - \tau_F)E_t \left\{ \rho_{t,t+1} \left[\frac{\lambda_{F,t+1}}{1 - \lambda_{F,t+1}}(1 - \sigma_{I,t+1})p(H_{F,t+1})HC_{F,t+1} \right] \right\}
\end{aligned} \tag{3.21}$$

Eq. 3.21 (Eq. 3.20) suggests that wages in the informal (formal) sector not only depend upon the rigidities in the informal (formal) labor market but also in the formal (informal) labor market.

3.2. Retailers: Free Entry and the Number of Firms

There are a continuum j_F and j_I of monopolistically competitive formal and informal retailers, who buy wholesale goods, $Y_{F,t}^W$ and $Y_{I,t}^W$, to produce different final good varieties, $Y_{F,t}(j_F)$ and $Y_{I,t}(j_I)$, and sell these at different prices, $P_{F,t}(j_F)$ and $P_{I,t}(j_I)$, respectively¹⁵.

In investigating the effects of deregulation in product markets, we allow for retail firm entry-exit decision following Bilbie et al. (2012). In every period there are $N_{s,t}$ retailers in each sector s , and we assume an unbounded mass of prospective entrants, $N_{s,t}^E$. Operating retailers make profits, $\Pi_{s,t}^R$, every period, and face an exogenous probability of going bankrupt, δ_s . Prospective entrants compute their value, $d_{s,t}$, if they decide to enter the market:

$$\begin{aligned}
d_{F,t} &= E_t \sum_{k=t}^{\infty} \rho_{k,k+1} (1 - \delta_F)^k \Pi_{F,s}^R \\
d_{I,t} &= E_t \sum_{k=t}^{\infty} \rho_{k,k+1} (1 - \delta_I)^k \Pi_{I,s}^R
\end{aligned}$$

New entrants have to pay an exogenously given sunk entry cost, $f_{F,t} > 0$ when starting a business in the formal sector, and an entry cost $f_{I,t} > 0$ in the informal sector. New firms

¹⁵We allow for monopolistically competitive retail sector in order to introduce price rigidity, which is one of the New Keynesians' main concepts. We also assume zero cost of differentiation.

in each sector, $N_{F,t}^E$ and $N_{I,t}^E$, enter until the firm value becomes equal to the sunk entry cost, which gives the free-entry conditions:

$$f_{F,t} = d_{F,t} \quad (3.22)$$

$$f_{I,t} = d_{I,t} \quad (3.23)$$

These determine the number of firms in each sector, which in turn determines the extent of competition in each sector. The number of firms operating each period is given by:

$$N_{F,t} = (1 - \delta_F) (N_{F,t-1} + N_{F,t-1}^E) \quad (3.24)$$

$$N_{I,t} = (1 - \delta_I) (N_{I,t-1} + N_{I,t-1}^E) \quad (3.25)$$

Here we assume that the firms which enter in period t , only start to produce goods in the next period $t + 1$, i.e. this is the standard time to build assumption. They are also subject to the same probability of bankruptcy, δ_s , as incumbent firms.

Aggregate Output

Total composite output in each sector s , $Y_{s,t}$, produced by retailers is a Dixit-Stiglitz (1977) constant elasticity of substitution (CES) aggregate of different varieties of goods produced by individual retailers $Y_{s,t}(j_s)$. In period t there are $N_{s,t}$ varieties being produced in each sector, and hence the the number of firms enters the aggregation conditions now:

$$Y_{s,t} = \left(\int_0^{N_{s,t}} Y_{s,t}(j_s)^{\frac{\varepsilon_{s,t}-1}{\varepsilon_{s,t}}} dj_s \right)^{\frac{\varepsilon_{s,t}}{\varepsilon_{s,t}-1}} \quad (3.26)$$

$\varepsilon_{s,t}$ stands for the elasticity of substitution between different varieties of goods. The corresponding price of the composite consumption good, $P_{s,t}$, is given as:

$$P_{s,t} = \left(\int_0^{N_{s,t}} P_{s,t}(j_s)^{1-\varepsilon_{s,t}} dj_s \right)^{\frac{1}{1-\varepsilon_{s,t}}} \quad (3.27)$$

Elasticity of substitution between different varieties is positively related to the number of firms in each sector (see Ebell and Haefke (2009); Felebermayr and Prat (2011)):

$$\varepsilon_{s,t} = \sigma_{N_s} N_{s,t} \quad (3.28)$$

where $\sigma_{N_s} > 0$ is a constant, and determines the sensitivity of the mark-up to changes in number of firms. Thus, the number of firms, $N_{s,t}$, determines the level of competition in period t for a firm in sector s .

The demand function facing each retailer can then be written as:

$$Y_{s,t}(j_s) = \left(\frac{P_{s,t}(j_s)}{P_{s,t}} \right)^{-\varepsilon_{s,t}} Y_{s,t} \quad (3.29)$$

Formal final good, $Y_{F,t}$, is tradable and it is consumed both domestically $Q_{F,t}^d$, by households, capital producers and government, while also being exported, Q_t^x , to the rest of the world.

$$\begin{aligned} Y_{F,t} &= C_{F,t} + I_{F,t} + G_{F,t} + Q_t^x \\ &\equiv Q_{F,t}^d + Q_t^x \end{aligned} \quad (3.30)$$

On the other hand, the informal sector good, $Y_{I,t}$, is a non-tradable good, and is only consumed domestically by households, $Q_{I,t}^d$.

$$\begin{aligned} Y_{I,t} &= C_{I,t} \\ &\equiv Q_{I,t}^d \end{aligned} \quad (3.31)$$

Price Setting

Retailer j_s sets its price, $P_{s,t}(j_s)$ that maximizes its expected discounted stream of future profits:

$$\text{Max}_{P_{s,t}(j_s)} E_t \sum_{k=0}^{\infty} \rho_{t,t+k} (1 - \delta_s)^k \Pi_{t,t+k}^R(j_s) \quad (3.32)$$

where the one-period profit in the formal sector, $\Pi_{F,t}^R(j_F)$ is given by the sum of total revenues from its domestic demand, $\left(\frac{P_{F,t}(j_F)}{P_{F,t}} \right)^{-\varepsilon_{F,t}} Q_{F,t}^d$ and export demand $\left(\frac{P_{F,t}(j_F)}{P_{F,t}} \right)^{-\varepsilon_{F,t}} Q_t^x$, net of the costs of price adjustment. Per-period profits are then obtained as:

$$\begin{aligned} \Pi_{F,t}^R(j_F) &= \left(\frac{P_{F,t}(j_F)}{P_t} - MC_{F,t}^W \right) \left(\frac{P_{F,t}(j_F)}{P_{F,t}} \right)^{-\varepsilon_{F,t}} (Q_{F,t}^d + Q_t^x) \\ &\quad - \frac{\phi_F^{adj}}{2} \left(\frac{P_{F,t}(j_F)/P_{F,t-1}(j_F)}{\pi} - 1 \right)^2 (Q_{F,t}^d + Q_t^x) \end{aligned} \quad (3.33)$$

Here $MC_{F,t}^W$ is the real marginal cost, which is equal to the perfectly competitive wholesalers' real price $\frac{P_{F,t}^W}{P_t}$. Aggregate price inflation and formal price inflation are given by $\pi_t = \frac{P_t}{P_{t-1}}$ and $\pi_{F,t} = \frac{P_{F,t}}{P_{F,t-1}}$, where π is the steady state economy wide inflation¹⁶. Following Rotemberg

¹⁶Variables without a time subscript t denotes their respective steady state values.

(1982), we have quadratic costs of price adjustment $\frac{\phi_F^{adj}}{2} \left(\frac{P_{F,t}(j_F)/P_{F,t-1}(j_F)}{\pi} - 1 \right)^2$, and $\phi_F^{adj} \geq 0$ is a parameter determining the degree of nominal rigidity in the formal sector.

Per-period profits of informal retailers are similar, except that the informal sector only sells its goods domestically:

$$\begin{aligned} \Pi_{I,t}^R(j_I) &= \left(\frac{P_{I,t}(j_I)}{P_t} - MC_{I,t}^W \right) \left(\frac{P_{I,t}(j_I)}{P_{I,t}} \right)^{-\varepsilon_I} Q_{I,t}^d \\ &\quad - \frac{\phi_I^{adj}}{2} \left(\frac{P_{I,t}(j_I)/P_{I,t-1}(j_I)}{\pi} - 1 \right)^2 Q_{I,t}^d \end{aligned} \quad (3.34)$$

where domestic demand for each variety is $\left(\frac{P_{I,t}(j_I)}{P_{I,t}} \right)^{-\varepsilon_I} Q_{I,t}^d$, and $\phi_I^{adj} \geq 0$ determines the degree of nominal rigidity in informal prices. $\pi_{I,t} = \frac{P_{I,t}}{P_{I,t-1}}$ is the inflation in informal prices.

The first order condition of the retailer optimization problem determines the optimal price-setting rule in each sector:

$$\begin{aligned} \frac{P_{s,t}(j_s)}{P_t} &= \frac{\varepsilon_{s,t}}{\varepsilon_{s,t} - 1} MC_{j,t}^W + \left(\frac{\phi_s^{adj}}{\varepsilon_{s,t} - 1} \right) \left(\frac{\pi_{s,t}}{\pi} - 1 \right) \left(\frac{\pi_{s,t}}{\pi} \right) \\ &\quad - E_t \left\{ \rho_{t,t+1} \left[\left(\frac{\phi_s^{adj}}{\varepsilon_{s,t} - 1} \right) \left(\frac{\pi_{s,t+1}}{\pi} - 1 \right) \left(\frac{\pi_{s,t+1}}{\pi} \right) \frac{Y_{s,t+1}(j_s)}{Y_{s,t}(j_s)} \right] \right\} \end{aligned} \quad (3.35)$$

$\frac{\varepsilon_{s,t}}{\varepsilon_{s,t} - 1}$ is the desired (gross) mark-up, resulting from the imperfections in the retail market. We assume that import prices follow a similar pricing rule as that of the formal goods, with $\phi_{f*}^{adj} \geq 0$ determining the degree of nominal rigidity in import prices.

3.3. Household

Utility Function

There is a representative household with a measure one continuum of identical infinitely lived members, who maximizes expected discounted lifetime utility of consumption:

$$\Lambda_t = E_0 \sum_{t=0}^{\infty} \beta^t \zeta_{C,t} \Lambda[C_t] \quad (3.36)$$

The following functional form of the utility function is assumed:

$$\Lambda[C_t] = (1 - h_c) \ln(C_t - h_c C_{t-1})$$

where β is the nominal discount factor, and $\zeta_{C,t}$ is the consumption preference shock. C_t denotes aggregate consumption at time t , while C_{t-1} is the average level of consumption in $t - 1$, where $h_c \in [0, 1)$ is the external habit formation parameter¹⁷. We assume that all households supply labor every period, and do not directly derive utility from employment or leisure.

¹⁷This functional form ensures that the habit persistence does not affect the long run equilibrium of the model.

Aggregate Consumption

Aggregate consumption, C_t , consists of domestically produced goods, $C_{D,t}$, and imported goods, $C_{f^*,t}$ (in terms of domestic currency), and is given by the following Dixit-Stiglitz (1977) aggregator:

$$C_t = \left[\alpha^{\frac{1}{\eta}} C_{D,t}^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}} C_{f^*,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad (3.37)$$

where $\alpha \in (0, 1)$ can be interpreted as a measure of domestic bias in consumption. $\eta > 1$ is the elasticity of substitution between domestic and foreign goods.

Aggregate price level, P_t , can be expressed as a composite of domestic price, $P_{D,t}$, and import price, $P_{f^*,t}$, and is given by the following CES form:

$$P_t = \left[\alpha P_{D,t}^{1-\eta} + (1-\alpha) P_{f^*,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad (3.38)$$

Domestic good consumption is a composite of formal good consumption, $C_{F,t}$, and informal good consumption, $C_{I,t}$. The aggregate domestic good consumption, $C_{D,t}$, and aggregate domestic good price, $P_{D,t}$, is:

$$C_{D,t} = \left[w^{\frac{1}{\mu}} C_{F,t}^{\frac{\mu-1}{\mu}} + (1-w)^{\frac{1}{\mu}} C_{I,t}^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}} \quad (3.39)$$

$$P_{D,t} = \left[w P_{F,t}^{1-\mu} + (1-w) P_{I,t}^{1-\mu} \right]^{\frac{1}{1-\mu}} \quad (3.40)$$

where $w \in (0, 1)$ is the weight on formal sector good, and $\mu > 1$ is the elasticity of substitution between the goods produced in the two sectors.

From households optimization problem (minimizing expenditure on the total composite demand)¹⁸, we can derive the following optimal consumption demand functions for aggregate domestic and imported market goods:

$$C_{D,t} = \alpha \left(\frac{P_{D,t}}{P_t} \right)^{-\eta} C_t \quad C_{f^*,t} = (1-\alpha) \left(\frac{P_{f^*,t}}{P_t} \right)^{-\eta} C_t \quad (3.41)$$

Similarly, we derive the optimal consumption demand functions for domestically produced formal and informal goods:

$$C_{F,t} = w \left(\frac{P_{F,t}}{P_{D,t}} \right)^{-\mu} C_{D,t} \quad C_{I,t} = (1-w) \left(\frac{P_{I,t}}{P_{D,t}} \right)^{-\mu} C_{D,t} \quad (3.42)$$

¹⁸Total consumption expenditures for the domestic household is given by $P_{D,t}C_{D,t} + P_{f^*,t}C_{f^*,t} = P_t C_t$, whereas total expenditure on domestically produced goods is: $P_{F,t}C_{F,t} + P_{I,t}C_{I,t} = P_{D,t}C_{D,t}$.

Budget Constraint

The representative household enters period t with one period (real) foreign and domestic bonds, B_{t-1}^* (in foreign currency) and D_{t-1} , both of which yield a nominal interest rate of i_{t-1}^f and i_{t-1} over the period t , respectively. In addition, during period t , individuals who are employed, earn after tax wage income of $(1 - \tau_F)W_{F,t}L_{F,t}$ and $W_{I,t}L_{I,t}$ in formal and informal jobs, and the unemployed receive social benefits, $(W_{U,t})(1 - L_{F,t} - L_{I,t})$. They receive real dividends arising from the ownership of the monopolistically competitive retail firms, $N_{F,t}\Pi_{F,t}^R$ and $N_{I,t}\Pi_{I,t}^R$. The income is spent on the consumption of market goods, C_t , purchase of one period bonds for the subsequent period, B_t and D_t , and in financing entry of new firms $N_{F,t}^E f_{F,t}$ and $N_{I,t}^E f_{I,t}$. Denoting e_t as the nominal exchange rate where an increase in its value implies depreciation of domestic currency, we have the following period budget constraint of the household in real terms, with $RER_t = \frac{e_t P_t^*}{P_t}$ as the real exchange rate:

$$\begin{aligned} C_t + (RER_t)B_t^* + D_t + N_{F,t}^E f_{F,t} + N_{I,t}^E f_{I,t} & \quad (3.43) \\ & = \left(\frac{e_t}{e_{t-1}} \right) \left(\frac{1 + i_{t-1}^f}{\pi_t} \right) (RER_{t-1})B_{t-1}^* \\ & + \left(\frac{1 + i_{t-1}}{\pi_t} \right) D_{t-1} + N_{F,t} (\Pi_{F,t}^R + f_{F,t}) + N_{I,t} (\Pi_{I,t}^R + f_{I,t}) \\ & + (1 - \tau_F)W_{F,t}L_{F,t} + W_{I,t}L_{I,t} + (W_{U,t})(1 - L_{F,t} - L_{I,t}) \end{aligned}$$

The resulting first order conditions with respect to C_t , B_t , and D_t yield the standard Euler equation for consumption:

$$1 = \beta E_t \left\{ \left(\frac{\zeta_{C,t+1}}{\zeta_{C,t}} \right) \left(\frac{C_t - h_C C_{t-1}}{C_{t+1} - h_C C_t} \right) \left(\frac{1 + i_t}{\pi_{t+1}} \right) \right\} \quad (3.44)$$

$$1 = \beta E_t \left\{ \left(\frac{\zeta_{C,t+1}}{\zeta_{C,t}} \right) \left(\frac{C_t - h_C C_{t-1}}{C_{t+1} - h_C C_t} \right) \left(\frac{1 + i_t^f}{\pi_{t+1}} \right) \left(\frac{e_{t+1}}{e_t} \right) \right\} \quad (3.45)$$

Combining Eq. 3.44 and Eq. 3.45 (up to a log-linear approximation) gives us the uncovered interest rate parity (UIP) condition $\left(\frac{1+i_t}{\pi_{t+1}} \right) = \left(\frac{1+i_t^f}{\pi_{t+1}} \right) \left(\frac{e_{t+1}}{e_t} \right)$.

The first order conditions with respect to $N_{F,t}^E$, and $N_{I,t}^E$, yield the Euler equation for investment in new formal and informal firms:

$$f_{F,t} = \beta(1 - \delta_F)E_t \left\{ (f_{F,t+1} + \Pi_{F,t+1}^R) \left(\frac{\zeta_{C,t+1}}{\zeta_{C,t}} \right) \left(\frac{C_t - h_C C_{t-1}}{C_{t+1} - h_C C_t} \right) \right\} \quad (3.46)$$

$$f_{I,t} = \beta(1 - \delta_I)E_t \left\{ (f_{I,t+1} + \Pi_{I,t+1}^R) \left(\frac{\zeta_{C,t+1}}{\zeta_{C,t}} \right) \left(\frac{C_t - h_C C_{t-1}}{C_{t+1} - h_C C_t} \right) \right\} \quad (3.47)$$

Eq. 3.46 (Eq. 3.47) implies that the ratio of current consumption to the future one decreases with a decrease in formal (informal) retailer entry costs, $f_{F,t}$ in the current period t , all else equal. It also decreases with an increase in expected formal (informal) entry costs, $f_{F,t+1}$.

3.4. Capital Producer

Capital producers combine the existing undepreciated capital stock, $(1 - \delta_K)K_{t-1}$, leased from wholesalers, with investment goods, I_t , to produce new capital K_t , using a linear technology¹⁹. The capital-producing sector is perfectly competitive. Capital evolves according to the following equation:

$$K_t = (1 - \delta_K)K_{t-1} + \frac{P_t^{Inv}}{P_t}I_t - \frac{\kappa}{2} \left(\frac{P_t^{Inv}}{P_t} \frac{I_t}{K_{t-1}} - \delta_K \right)^2 K_{t-1} \quad (3.48)$$

where $\frac{\kappa}{2} \left(\frac{P_t^{Inv}}{P_t} \frac{I_t}{K_{t-1}} - \delta_K \right)^2 K_{t-1}$ is the capital adjustment cost. Here $\kappa \geq 0$ is the capital adjustment coefficient, and δ_K is the depreciation rate of physical capital.

Capital production is confined to the formal sector, and investment is thus a composite of domestic formal goods, and foreign imports:

$$I_t = \left[\alpha^{\frac{1}{\eta}} I_{F,t}^{\frac{\eta-1}{\eta}} + (1 - \alpha)^{\frac{1}{\eta}} I_{f*,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad (3.49)$$

and the price of investment is:

$$P_t^{Inv} = \left[\alpha P_{F,t}^{1-\eta} + (1 - \alpha) P_{f*,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad (3.50)$$

The capital producer invests such that its profit is maximized, where Q_t is the real price of capital:

$$\max_{I_t} Q_t \left(\frac{P_t^{Inv}}{P_t} I_t - \frac{\kappa}{2} \left(\frac{P_t^{Inv}}{P_t} \frac{I_t}{K_{t-1}} - \delta_K \right)^2 K_{t-1} \right) - \frac{P_t^{Inv}}{P_t} I_t$$

The corresponding first order condition with respect to the choice of I_t determines the capital supply equation:

$$Q_t \left[1 - \kappa \left(\frac{P_t^{Inv}}{P_t} \frac{I_t}{K_{t-1}} - \delta_K \right) \right] = 1 \quad (3.51)$$

This is the Tobin's (1969) Q equation relating the price of capital to marginal adjustment costs. Demand for capital by wholesalers in sector s must satisfy the following condition:

$$E_t (R_{t+1} Q_t) = E_t \left\{ \psi_F \left(\frac{P_{s,t+1}^W}{P_{t+1}} \right) \left(\frac{Y_{s,t+1}^W}{K_{s,t}} \right) + (1 - \delta_K) Q_{t+1} \right\}$$

¹⁹Capital producers rent the capital stock from entrepreneurs and use it to produce new capital. Since this takes place within the same period, we assume that the rental rate is zero.

3.5. Rest of the World

Foreign economy imports domestic formal goods, Q_t^x , exports foreign goods to domestic country, Q_t^m , and sells foreign bonds, B_t^* . We assume that the domestic economy is small, which implies that it cannot affect foreign output, Y_t^* , foreign inflation, $\pi_t^* = \frac{P_t^*}{P_{t-1}^*}$, and the foreign interest rate, i_t^* , all of which are assumed to be exogenously determined in the rest of the world²⁰.

Demand for domestic formal exports by the foreign economy, is assumed to have a similar structure to that of domestic consumption in Eq. 3.41:

$$Q_t^x = \alpha_x^* \left(\frac{P_{X,t}^*}{P_t^*} \right)^{-\eta_x^*} Y_t^* \quad (3.52)$$

where $\alpha_x^* \in (0, 1)$ is a parameter determining the share of domestic goods in foreign consumption bundle, and $\eta_x^* > 1$ is the substitution elasticity between exports and foreign domestic goods. We assume that law of one price (LOOP) holds for domestic goods, allowing us to express the price of exports in foreign currency as $P_{X,t}^* = \frac{P_{F,t}}{e_t}$ ²¹.

Total imports from the foreign economy, Q_t^m , are consumed by households, capital producers, and the government:

$$Q_t^m = C_{f^*,t} + I_{f^*,t} + G_{f^*,t}$$

3.6. Government Policy

Government consists of monetary and fiscal authorities. The monetary authority sets the nominal interest rate, i_t , to stabilise the business cycle fluctuations, based on a Taylor-type (1993) feedback rule. It responds to deviations in inflation, and gross domestic product:

$$\frac{i_t}{i} = \left(\frac{i_{t-1}}{i} \right) \alpha_i \left(\frac{\pi_t}{\pi} \right) \alpha_\pi \left(\frac{Y_t}{Y} \right) \alpha_Y \varepsilon_{i,t} \quad (3.53)$$

where α_i captures interest rate smoothing, and the Taylor rule coefficients, α_π and α_Y , are the relative weights on inflation and output stabilization respectively. i , π , and GDP are the steady state values for nominal interest rate, inflation, and gross domestic product. $\varepsilon_{i,t}$ is a monetary policy shock to capture unanticipated changes in the nominal interest rate.

²⁰We normalise the value of foreign output by assuming $Y_t^* = 1$. Interest rate on foreign bond, i_t^f , depends not only on the exogenous foreign interest rate, i_t^* , but also on the foreign currency borrowing premium, χ , following Schmitt-Grohe and Uribe (2003), whereby holders of foreign debt are assumed to face an interest rate that is increasing in the country's net foreign debt. This is a standard assumption in the small open economy literature.

²¹Substituting the LOOP condition, and $RER_t = \frac{e_t P_t^*}{P_t}$ in Eq. 3.52 we get the following $Q_t^x = \alpha_x^* \left(\frac{P_{F,t}}{P_t} \frac{1}{RER_t} \right)^{-\eta_x^*} Y_t^*$. Therefore, a real depreciation of the currency increases exports.

In addition, the fiscal authority finances its expenditure, G_t , and unemployment benefit payments, $W_{U,t}(1 - L_{F,t} - L_{I,t})$, by taxing wage income in the formal sector at the rate τ_F ²². The government budget constraint every period is²³:

$$\frac{P_t^{Inv}}{P_t} G_t + W_{U,t}(1 - L_{F,t} - L_{I,t}) = \tau_F W_{F,t} L_{F,t} \quad (3.54)$$

3.7. Market Clearing and Aggregation

Equilibrium in the labor market ensures:

$$U_t = 1 - L_{F,t} - L_{I,t} \quad (3.55)$$

Equilibrium in the asset market ensures that the total number of bonds issued is equal to the cost of desired capital in the economy:

$$D_{t-1} = Q_{t-1}(K_{F,t-1} + K_{I,t-1}) \quad (3.56)$$

The wholesale goods market equilibrium for the formal sector is²⁴:

$$\frac{P_{F,t}^W}{P_t} Y_{F,t}^W = \frac{P_{F,t}}{P_t} Y_{F,t} \left(1 + \frac{\phi_F^{adj}}{2} \left(\frac{\pi_{F,t}}{\pi} - 1 \right)^2 \right) + HC_{F,t} H_{F,t} + N_{F,t}^E f_{F,t} \quad (3.57)$$

where total demand for formal good, $Y_{F,t}$, is given by 3.30.

Similarly, the wholesale goods market equilibrium for the informal sector is:

$$\frac{P_{I,t}^W}{P_t} Y_{I,t}^W = \frac{P_{I,t}}{P_t} Y_{I,t} \left(1 + \frac{\phi_I^{adj}}{2} \left(\frac{\pi_{I,t}}{\pi} - 1 \right)^2 \right) + HC_{I,t} H_{I,t} + N_{I,t}^E f_{I,t} \quad (3.58)$$

where informal good is only consumed by domestic households, given as in 3.31.

Finally, GDP in the economy satisfies the following constraint:

$$Y_t = C_t + \frac{P_t^{Inv}}{P_t} (I_t + G_t) + \frac{P_{F,t}}{P_t} Q_t^x - \frac{P_{f*,t}}{P_t} (C_{f*,t} + I_{f*,t} + G_{f*,t})$$

²²For simplicity, we assume that the government does not invest in domestic or international bond markets, and do not take into account capital and consumption taxes.

²³We assume that government expenditure basket, G_t , analogous to the investment basket in 3.49, consists of domestic formal goods, $G_{F,t}$, along with imports, $G_{f*,t}$.

²⁴For simplification we assume that entry cost is a pure deadweight loss.

3.8. Shock Processes

We include fifteen exogenously given shocks in the economy: eleven domestic, and two determined in the rest of the world. These include labor market shocks to worker bargaining power ($\lambda_{F,t}$ and $\lambda_{I,t}$), wholesaler hiring cost ($\beta_{HC_F,t}$ and $\beta_{HC_I,t}$), and firing probability ($\sigma_{F,t}$ and $\sigma_{I,t}$) as well as the product market shock to retailer entry cost, ($f_{F,t}$ and $f_{I,t}$). Shocks to domestic technology ($\theta_{F,t}$ and $\theta_{I,t}$), government spending (G_t), monetary policy ($\varepsilon_{i,t}$), consumption preference ($\zeta_{C,t}$), foreign inflation (π_t^*), and foreign interest rate (i_t^*) are also modeled. In particular, the number of exogenous shocks must be at least as large as the number of observed variables in order to estimate the model using Bayesian methods. With the exception of the monetary policy shock, $\varepsilon_{i,t}$, which is assumed to be a white noise process, all shock processes in the economy are assumed to follow a first order autoregressive process (AR(1)) in logs as follows:

$$\log\left(\frac{z_t}{z}\right) = \rho_z \log\left(\frac{z_{t-1}}{z}\right) + \varepsilon_{z,t}$$

where $z_t \in \{\theta_{F,t}, \theta_{I,t}, \pi_t^*, i_t^*, \zeta_{C,t}, G_t, f_{F,t}, f_{I,t}, \beta_{HC_F,t}, \beta_{HC_I,t}, \lambda_{F,t}, \lambda_{I,t}, \sigma_{F,t}, \sigma_{I,t}\}$, $\rho_z \in (0, 1)$ is the persistence of shocks, and $\varepsilon_{z,t}$ is assumed to be i.i.d with mean zero and standard deviation given by $sd(\varepsilon_z)$. This completes the specification of the Baseline model.

4. Method of Estimation

This section describes our data, calibration approach, and presents details regarding the main estimation procedure. We choose to calibrate some parameters, as these are more important in matching the first moments of the data, and then estimate the remaining using Bayesian approach in Dynare.

4.1. Data

To estimate the model, we use information on nine key macroeconomic variables for India: GDP, private consumption expenditure, investment, government consumption expenditure, exports, imports (all expressed in constant prices), the real exchange rate, the wholesale price inflation (WPI), and the nominal interest rate. The 3-month Treasury bill rate is used as a proxy for the nominal interest rate, and the real effective exchange rate (REER) is used as a proxy for the real exchange rate. The sample runs from 1996Q1 to 2012Q1, which gives us 65 observations for each of the time series. We remove a time trend in the data using the Hodrick-Prescott (HP) filter to obtain the stationary series, and measure these in terms of the percent deviation from the steady state (i.e. the HP trends corresponding to each)²⁵. The data is also seasonally adjusted using the X12 filter (except the real exchange rate and the nominal interest rate). All data is taken from the CEIC database.

²⁵This makes the data suited to the log-linearised DSGE model.

4.2. Calibration

Table 1 summarizes the calibrated values of parameter in our model for India, where we calibrate a set of parameters, and the steady state values for some endogenous variables, which characterise the model economy.

As in much of the literature, the depreciation rate of capital, δ_K , is set at 10 percent per annum, implying a quarterly value of 0.025. Steady state inflation, π , is 4.5 percent which corresponds to the average seasonally adjusted quarterly WPI over this period on an annualized basis. The discount rate β is set at 0.994 which corresponds to an annual nominal interest rate, $i(= \frac{\pi}{\beta} - 1)$ of 7 percent, matching the mean of the sample. Foreign inflation, π^* , is 2.5 percent annually, which corresponds to an annual foreign interest rate, $i^*(= \frac{\pi^*}{\beta} - 1)$, of 5 percent²⁶. The depreciation rate of the nominal exchange rate, $dep(= \frac{\pi}{\pi^*})$ is calculated at 2 percent on an annual basis.

The share of government expenditure in GDP, $(\frac{P^{Inv} G}{P Y})$, is set at 11 percent, as in the data. In 2005, Government of India spent 1.4 percent of its GDP on social protection, which forms the basis of our calibration for the steady state unemployment benefits to GDP ratio, $\frac{W_U}{Y}$ ²⁷.

The substitution elasticity between imported and domestically produced goods, η , is set at 1.15, which is close to the value estimated by Medina and Soto (2005) for Chile, and Castillo et al. (2006) who obtain values close to 1. With the share of domestically produced goods in the market consumption basket, α , at 0.8, this corresponds to a steady state import to GDP ratio, $(\frac{P_{F^*} Q^m}{P Y})$ of 21 percent, as in the data. Elasticity of substitution of exports, η_x^* is set at 4.5, a value consistent with the calibrated steady state export to GDP ratio, $(\frac{P_F Q^x}{P Y})$ of 19 percent²⁸.

Matching Informality Statistics

The parameters relating to labor market and goods market rigidities, are all calibrated to be higher in the formal sector, corresponding to the regulations in this sector as opposed to the unregulated informal sector. Because of scarce empirical evidence regarding the value of these parameters, our calibration strategy aims to match, as accurately as possible, the empirical evidence, and available data on key statistics relating to the formal and informal sector in India.

Using industry level panel data for the period 1980-2007, Pal and Rathore (2013) estimate the size of the firms' mark-up in India to have a long run average of 1.19 during 2000-07. Thus, the elasticity of substitution among different retail varieties, ϵ_F and ϵ_I , is calibrated at 7 and

²⁶This is close to the value of 6 percent used in much of the macro-RBC literature for calibrating i^* .

²⁷This is done because unemployment benefits are very low and not as relevant for India. The value for the wage income tax rate in the steady state, τ_F is then endogenously determined.

²⁸The steady state share of domestic exports in the foreign consumers' consumption bundle, α_x^* , is obtained endogenously.

12, so that the retail firms' desired mark-up is pinned down at $\frac{\varepsilon_F}{\varepsilon_F-1} = 1.17$ and $\frac{\varepsilon_I}{\varepsilon_I-1} = 1.09$, in each sector correspondingly. A lower mark-up in informal prices corresponds to much higher competition in this sector²⁹.

Table 1: Parameter Calibration, Baseline model for India

Parameter	Value	Description
β	0.994	discount rate
δ_K	0.025	capital depreciation rate
α	0.8	share of home good in consumption
η	1.15	substitutability between domestic and foreign goods
π	4.5	gross inflation in the steady state (% annually)
π^*	2.5	gross foreign inflation in the steady state (% annually)
$\left(\frac{P^{Inv} G}{P Y}\right)$	0.11	government spending-to-GDP ratio in the steady state
$\frac{W_U}{Y}$	0.014	social spending-to-GDP ratio in the steady state
$\left(\frac{P_F Q^x}{P Y}\right)$	0.19	export-to-GDP ratio in the steady state
$\left(\frac{P_{f^*} Q^m}{P Y}\right)$	0.21	import-to-GDP ratio in the steady state
η_x^*	4.5	price elasticity of exports
μ	1.5	substitutability between formal and informal goods
w	0.5	share of formal goods in consumption
ψ_F	0.34	capital share in formal production function
ψ_I	0.34	capital share in informal production function
ε_F	7	elasticity of substitution among formal retail goods
ε_I	12	elasticity of substitution among informal retail goods
θ_F	1.5	formal productivity in the steady state
θ_I	1	informal productivity in the steady state
HC_F/W_F	3	share of formal hiring costs in formal sector wages
HC_I/W_I	0.5	share of informal hiring costs in informal sector wages
λ_F	0.8	formal worker bargaining power
λ_I	0.1	informal worker bargaining power
α_{HCF}	0.5	formal hiring cost elasticity to job-finding rate
α_{HCI}	0.5	informal hiring cost elasticity to job-finding rate
σ_F	0.1	formal worker firing rate in steady state
σ_I	0.75	informal worker firing rate in steady state
$P_F^W f_F / P_F Y_F$	0.5	formal firm entry cost-to-output ratio
$P_I^W f_I / P_I Y_I$	0.15	informal firm entry cost-to-output ratio

Based on the estimates of share of compensation of employees in Chandrasekhar and Ghosh (2015), we calibrate the cost share of capital in the wholesalers' production function, ψ_F and

²⁹The sensitivity of the mark-up to the number of firms, σ_N , is then obtained from $\sigma_{N_F} = \frac{\varepsilon_F}{N_F}$ and $\sigma_{N_I} = \frac{\varepsilon_I}{N_I}$, respectively.

ψ_I , at 0.34, for both sectors. As in Ulyssea (2009), the productivity of informal wholesalers, θ_I is normalised to 1, whereas the productivity of the formal firms, θ_F , is 1.5 capturing a productivity differential of 50 percent between the two sectors³⁰.

Since formal goods are traded and informal goods are non-traded, we match the substitution elasticity between formal and informal goods, μ , to values commonly used in the literature for the substitution elasticity between traded and non-traded goods. Then the formal goods bias in consumption basket, w , is set at 0.5, such that the share of informal sector output in total output, $\frac{P_I \bar{Y}_I}{P \bar{Y}} (= \frac{P_I C_I}{P \bar{Y}})$, is obtained at 55 percent (close to the value of 49 percent estimated by the NCEUS (2009)).

According to The Global Competitiveness Report published by the World Economic Forum (2014), the redundancy costs of workers in India is estimated to be equivalent to 55.9 weeks of annual salary since 2006. This is equivalent to 4.53 times the quarterly wage rate. Since in our model the hiring costs also reflect the difficulty in firing workers, we calibrate the hiring cost to wage ratio in the formal sector close to this value, at $\frac{HC_F}{W_F} = 3$, which corresponds to 38 weeks of annual salary. Since only the formal sector is regulated, for the corresponding informal sector ratio, $\frac{HC_I}{W_I}$, we assume it to be much lower at 0.5³¹. The elasticity of hiring costs to hiring probabilities, α_{HCF} and α_{HCI} , are both calibrated at 0.5, following Blanchard and Gali (2010)³².

We follow Cacciatore et al. (2012) and Ebell and Haefke (2009) to calibrate the entry costs based on data that measures entry delay by months of lost output. We follow the same approach here. According to the 'Doing Business Report' published by the World Bank (2013), starting a business in India costs 49.8 percent output per firm³³ and hence we use a value of 0.5 for the ratio of entry cost to output in the formal sector, $\frac{P_F^W f_F}{P_F Y_F}$, while we assume a value of 0.15 in the informal sector, $\frac{P_I^W f_I}{P_I Y_I}$ ³⁴.

There is mixed evidence in the literature regarding the extent of wage inequality between the formal and informal sector, $\frac{W_F}{W_I}$ in India. For instance, using NSSO data (2004-05), Karan and Selvaraj (2008) and Das (2012) estimate a formal sector wage premium of 3, whereas Gabriel et al. (2010) estimate its value at 1.78. We obtain a steady state value of 2.4 for $\frac{W_F}{W_I}$ by calibrating the formal and informal worker bargaining power, λ_F and λ_I , at 0.8 and 0.1, respectively. Higher bargaining power in the formal sector corresponds to the presence of strong labor unions in this sector.

According to the Employment and Unemployment Survey (EUS) of the National Sample Survey Organization (NSSO, 2009-10), the unorganized (i.e, informal) sector employs nearly 84

³⁰This is consistent with the estimates in Sahoo and Raa (2009), who find that the formal sector activities are strictly more productive than the informal ones in India.

³¹In India, firing regulations are more stringent than hiring regulations and difficulty in firing workers impacts hiring decisions, which is being captured through hiring costs.

³²Steady state values of the exogenous hiring cost variable, β_{HCF} and β_{HCI} , are then obtained from the hiring cost functions in each sector.

³³On an average, it requires 12 procedures, takes 27 days, and requires paid-in minimum capital of 140.1 percent of output per firm.

³⁴The firm bankruptcy rates, δ_F and δ_I , are thus obtained from the free entry conditions of retailers.

percent of the Indian workforce. Setting the probability of getting fired, σ_F and σ_I , at 0.1 and 0.75, gives us the informal employment share, $\frac{L_I}{L_F+L_I}$ at 82 percent, and an unemployment rate, U , of 22 percent³⁵. A significantly lower value for the firing probability in the formal sector corresponds to the formal employment protection legislations.

4.3. Bayesian Estimation

We estimate the model using Bayesian approach in Dynare. This choice is driven by the widely recognised advantages of the Bayesian-Maximum Likelihood methodology, which are as follows³⁶. First, prior information about parameters available from empirical studies or previous macroeconomic studies, can be incorporated with the data in the estimation process. Second, it facilitates representing and taking fuller account of the uncertainties related to models and parameter values. Third, it allows for a formal comparison between different mis-specified models that are not necessarily encapsulated in the marginal likelihood of the model. In addition, there has been a growing trend among central banks to employ Bayesian methods for conducting policy analysis.

Table 2 summarizes the choice of prior distributions for the estimated parameters. The prior densities for the estimated parameters are chosen by considering the theoretical restrictions for the parameters, and empirical evidence. Due to scarce empirical evidence on India, we choose relatively diffuse priors that cover a wide range of parameter values.

5. Estimation Results

5.1. Posterior Estimates for India

The estimation results are reported in Table 2. The last three columns report the posterior means along with the 95% confidence intervals based on the posterior probability densities.

Looking at price adjustment costs, consistent with the estimates in Gabriel et al. (2010), the estimation indicates that price re-setting is highest in the informal sector (i.e. lowest estimate for price adjustment costs, $\phi_I^{adj} = 11.47$, in the informal sector), and lowest for the formal sector (i.e. highest value for price adjustment costs, $\phi_F^{adj} = 18.09$, in the formal sector). This means that the fluctuations in the formal sector are more persistent in response to shocks compared with the informal sector. Import price rigidity is lower but close to the value in

³⁵The official unemployment rate published by the Planning Commission in India is around 8 percent for 2009-10. However, empirical estimates in the literature suggest a much higher unemployment, close to 20 percent, with even higher estimates for youth employment (Sinha (2013), Mitra and Verick (2013)). These high estimates are due to 'disguised' unemployment, especially in Indian agriculture (which employs nearly 70 percent of the working population) in rural India, where it seems that everyone is employed but in reality sufficient full time work is not available for all (Mehrotra et al. (2012)).

³⁶See, for instance, An and Schorfheide (2007).

the formal sector at $\phi_{f^*}^{adj} = 17.01$, indicating that import prices change more frequently in comparison to formal prices, but less frequently relative to informal prices. This is in contrast to the results in Anand et al. (2010), who find import price rigidity to be lower than domestic price rigidity, in their one-sector model with no informality for India. This puts a warning sign in interpreting the estimates of price stickiness in the literature, which does not allow for sectorial decomposition of inflation, where all goods are assumed to be tradable.

Comparing the estimates for the shock processes in the formal and informal sector, we learn that, whereas the volatility of shocks in the informal sector is higher, the opposite holds true for the shock persistence, which is higher in the formal sector instead. Larger shock size in the informal sector indicates that the volatility in the economy is coming more from shocks on the informal side of the economy. On the other hand, significantly higher flexibility in the informal sector increases the adjustment to any shocks originating in this sector, thus making these shocks less persistent. Our estimates are consistent with the findings of Cacciatore and Fiori (2012).

To sum up, we draw the following conclusions from the posterior estimates. First, the persistence of formal sector shocks is higher relative to informal sector shocks. Also, in absolute terms, the shocks in the formal sector have considerably high persistence. Second, shocks in the informal sector are more volatile than the corresponding shocks in the formal sector. Third, our estimates of the Taylor rule imply a strong preference to smooth inflation and interest rate fluctuations. Fourth, the data is not very informative about some of the parameters, in particular, the standard error of the sectorial labor firing probabilities, $sd(\epsilon_{\sigma F})$ and $sd(\epsilon_{\sigma I})$, and the government spending shock, $sd(\epsilon_G)$ ³⁷.

In Appendix A, we examine the sensitivity of the predictions of the model to changes in parameter values and the theoretical structure, and find that our estimation results to be robust across different model specifications.

6. Dynamic Adjustment to Market Deregulation

In this section, we investigate the impact of structural reforms in the short run and long run in our Baseline model for India. Both, a permanent shock to parameters, as well as a stochastic but highly persistent shock in line with our estimation results above, are considered³⁸.

Labor market deregulation is modeled as the following: (i) a negative shock to formal wholesalers' labor hiring cost, β_{HCF} , and (ii) a negative shock to wage bargaining power of formal workers, λ_F . On the other hand, product market deregulation leads to a decrease in formal retailers' entry cost, f_F . We also investigate the effects of implementing a combined package of reforms above. Finally, we compare the impacts of deregulation in our high informality Baseline model with the impacts in an economy with low informality.

³⁷These estimates do not impact our policy analysis.

³⁸Stochastic nature of reforms captures the uncertainty associated with structural reforms due to long political processes involved. Using annual data for a sample of twenty OECD countries over the period 1981-2005, Cacciatore and Fiori (2012) find that market deregulation is a persistent but stationary process.

Regarding the size of each shock, we assume that the parameter values are lowered by 10 percent, in both deterministic and stochastic cases³⁹. Table 4 displays both the short run and long run quantitative effects of all policy experiments, and Figure 4 to Figure 11 show how the economy transitions from the initial to the new steady state post reform.

6.1. Labor Market Deregulation

The impact of a labor market deregulation is a combination of its direct impact on employment in the labor market, along with its impact on the number of firms in each sector.

a. Fall in Formal Wholesalers' Hiring Cost

Figure 4 shows the long run effects of a 10 percent permanent decrease in formal firms' hiring cost, β_{HCF} , in our Baseline model, and Figure 5 (continuous line) shows the short run effects.

In the long run, the effect of a decrease in formal wholesalers' labor hiring costs is (i) an increase in GDP and consumption, (ii) a decrease in unemployment, (iii) an increase in both formal and informal employment, but to a larger extent in the formal sector, thus leading to higher formality in the labor market, (iv) a decrease in formal sector wage premium, and (v) an increase in formality in the goods market. However, reallocation of economic resources between sectors leads to adjustment costs in the short run, where GDP falls, unemployment increases, and relative competition in the formal sector is lower in the first 4-5 quarters post reform. Below we present a detailed analysis of the exact transmission channels involved.

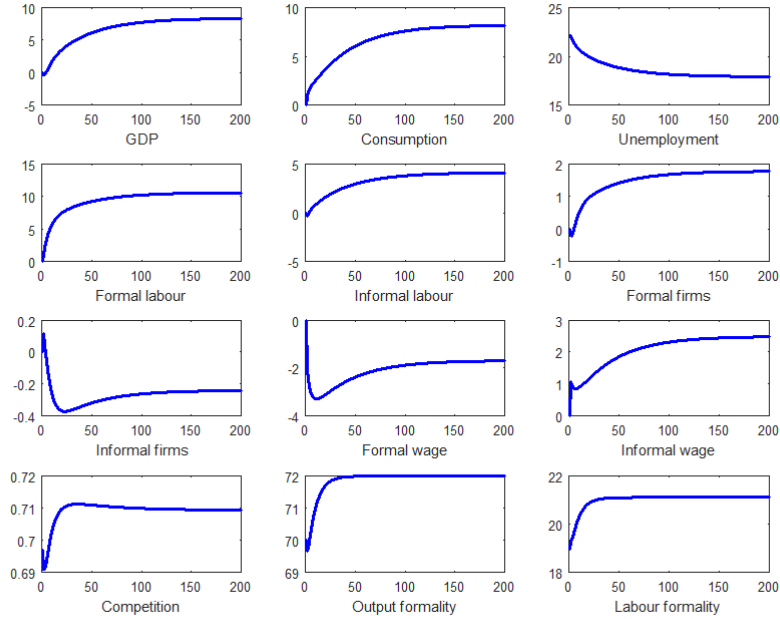
Formal firms hire more workers when the costs of hiring are lower, increasing formal employment, L_F . There are two impacts on formal sector wage rate, W_F : on one hand (i) lower hiring costs in the formal sector lower W_F (from the Nash bargaining solution), however, on the other hand (ii) an increase in formal labor demand, L_F , increases W_F . We find that the former effect is stronger, and W_F falls. Lower labor costs increase profits, leading to higher relative competition (i.e. $\frac{\varepsilon_F}{\varepsilon_I}$ is higher), as more firms choose to operate in the formal sector. This leads to lower formal price mark-ups, $\frac{\varepsilon_F}{\varepsilon_{F-1}}$ falls, and boosts the external competitiveness of the economy, leading to higher exports (lower imports) and investment, which increases GDP⁴⁰. Fall in import demand increases demand for domestic goods in both sectors, where informal firms meet this demand by hiring more labor, L_I ; but this is of smaller magnitude compared to formal employment, thus increasing over formality in the labor market, $\frac{L_F}{L_F+L_I}$. Increase in employment in both sectors, leads to a significantly large fall in unemployment, U . Since both sectors share the same pool of unemployed workers, higher formal job finding rate reduces labor supply to the informal sector, resulting in an increase in informal sector wages, W_I ; thus lowering formal sector wage premium, $\frac{W_F}{W_I}$ ⁴¹.

³⁹In order to compare the quantitative impacts across different policies, we choose to keep the size of the shock same across all policy experiments, and hence abstract from using the Bayesian mean estimates for the standard error of shocks. Regarding the persistence of stochastic shocks, we use their estimated mean values from Section 5.

⁴⁰In the real world, not all formal firms are more productive than informal ones and hence the magnitude of impacts in Table 4 might be overstated.

⁴¹Impact on wages is in contrast to the findings in Charlot et al. (2011) where they find a fall in both formal

Figure 4: Long run impact of a fall in formal hiring cost



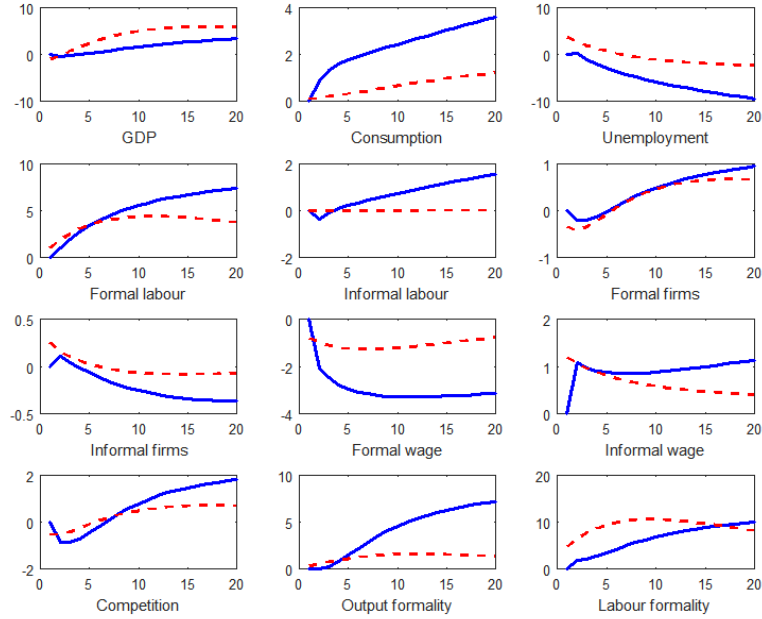
Note: The impact on GDP, consumption (C), formal and informal employment (L_F and L_I), number of firms in each sector (N_F and N_I), and sector-specific wages (W_F and W_I), is the percentage change in each variable, whereas the impact on unemployment (U), relative competition in the formal sector ($\frac{E_F}{E_I}$), output formality ($\frac{P_F Y_F}{P_F Y_F + P_I Y_I}$), and labor formality ($\frac{L_F}{L_F + L_I}$) are expressed in levels.

In the short run, however, GDP falls, unemployment increases, and number of formal firms fall, where this impact lasts up to 4-5 quarters post-reform. This is because the relatively flexible informal sector adjusts more promptly to shocks in the economy, as compared to the formal sector where higher rigidities generate a slower response. Incumbent informal wholesalers' anticipate their future fall in profits, and immediately downsize by reducing informal employment, L_I ⁴². The slow reallocation of unemployed workers to the formal sector temporarily increases U , which lowers GDP. Despite the increase in unemployment, as in Cacciatore and Fiori (2012) we find that consumption, C , still increases even in the short run. This is because households reduce savings to smooth consumption in anticipation of the future permanent increase in income. In addition, since incumbents do not have to incur sunk costs in order to benefit from the labor market reform, they have a competitive advantage with respect to potential entrants, which increases entry costs, inducing households to invest less in new firms, thus also increasing C . This latter effect combined with the 'congestion externalities' effect in Cacciatore and Fiori (2012), results in a fall in N_F in the short run. Rising formal profits over time, leads to an increase in the number of formal firms after 5 quarters.

sector and informal sector wages with a labor market reform in Brazil. This is because they abstract from modelling a comprehensive demand side of the economy.

⁴²This impact outweighs the positive impact of higher consumption demand on L_I .

Figure 5: Short run impact of a fall in formal hiring cost



Note: The impact is the percentage change in each variable.

Figure 5 (dashed line) shows that the dynamic effects are qualitatively similar in the case of a temporary but persistent reduction in hiring costs⁴³. In terms of magnitudes, however, the initial impact is larger, since the short run incentives of agents in the economy in case of a temporary fall in hiring costs are higher⁴⁴. For instance, formal firms hire more labor today when the fall in hiring costs is only temporary, and incumbent informal firms downsize more leading to a larger fall in L_I , which results in a larger increase in unemployment in the short run, and so on.

b. Fall in Formal Worker Bargaining Power

Figure 6 shows the long run effects of a 10 percent permanent decrease in formal workers' bargaining power, λ_F , in our Baseline model, and Figure 7 (continuous line) shows the short run effects.

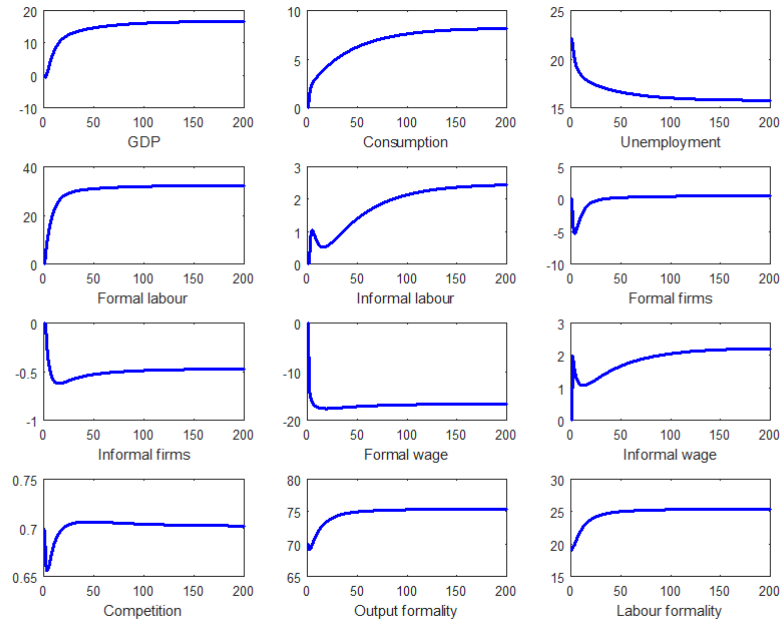
We find that, qualitatively, the long run effects of a fall in formal workers' bargaining power are analogous to the ones with a fall in formal wholesalers' hiring cost. Quantitatively, however, the effects are now larger. In the short run, as with the hiring cost reform, GDP falls and relative competition in the formal sector is lower, but in contrast to the hiring cost reform, there no increase in unemployment. Below we present a detailed analysis of the main channels at play.

⁴³This

⁴⁴This matches the findings in Cacciatore and Fiori (2012).

Formal wholesalers pay lower wages when formal workers' bargaining power is lower, which increases formal employment, L_F . As this reform directly affects wages, we see a large fall in wages, which in turn leads to a large increase in formal employment. Competition in the formal sector increases as new firms enter this sector due to lower labor costs which expands profits, leading to higher N_F and lower formal price mark-ups ($\frac{\epsilon_F}{\epsilon_{F-1}}$ falls). On the other hand, N_I falls, leading to higher relative competition in the formal sector. Fall in formal export prices boosts the external competitiveness of the economy, leading to higher exports and investment, raising GDP. Higher formal employment generates a positive household income effect on consumption, C . Higher demand for consumption goods raises labor demand in the informal sector, which increases L_I and W_I , leading to lower wage inequality, $\frac{W_F}{W_I}$. Increase in both L_F and L_I reduces unemployment, U , where increase in L_F is larger, expanding aggregate formality in the labor market, $\frac{L_F}{L_F+L_I}$.

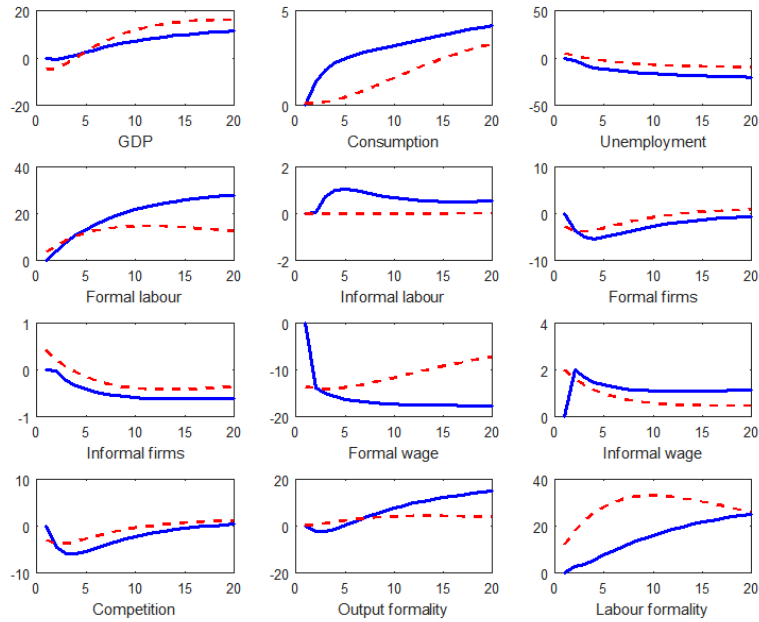
Figure 6: Long run impact of a fall in formal bargaining power



Note: The impact on GDP, consumption (C), formal and informal employment (L_F and L_I), number of firms in each sector (N_F and N_I), and sector-specific wages (W_F and W_I), is the percentage change in each variable, whereas the impact on unemployment (U), relative competition in the formal sector ($\frac{\epsilon_F}{\epsilon_I}$), output formality ($\frac{P_F Y_F}{P_F Y_F + P_I Y_I}$), and labor formality ($\frac{L_F}{L_F + L_I}$) are expressed in levels.

In the short run, as with the hiring cost reform, GDP falls and the number of formal firms fall, in the first 4 to 5 quarters post-reform. However, informal employment increases marginally, as opposed to an immediate fall in L_I with a hiring cost reform, which combined with the boost in formal employment leads to lower unemployment even in the short run, in contrast to a higher U with the hiring cost reform.

Figure 7: Short run impact of a fall in formal bargaining power



Note: The impact is the percentage change in each variable.

Figure 7 (dashed line) shows that the dynamic effects are qualitatively similar in the case of a temporary but persistent reduction in formal workers' bargaining power, except for the impact on informal employment and unemployment. For instance, fall in formal sector wages are higher if there is a temporary fall in bargaining power today, which leads to a larger increase in hiring by formal firms, L_F , resulting in large numbers of workers moving from informal to formal jobs. This reduces informal employment, L_I , which combined with the slower increase in L_F , increases U in the short run, in contrast to a fall with a permanent shock. Hence, we see a larger fall in GDP when the shock is temporary.

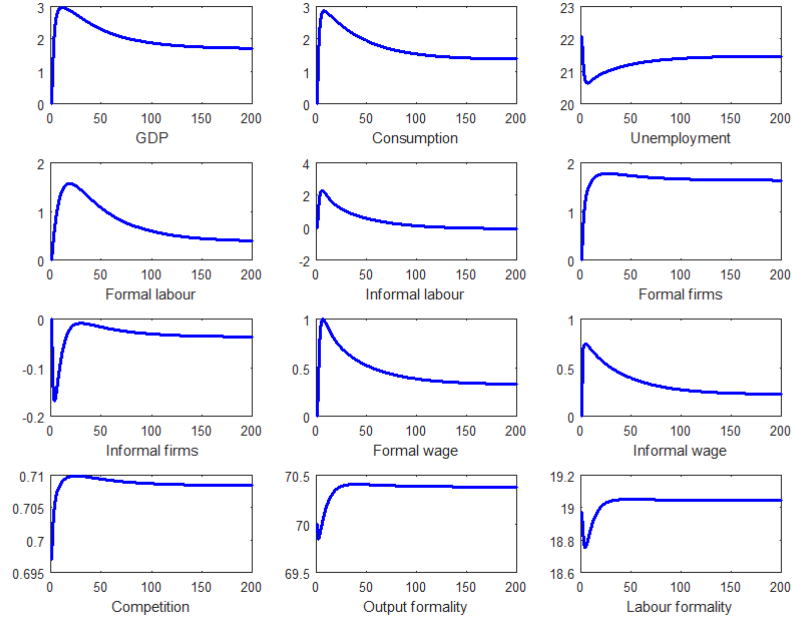
6.2. Product Market Deregulation

Figure 8 shows the long run effects of a 10 percent permanent decrease in formal retailers' entry costs, f_F , in our Baseline model, and Figure 9 (continuous line) shows the short run effects.

We find that, qualitatively, the long run effects of product market deregulation are analogous to the ones with labor market deregulation, except for the impact on sectorial wage rates, where lowering formal firm entry costs worsens wage inequality, as opposed to a decrease in wage inequality with the labor market reforms. Quantitatively, the effects are now smaller. On the other hand, in the short run, in contrast to either of the two labor market reforms, there is an immediate increase in GDP, fall in unemployment, and increase in formal relative competition.

Instead, formality in the labor market goes down now in the first 4 quarters. Below we present a detailed analysis of the main channels involved.

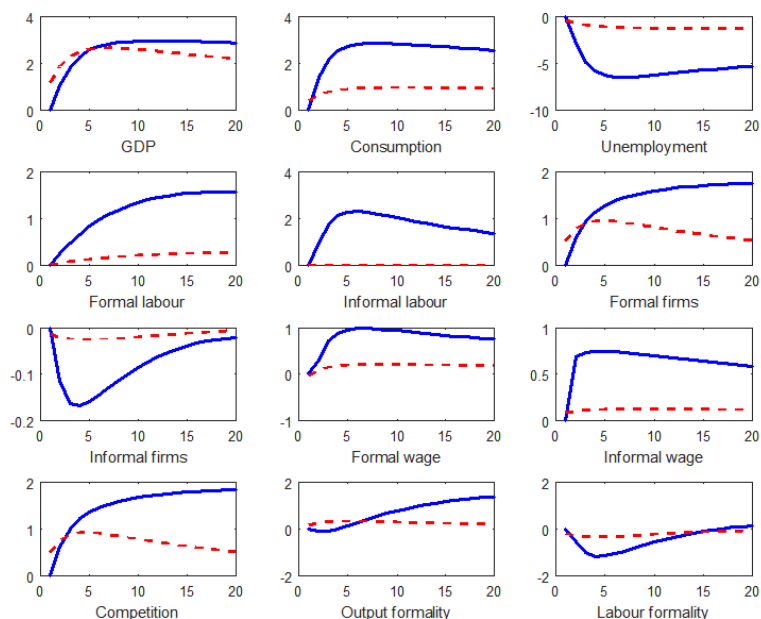
Figure 8: Long run impact of a fall in formal entry cost



Note: The impact on GDP, consumption (C), formal and informal employment (L_F and L_I), number of firms in each sector (N_F and N_I), and sector-specific wages (W_F and W_I), is the percentage change in each variable, whereas the impact on unemployment (U), relative competition in the formal sector ($\frac{\varepsilon_F}{\varepsilon_I}$), output formality ($\frac{P_F Y_F}{P_F Y_F + P_I Y_I}$), and labor formality ($\frac{L_F}{L_F + L_I}$) are expressed in levels.

Lowering entry costs in the formal sector increases the number of firms entering this sector, N_F , and at the same time lowers the number of firms operating in the informal sector, N_I . This leads to higher relative competition ($\frac{\varepsilon_F}{\varepsilon_I}$ increases), and lower price mark-ups in the formal sector. Fall in prices increases the demand for formal goods (hence exports), which combined with the increase in hiring by new firms boosts formal employment, L_F . Shifting out of the formal labor demand curve increases formal sector wages, W_F . Higher wage income increases households' consumption demand for both formal and informal goods. To meet this increase in demand, informal wholesalers' expand production by hiring more labor, L_I , increasing informal sector wages, W_I . Increase in L_F is higher than the increase in L_I , which increases formality in the labor market, $\frac{L_F}{L_F + L_I}$. On the other hand, a larger increase in the labor demand in the formal sector relative to the informal labor demand, leads to a larger increase in W_F relative to W_I , which worsens wage inequality, i.e., $\frac{W_F}{W_I}$ is higher (Charlot et al. (2011) find the same impact for Brazil). This is in contrast to the labor market deregulation reform, where wage inequality, $\frac{W_F}{W_I}$, falls. This is because, both fall in formal wholesalers' labor hiring cost or a fall in formal workers' bargaining power lead to a negative impact on W_F via the Nash

Figure 9: Short run impact of a fall in formal entry cost



Note: The impact is the percentage change in each variable.

bargaining solution, the impact of which is larger than the positive impact of increased formal labor demand, which leads to a fall in W_F instead.

GDP increases and U falls even in the short run, which matches the findings in Cacciatore et al. (2013)⁴⁵. However, higher rigidities in the formal sector leads to a larger increase in L_I relative to L_F , which lowers formality in the labor market up to 4 quarters post-reform, which is not captured by their one-sector framework.

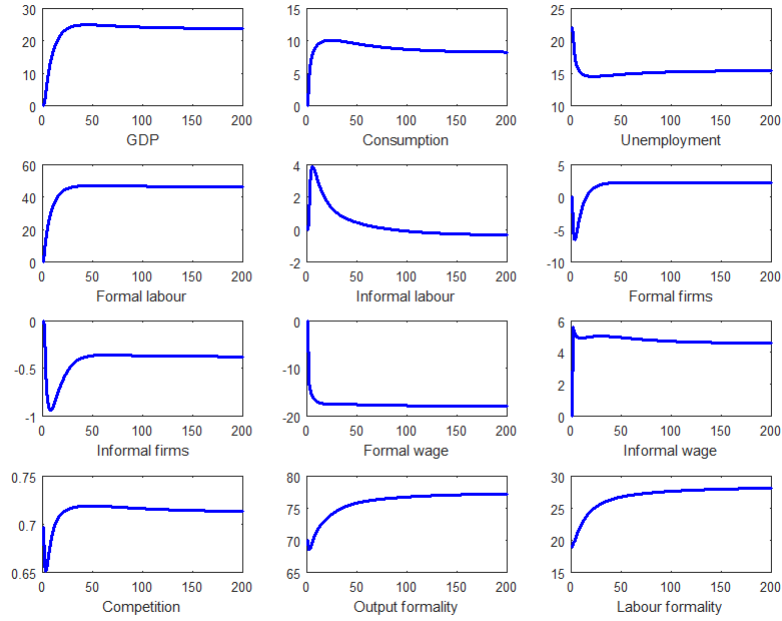
Figure 9 (dashed line) shows that while the dynamic effects are qualitatively similar, the initial impact is larger in size in the case of a temporary but persistent reduction in formal firm entry cost. For instance, more firms enter the formal sector today when fall in entry costs are only temporary, as it is more profitable to enter now than in the subsequent periods, which produces a larger increase in formal employment, and so on.

6.3. Reform Combination

In this part, we investigate the effects of a combination of the above policies, and consider two cases in particular: (i) combined labor market reform where there is a simultaneous decrease

⁴⁵In contrast to labor market deregulation, lowering entry costs leads to an immediate positive effect because higher formal and informal sector wages combined with formal job creation by new formal firms leads to an immediate increase in consumption demand, which boosts employment in both sectors, thus lowering unemployment and boosting GDP.

Figure 10: Long run impacts of a fall in formal hiring cost combined with fall in formal bargaining power



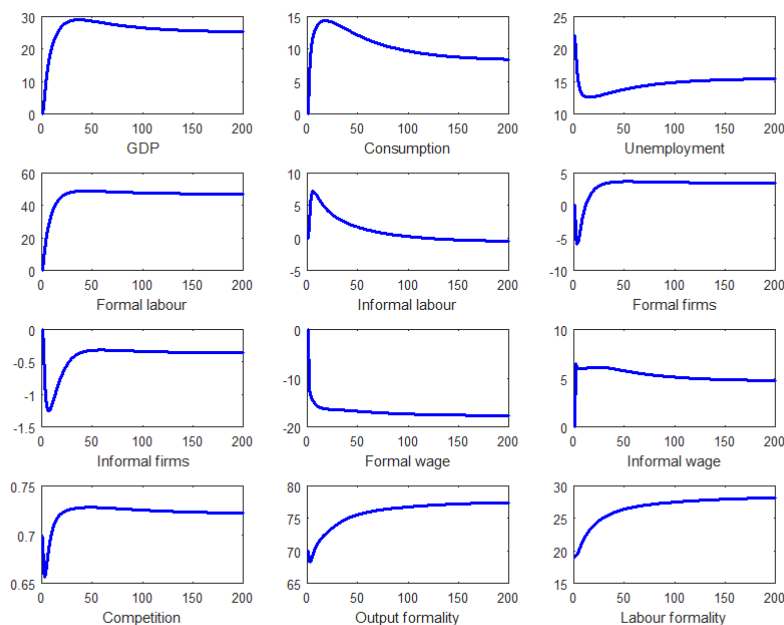
Note: The impact on GDP, consumption (C), formal and informal employment (L_F and L_I), number of firms in each sector (N_F and N_I), and sector-specific wages (W_F and W_I), is the percentage change in each variable, whereas the impact on unemployment (U), relative competition in the formal sector ($\frac{E_F}{E_I}$), output formality ($\frac{P_F Y_F}{P_F Y_F + P_I Y_I}$), and labor formality ($\frac{L_F}{L_F + L_I}$) are expressed in levels.

in both formal wholesalers' labor hiring cost and formal workers' wage bargaining power (i.e, a lower value of β_{HCF} and λ_F), and (ii) a combined labor and product market reform, i.e, a simultaneous decrease in formal wholesalers' labor hiring cost, formal workers' wage bargaining power, and formal retailers' entry cost (i.e, a lower value of β_{HCF} , λ_F , and f_F). Table 4 in Appendix A displays both the short run and long run effects.

Figure 10 and Figure 12a (Appendix A) show the long run and short run effects of a 10 percent permanent decrease in both formal wholesalers' hiring costs, β_{HCF} , combined with a 10 percent decrease in formal workers' bargaining power, λ_F , in our Baseline model, respectively. Overall, we find that the two reforms combined reinforce their effects on the economy, leading to significantly higher gains in GDP, employment and formality in the long run. In the short run, on one hand, this helps overturn the fall in GDP and increase in unemployment associated with individual reforms. However, on the other hand, the fall in the number of formal firms in the short run is now larger, compared to when either reform is implemented on its own.

Figure 11 and Figure 12b (Appendix A) show the long run and short effects of a 10 percent permanent decrease in formal wholesalers' hiring costs, β_{HCF} , and in formal workers' bargaining power, λ_F , combined with a 10 percent permanent decrease in formal retailers' entry cost, f_F , respectively. A combination of product and labor market deregulation leads to significantly

Figure 11: Long run impact of a labor and product market deregulation



Note: The impact on GDP, consumption (C), formal and informal employment (L_F and L_I), number of firms in each sector (N_F and N_I), and sector-specific wages (W_F and W_I), is the percentage change in each variable, whereas the impact on unemployment (U), relative competition in the formal sector ($\frac{\epsilon_F}{\epsilon_I}$), output formality ($\frac{P_F Y_F}{P_F Y_F + P_I Y_I}$), and labor formality ($\frac{L_F}{L_F + L_I}$) are expressed in levels.

larger gains in comparison to when any of the three reforms are implemented individually. In addition, wage inequality is also lower. In the short run, a package of product and labor market reforms helps overturn the fall in GDP and increase in unemployment associated with individual labor reforms. Moreover, it also helps mitigate the fall in number of formal firms, and hence is the most favourable policy strategy⁴⁶.

It is interesting to note that if all regulation asymmetries between the formal and informal sector are removed (i.e. firm entry cost, labor bargaining power, and labor hiring costs in the formal sector are at the informal sector level), then informality in India drops from 82 percent to 61 percent, ceteris paribus.

6.4. Low Informality

In this part, we compare the effects of market deregulation in two economies: one with low informality with share of employed workers in the informal sector, $\frac{L_I}{L_F + L_I}$, at 24 percent, and the Baseline model with high informality with a 82 percent share. We obtain the model with

⁴⁶Note that a full welfare analysis is beyond the scope of this paper, as we only focus on the distortive features of market regulations.

low informality by setting the weight on informal good in the household consumption basket at $(1 - w) = 0.1$ as opposed to 0.5 in the Baseline model. We consider 10 percent deterministic shocks. Table 5 in Appendix A shows the short run and long run effects of labor and product market deregulation with low informality. Figure 13 in Appendix A plots the short run effects under both low informality (dashed line) and high informality (continuous line), where the y-axis is the percentage change in each variable.

Figure 13a shows that the direction of impacts are the same across the two economies with a product market deregulation. Quantitatively, however, the impacts are much smaller in magnitude in the economy with low informality. This holds true in both the short run and long run. However, the effect of a labor market deregulation as seen in Figure 13b, i.e. a fall in formal wholesalers' labor hiring cost, differs in the two economies, both qualitatively and quantitatively. Specifically, this difference is driven by contrasting impacts on the informal sector across the two economies. In the long run, fall in formal hiring costs leads to an increase in formal employment, L_F , in both economies. In the economy with a large informal sector, lower hiring costs reduce W_F , whereas in the economy with a small informal sector, the impact of higher labor demand dominates, instead leading to an increase in W_F . Decrease in both hiring costs and W_F lowers labor costs by more in an economy with high informality, leading to a larger increase in N_F , as compared to with low informality where hiring costs fall but W_F is higher. In both economies, unemployment falls, where with high informality an increase in both L_F and L_I leads to a larger fall in U , compared to the economy with low informality, where the fall in U is not as large due to decrease in L_I ⁴⁷. Fall in U and higher L_F increases household income, which leads to an increase in C . All the above effects combined lead to a larger increase in GDP in an economy with a larger informal sector.

In the short run, however, a larger reallocation of economic resources between the formal and the informal sectors also leads to higher short run costs in terms of a fall in GDP and increase in unemployment, in an economy with a large informal sector. In contrast, with low informality there is an immediate increase in GDP and a fall in unemployment.

7. Conclusion

In this paper, we investigate the impact of product market deregulation and labor market deregulation on output, unemployment, and informality in India. To achieve this goal, we have constructed a two-sector small open economy New Keynesian DSGE model with informality in both goods and labor markets. Our model integrates the literature on market deregulation with the literature on informality, within a unified theoretical framework. Informality stems from higher rigidities in the formal sector, modeled as higher firm entry costs, higher labor hiring costs, and higher worker wage bargaining power in the formal relative to the informal sector.

⁴⁷In the economy with a large informal sector, increase in demand for consumption goods, leads to an increase in demand for both formal and informal goods, which also increases L_I . However, in contrast, informal goods' demand does not increase in an economy with a small informal sector, leading to a fall in L_I instead.

We were motivated by the fact that the existing literature analyses the impact of these reforms in one-sector closed economy models with no informality. Additionally, these models are created for developed countries where they apply calibration techniques to assign values for relevant parameters using reference studies from these economies. Instead, we choose to estimate our model by Bayesian methods, using quarterly data on India. We find that our estimates are consistent with the empirical literature on India, and are robust across alternative models with different model specifications.

We study, alternatively, the impact of product market deregulation, modeled as a fall in formal firm entry cost, and labor market deregulation modeled as a fall in formal worker wage bargaining power and a fall in formal firm labor hiring cost. Our findings in this paper can be summarized as follows. Overall, we find that less regulation increases GDP, and reduces both informality and unemployment in the long run. The effects of labor market deregulation are stronger than those of product market deregulation. With regard to wages, labor market deregulation leads to an increase in informal sector wages and a fall in formal sector wages, reducing wage inequality between the two sectors. On the other hand, product market deregulation increases wages in both sectors, while also leading to higher wage inequality. There are costs involved in the transition to the new steady state post-reform. There is a fall in GDP, a rise in unemployment, and a fall in the share of formal firms in the first four to five quarters post a labor market reform. On the other hand, with product market deregulation, we find that GDP increases and unemployment falls even in the short run, however, there is an increase in informality in the labor market due to a larger increase in informal relative to formal employment. Simultaneously lowering regulations in both the labor and product markets minimizes these short run adjustment costs, while also leading to larger gains in the long run. Finally, the larger the size of the informal sector in an economy, the greater are the long run gains from market deregulation, due to the larger reallocation of resources from the informal to the formal sector, which also results in higher adjustment costs in the short run.

We conclude by suggesting several potential avenues for future research. First, we abstain from modeling the impact of deregulation on labor participation. It could be of interest to investigate how changes in labor participation alter the effects of deregulation policy in developing economies, where low labor force participation, mainly due to significantly low female labor force participation, is a common policy concern. A second relevant study would be to use the framework in this paper to study the effectiveness of different monetary policy regimes in helping overcome short run adjustment costs in order to maximize long run gains of deregulation reforms. Finally, by adding the tax evasion and corruption aspects of informality, it might be interesting to quantify the impact of deregulation reforms on improvements in tax receipts of the government, and thus on fiscal deficits in emerging economies. This would require a more detailed modeling of the fiscal side of the economy in our framework.

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A. Appendix: Estimation Results and Robustness

Table 2: Prior and Posterior Distributions, Baseline Model (India)

Parameter	Description	Dist.	Prior		Posterior	
			Mean	Std. Dev.	Mean	95% CB
h_C	Habit	B	0.5	0.35	0.2394	[0.1141, 0.3239]
ϕ_F^{adj}	Price A.C. in F	G	10	10	18.0919	[17.783, 19.949]
ϕ_I^{adj}	Price A.C. in I	G	10	10	11.4786	[8.2056, 14.829]
$\phi_{f^*}^{adj}$	Price A.C. in f^*	G	10	10	17.0167	[13.370, 19.981]
κ	Cap. A.C.	IG	5	10	4.8106	[3.8287, 5.7243]
χ	Country premium	IG	0.001	0.001	0.0008	[0.0006, 0.0010]
α_i	Coef. of i_{t-1}	B	0.75	0.20	0.8384	[0.7791, 0.9000]
α_π	Coef. of π	U	1.5	[0,3]	2.8948	[2.8722, 2.9710]
α_Y	Coef. of GDP	U	0	[-1,1]	1.0763	[0.9368, 1.2014]
$\rho_{\theta F}$	Pers. of θ_F	B	0.75	0.20	0.9459	[0.9219, 0.9676]
$\rho_{\theta I}$	Pers. of θ_I	B	0.75	0.20	0.6168	[0.5505, 0.6826]
ρ_G	Pers. of G	B	0.70	0.20	0.1537	[0.1318, 0.1782]
$\rho_{\zeta C}$	Pers. of ζ_C	B	0.75	0.20	0.6706	[0.5357, 0.8514]
$\rho_{\beta_{HCF}}$	Pers. of β_{HCF}	B	0.75	0.20	0.8162	[0.7507, 0.8880]
$\rho_{\beta_{HCI}}$	Pers. of β_{HCI}	B	0.30	0.20	0.2571	[0.1569, 0.3674]
$\rho_{\sigma F}$	Pers. of σ_F	B	0.75	0.20	0.2158	[0.0835, 0.3341]
$\rho_{\sigma I}$	Pers. of σ_I	B	0.40	0.20	0.4478	[0.3641, 0.5234]
$\rho_{\lambda F}$	Pers. of λ_F	B	0.80	0.2	0.9105	[0.8802, 0.9443]
$\rho_{\lambda I}$	Pers. of λ_I	B	0.70	0.2	0.7115	[0.6151, 0.8095]
ρ_{fF}	Pers. of f_F	B	0.75	0.2	0.7007	[0.5930, 0.7939]
ρ_{fI}	Pers. of f_I	B	0.75	0.2	0.6182	[0.4742, 0.7660]
ρ_{π^*}	Pers. of π^*	B	0.75	0.2	0.2195	[0.1310, 0.3044]
ρ_{i^*}	Pers. of i^*	B	0.75	0.2	0.7731	[0.6738, 0.8628]
$sd(\varepsilon_{\theta F})$	Std. Dev. of θ_D	IG	1	1	0.4006	[0.3321, 0.4663]
$sd(\varepsilon_{\theta I})$	Std. Dev. of θ_I	IG	1	1	0.4544	[0.3724, 0.5325]
$sd(\varepsilon_G)$	Std. Dev. of G	IG	1	1	3.0404	[2.5705, 3.4826]
$sd(\varepsilon_{\zeta C})$	Std. Dev. of ζ_C	IG	0.001	1	0.0059	[0.0047, 0.0071]
$sd(\varepsilon_{HCF})$	Std. Dev. of β_{HCF}	IG	0.10	0.10	0.4857	[0.3870, 0.5868]
$sd(\varepsilon_{HCI})$	Std. Dev. of β_{HCI}	IG	0.10	0.10	1.0383	[0.9536, 1.1192]
$sd(\varepsilon_{\sigma F})$	Std. Dev. of σ_F	IG	0.10	0.10	0.0729	[0.0350, 0.1116]
$sd(\varepsilon_{\sigma I})$	Std. Dev. of σ_I	IG	0.10	0.10	0.0733	[0.0342, 0.1111]
$sd(\varepsilon_{\lambda F})$	Std. Dev. of λ_F	IG	0.10	0.10	0.2256	[0.1674, 0.2816]
$sd(\varepsilon_{\lambda I})$	Std. Dev. of λ_I	IG	0.10	0.10	0.1438	[0.1077, 0.1772]
$sd(\varepsilon_{fF})$	Std. Dev. of f_F	IG	0.01	0.01	0.0517	[0.0465, 0.0563]
$sd(\varepsilon_{fI})$	Std. Dev. of f_I	IG	0.01	0.01	0.0686	[0.0620, 0.0743]
$sd(\varepsilon_{\pi^*})$	Std. Dev. of π^*	IG	0.05	0.1	0.3418	[0.2969, 0.3893]
$sd(\varepsilon_{i^*})$	Std. Dev. of i^*	IG	0.10	0.10	0.0648	[0.0347, 0.0946]
$sd(\varepsilon_i)$	Std. Dev. of i	IG	1	1	0.1709	[0.1564, 0.1873]

Robustness and Sensitivity Analysis

To establish the robustness of our results, we examine the sensitivity of the predictions of the model to changes in parameter values and theoretical structure

Alternative Models

This section estimates and compares two model variants where Table 3 provides an overview of the posterior estimates.:

Model 1: Baseline model with a small informal sector, $(1 - w) = 0.1$

Model 2: One-sector variant of the Baseline model (no informal sector)

To test the sensitivity of our results to the size of the informal sector, we estimate Model 1 which is a variant of the Baseline model with a significantly smaller informal sector by setting the weight on the informal good in the household consumption basket at $(1 - w) = 0.1$ as opposed to 0.5 in the Baseline model. Informality in employment, $\frac{L_I}{L_F + L_I}$, is obtained at 24 per cent in Model 1, compared to 82 per cent in the Baseline specification. For consistency and comparability, all priors are kept the same.

Overall, parameter estimates are fairly robust across Model 1 and the Baseline model. The estimated Taylor-rule does show a strong response to inflation ($\alpha_\pi = 2.65$) as opposed to output fluctuations ($\alpha_Y = 1.85$), with a high degree of interest rate smoothing ($\alpha_i = 0.85$). In terms of the persistence of the exogenous shocks, overall persistence is higher for the formal relative to the informal sector shocks, and according to the estimated mean of standard deviations, shocks in the informal sector are more volatile. Finally, price adjustment costs are higher in the formal relative to the informal sector, however, the estimated mean values are now smaller (estimated at $\phi_F^{adj} = 9.75$ and $\phi_I^{adj} = 1.18$, in contrast to $\phi_F^{adj} = 18.09$ and $\phi_I^{adj} = 11.47$ in the Baseline). Consistent with the Baseline estimates, import price rigidity (with mean estimates of $\phi_{f^*}^{adj} = 3.45$) is lower than formal domestic price rigidity, but higher than the rigidity in informal prices, though the difference with the latter is not as large now.

We also estimate Model 2, a one-sector variant of the Baseline model, where there is no informal sector. The theoretical structure in Model 2 is now different to the two-sector Baseline model. Overall, we find that the Bayesian estimates with Model 2 closely match the estimates in the related literature for developing economies as these are mostly based on one-sector models with no informality (see Castillo et al. (2006), Tovar (2006a, 2006b), and Anand et al. (2010)). Taylor-rule does not suggest as strong a response to inflation, now estimated at $\alpha_\pi = 1.78$, as opposed to a corresponding mean value of greater than 2 in both the Baseline and Model 1 specifications. The stronger response of interest rates to inflation in the two sector model is potentially capturing the shock absorbing role of the informal sector, because of which policy needs to be more aggressive in order to stabilize prices and output. Similarly, response to output deviations, are also much lower at $\alpha_Y = 0.48$, compared to values greater than 1 in the two sector models. Moving on to the price adjustment costs, domestic prices are still more flexible than import prices, estimated at $\phi_F^{adj} = 2.97$ and $\phi_{f^*}^{adj} = 1.48$, respectively,

but the extent of rigidity is much lower than the Baseline model (where $\phi_F^{adj} = 18.89$ and $\phi_{f^*}^{adj} = 17.01$).

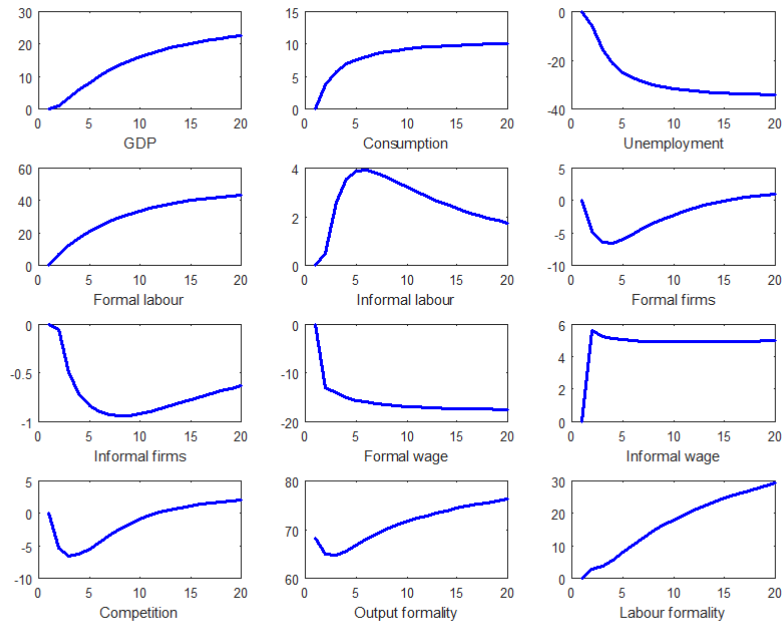
The bottom line of Table 3 also reports the log marginal likelihood value associated with each model specification, where the differences in these across models are important as decisive evidence of one model over the other using Bayesian estimation (see Geweke (1999) and Smets and Wouters (2003) for details). This value is higher for the Baseline model than the ones corresponding to the low-informality and the one-sector specifications, hence indicating that the data favours the model with a large informal sector. Moreover, it is interesting to note that the one-sector specification provides a better fit to the data as compared to the model with low informality.

Table 3: Robustness of Result, Alternative and Baseline Model (India)

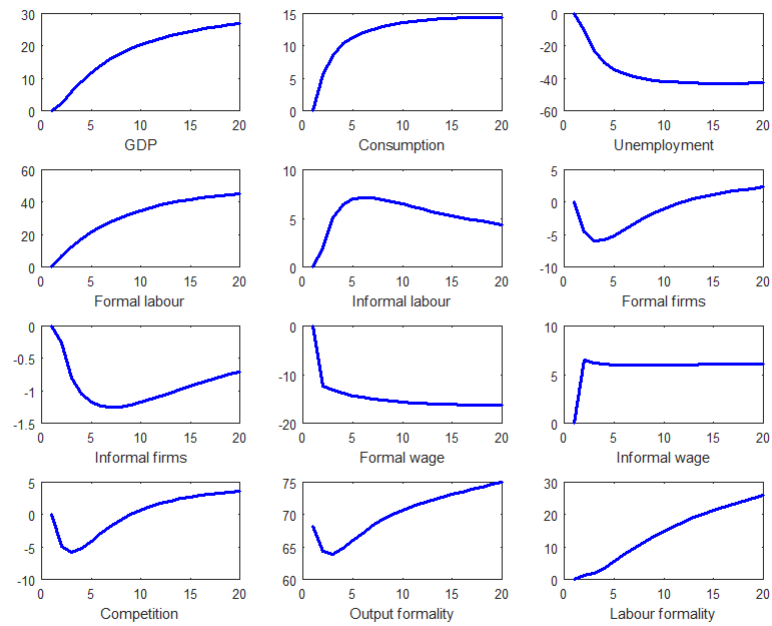
Param.	Prior			Posterior				
	Dist.	Mean	Std Dev.	Baseline	Model 1		Model 2	
				Mean	Mean	95% C.I.	Mean	95% C.I.
h_C	B	0.5	0.35	0.23	0.31	[0.23, 0.37]	0.46	[0.34, 0.48]
ϕ_F^{adj}	G	10	10	18.09	9.75	[7.41, 12.28]	2.97	[1.06, 5.50]
ϕ_I^{adj}	G	10	10	11.47	1.18	[1.00, 1.39]		
$\phi_{f^*}^{adj}$	G	10	10	17.01	3.45	[1.44, 4.99]	1.48	[1.00, 2.14]
κ	IG	5	10	4.81	38.51	[29.58, 45.86]	8.41	[7.36, 9.79]
χ	IG	0.001	0.001	0.08	0.02*	[0.01, 0.02]*	0.02*	[0.01, 0.02]*
α_i	B	0.75	0.20	0.83	0.85	[0.79, 0.90]	0.89	[0.88, 0.90]
α_π	U	1.5	[0,3]	2.89	2.65	[2.61, 2.92]	1.78	[1.67, 1.92]
α_Y	U	0	[-1,1]	1.07	1.85	[1.75, 1.96]	0.48	[0.41, 0.56]
$\rho_{\theta F}$	B	0.75	0.20	0.94	0.82	[0.76, 0.89]	0.83	[0.81, 0.86]
$\rho_{\theta I}$	B	0.75	0.20	0.61	0.36	[0.24, 0.50]		
ρ_G	B	0.70	0.20	0.15	0.07	[0.01, 0.16]	0.39	[0.34, 0.45]
$\rho_{\zeta C}$	B	0.75	0.20	0.67	0.38	[0.27, 0.45]	0.74	[0.70, 0.77]
$\rho_{\beta_{HCF}}$	B	0.75	0.20	0.81	0.40	[0.33, 0.47]	0.79	[0.75, 0.83]
$\rho_{\beta_{HCI}}$	B	0.30	0.20	0.25	0.31	[0.21, 0.41]		
$\rho_{\sigma F}$	B	0.75	0.20	0.21	0.28	[0.15, 0.38]	0.44	[0.39, 0.47]
$\rho_{\sigma I}$	B	0.40	0.20	0.44	0.82	[0.67, 0.95]		
$\rho_{\lambda F}$	B	0.80	0.2	0.91	0.86	[0.77, 0.96]	0.89	[0.87, 0.90]
$\rho_{\lambda I}$	B	0.70	0.2	0.71	0.71	[0.53, 0.85]		
ρ_{fF}	B	0.75	0.2	0.61	0.44	[0.36, 0.50]	0.69	[0.68, 0.71]
ρ_{fI}	B	0.75	0.2	0.70	0.65	[0.54, 0.77]		
ρ_{π^*}	B	0.75	0.2	0.21	0.26	[0.23, 0.41]	0.65	[0.61, 0.70]
ρ_{i^*}	B	0.75	0.2	0.77	0.52	[0.44, 0.61]	0.64	[0.60, 0.67]
$sd(\varepsilon_{\theta F})$	IG	1	1	0.40	0.16	[0.16, 0.17]	0.16	[0.16, 0.17]
$sd(\varepsilon_{\theta I})$	IG	1	1	0.45	0.72	[0.37, 1.06]		
$sd(\varepsilon_G)$	IG	1	1	3.04	0.20	[0.17, 0.24]	0.16	[0.16, 0.18]
$sd(\varepsilon_{\zeta C})$	IG	0.001	1	0.59	5.16*	[2.92, 6.94]*	4.3*	[3.50, 5.00]*
$sd(\varepsilon_{HCF})$	IG	0.10	0.10	0.48	0.28	[0.23, 0.33]	0.03	[0.02, 0.04]
$sd(\varepsilon_{HCI})$	IG	0.10	0.10	1.03	0.06	[0.03, 0.08]		
$sd(\varepsilon_{\sigma F})$	IG	0.10	0.10	0.07	0.14	[0.08, 0.21]	0.11	[0.09, 0.14]
$sd(\varepsilon_{\sigma I})$	IG	0.10	0.10	0.07	0.07	[0.03, 0.12]		
$sd(\varepsilon_{\lambda F})$	IG	0.10	0.10	0.22	0.06	[0.03, 0.08]	0.16	[0.15, 0.18]
$sd(\varepsilon_{\lambda I})$	IG	0.10	0.10	0.14	0.17	[0.09, 0.25]		
$sd(\varepsilon_{fF})$	IG	0.01	0.01	0.05	0.93*	[0.50, 1.35]*	0.50*	[0.30, 0.69]*
$sd(\varepsilon_{fI})$	IG	0.01	0.01	0.07	0.03	[0.02, 0.04]		
$sd(\varepsilon_{\pi^*})$	IG	0.05	0.1	0.34	0.46	[0.39, 0.55]	0.56	[0.48, 0.61]
$sd(\varepsilon_{i^*})$	IG	0.10	0.10	0.06	0.08	[0.06, 0.13]	0.09	[0.07, 0.12]
$sd(\varepsilon_i)$	IG	1	1	0.17	0.16	[0.16, 0.17]	0.15	[0.14, 0.16]
Log- Marginal Likelihood				654.32	630.16		648.69	

*values are to the power of $10^{(-2)}$

Figure 12: Short run impact of a combined package of reforms



(a) Combined labor market reform



(b) Combined labor and product market reform

Note: The impact is the percentage change in each variable.

Table 4: Impact of Deregulation Policies, Baseline Model

Shock	Output		Cons.		Unemp.		F emp.		I emp.		F firms		I firms		F wage		I wage	
	Y	C	U	L _F	L _I	N _F	N _I	W _F	W _I									
F-labour hiring cost	SR	-0.38	0.86	0.28	1.07	-0.35	-0.20	0.11	-2.08	1.08								
	LR	8.32	8.17	-17.73	10.59	4.11	1.77	-0.24	-1.72	2.46								
F-worker bargaining power	SR	-0.70	1.24	-2.94	4.27	0.03	-3.66	-0.01	-13.75	1.98								
	LR	16.68	8.16	-28.61	30.29	2.44	0.51	-0.47	-16.67	2.21								
F-firm entry cost	SR	1.03	1.42	-2.83	0.25	0.95	0.59	-0.12	0.31	0.68								
	LR	1.71	1.38	-2.71	0.40	0.06	1.64	-0.04	0.33	0.23								
F-hiring & F-bargaining	SR	0.88	3.75	-5.86	6.64	0.49	-4.75	-0.05	-12.97	5.64								
	LR	22.84	8.28	-30.20	45.50	-0.33	2.20	-0.38	-16.91	4.55								
All together	SR	2.25	5.59	-10.37	6.89	2.01	-4.61	-0.26	-12.28	6.45								
	LR	25.34	8.42	-30.12	47.07	-0.49	4.50	-0.36	-17.68	4.76								

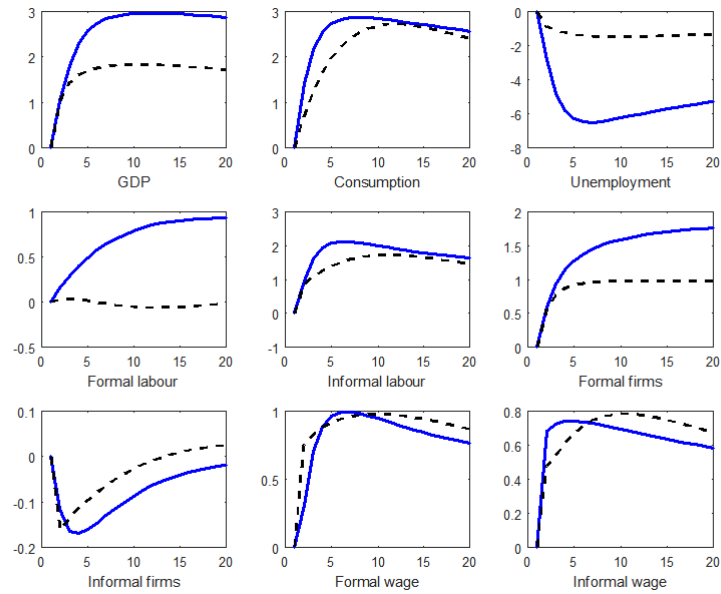
Note: LR denotes the long run (200 quarters) effects of shocks, whereas SR denotes the immediate effects (first 4 quarters). All values correspond to percentage change.

Table 5: Impact of deregulation with low informality

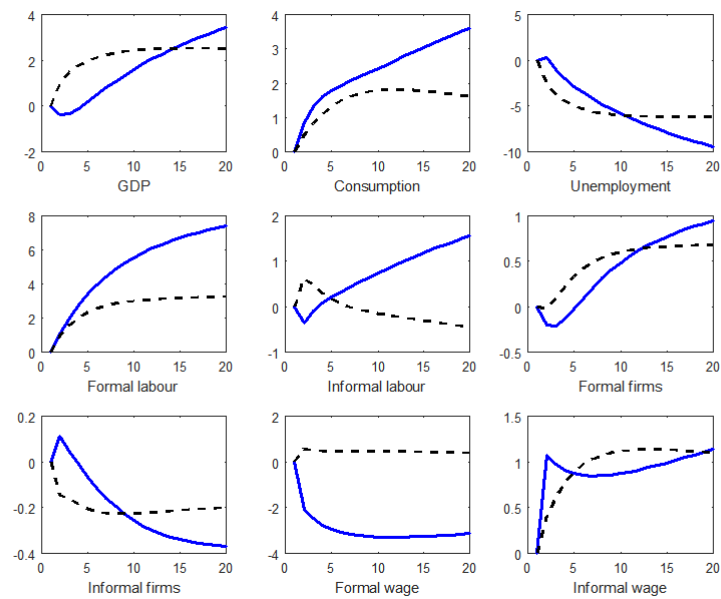
Shock	Output		Cons.		Unemp.		F emp.		I emp.		F firms		I firms		F wage		I wage	
	Y	C	U	L _F	L _I	N _F	N _I	W _F	W _I									
F-labour hiring cost	SR	1.01	0.46	-2.51	0.93	0.63	-0.03	-0.15	0.58	0.39								
	LR	2.50	1.61	-6.22	3.47	-1.57	0.66	-0.22	-0.10	0.68								
F-worker bargaining	SR	0.56	0.24	-2.81	1.18	0.40	-0.49	-0.11	-1.66	0.06								
	LR	2.00	0.78	-7.31	4.14	-1.83	0.10	-0.29	-2.09	0.69								
F-firm entry cost	SR	1.04	0.68	-0.85	0.03	0.84	0.54	-0.16	0.75	0.48								
	LR	0.80	0.17	-0.34	0.24	-0.18	0.93	-0.01	0.13	0.03								
F-hiring & F-bargaining	SR	1.59	0.68	-5.43	2.18	1.00	-0.50	-0.25	-1.08	0.43								
	LR	4.37	2.37	-13.16	7.60	-3.35	0.75	-0.51	-2.06	1.37								
All together	SR	2.62	1.37	-6.24	2.18	1.86	0.02	-0.42	-0.35	0.90								
	LR	6.02	4.87	-14.23	6.02	4.87	-14.23	6.02	4.87	-14.23								

Note: LR denotes the long run (200 quarters) effects of shocks, whereas SR denotes the immediate effects (first 4 quarters). Low informality refers to effects of deregulation in an economy with 24 per cent informality in the labor market. All values correspond to percentage change.

Figure 13: Impact of deregulation reforms with low informality



(a) Impact of a fall in formal entry cost



(b) Impact of a fall in formal hiring cost

Note: The impact is the percentage change in each variable where the blue thick line shows the impact in the Baseline model (high informality), and the black dotted line shows the impact in an economy with low informality.

B. Technical Appendix

This Appendix discusses the derivation of the model's optimality conditions.

Solution to Household Utility Maximization Problem

To solve the households' utility maximization problem described in the text, we insert the formal and informal retailers' firm dynamics equation, given by 3.24 and 3.25 in the text, in the household budget constraint 3.43, and establish the associated Lagrangian as follows:

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{l} [\zeta_{C,t} (1 - h_C) \ln(C_t - h_C C_{t-1})] \\ -\lambda_t [C_t + (RER_t) B_t^* + D_t + N_{F,t}^E f_{F,t} + N_{I,t}^E f_{I,t}] \\ +\lambda_t \left[\left(\frac{e_t}{e_{t-1}} \right) \left(\frac{1+i_{t-1}^f}{\pi_t} \right) (RER_{t-1}) B_{t-1}^* + \left(\frac{1+i_{t-1}}{\pi_t} \right) D_{t-1} \right] \\ +\lambda_t [(1 - \tau_F) W_{F,t} L_{F,t} + W_{I,t} L_{I,t} + (W_{U,t})(1 - L_{F,t} - L_{I,t})] \\ +\lambda_t \left[\left(\Pi_{F,t}^R + f_{F,t} \right) (1 - \delta_F) (N_{F,t-1} + N_{F,t-1}^E) \right] \\ +\lambda_t \left[\left(\Pi_{I,t}^R + f_{I,t} \right) (1 - \delta_I) (N_{I,t-1} + N_{I,t-1}^E) \right] \end{array} \right\} \quad (\text{B.1})$$

where λ_t is the shadow price for the budget constraint in period t , i.e. the value in terms of utility of relaxing the budget constraint at the margin. Differencing the above Lagrangian with respect to C_t , B_t , and D_t , yields the following first order conditions:

$$[C_t]: \quad \frac{\zeta_{C,t}(1 - h_C)}{C_t - h_C C_{t-1}} - \lambda_t = 0 \quad (\text{B.2})$$

$$[D_t]: \quad -\lambda_t + \beta E_t \left[\lambda_{t+1} \left(\frac{1 + i_t}{\pi_{t+1}} \right) \right] = 0 \quad (\text{B.3})$$

$$[B_t]: \quad -\lambda_t + \beta E_t \left[\lambda_{t+1} \left(\frac{1 + i_t^f}{\pi_{t+1}} \right) \left(\frac{e_{t+1}}{e_t} \right) \right] = 0 \quad (\text{B.4})$$

B.3 and B.4 imply the evolution of shadow price evaluated in domestic and foreign interest rate. Combining B.2 and B.3 derives the Euler equation relating to domestic bonds given as 3.44 in the text, and combining B.2 and B.4 derives the Euler equation for foreign bonds given as 3.45 in the text.

Differencing the above Lagrangian with respect to $N_{F,t}^E$ and $N_{I,t}^E$, yields the following first order conditions:

$$[N_{F,t}^E]: \quad -\lambda_t f_{F,t} + \beta E_t \left[\lambda_{t+1} (\Pi_{F,t+1}^R + f_{F,t+1}) (1 - \delta_F) \right] = 0 \quad (\text{B.5})$$

$$[N_{I,t}^E] : -\lambda_t f_{I,t} + \beta E_t [\lambda_{t+1} (\Pi_{I,t+1}^R + f_{I,t+1}) (1 - \delta_i)] = 0 \quad (\text{B.6})$$

These correspond to the Euler equations for investment in formal and informal firms, given by 3.46 and 3.47 in the main text.

Solution to Wholesaler Profit Maximization Problem

To solve the wholesalers' profit maximization problem described in the text, we establish the associated Lagrangian for the wholesalers in each sector s as follows ($l = t + k$):

$$\mathcal{L}_s^E = E_t \sum_{k=0}^{\infty} \rho_{t,t+k} \left\{ \begin{array}{l} \frac{P_{s,l}^W}{P_t} \theta_{s,t} (K_{s,l-1})^{\psi_s} (L_{s,l})^{1-\psi_s} \\ - W_{s,l} L_{s,l} - R_t^K K_{s,l} - HC_{s,l} H_{s,l} \\ - \Omega_{s,l} [L_{s,l} - (1 - \sigma_{s,l}) L_{s,l-1} - H_{s,l}] \end{array} \right\} \quad (\text{B.7})$$

where $\Omega_{s,t}$ is the Lagrangian multiplier for the law of motion of labor in period t . Differencing the above Lagrangian with respect to $K_{s,t-1}$, $L_{s,t}$, and $H_{s,t}$ results in the following first order conditions:

$$[K_{s,t-1}] : \psi_s \frac{P_{s,t}^W}{P_t} \frac{Y_{s,t}^W}{K_{s,t-1}} - R_t^K = 0 \quad (\text{B.8})$$

$$[L_{s,t}] : (1 - \psi_s) \frac{P_{s,t}^W}{P_t} \frac{Y_{s,t}^W}{L_{s,t}} - \Omega_{s,t} + E_t [\rho_{t,t+1} (\Omega_{s,t+1}) (1 - \sigma_{s,t+1})] = 0 \quad (\text{B.9})$$

$$[H_{s,t}] : HC_{s,t} - \Omega_{s,t} = 0 \quad (\text{B.10})$$

B.8 determines the demand for capital given in the main text as 3.12 and 3.14 for formal ($s = F$) and informal ($s = I$) sectors, respectively. Labor demand equations are derived by combining B.9 and B.10 for formal ($s = F$) and informal ($s = I$) sector, respectively, giving us:

$$(1 - \psi_F) \frac{P_{F,t}^W}{P_t} \frac{Y_{F,t}^W}{L_{F,t}} = W_{F,t} + HC_{F,t} - E_t (\rho_{t,t+1} HC_{F,t+1} (1 - \sigma_{F,t+1}))$$

$$(1 - \psi_I) \frac{P_{I,t}^W}{P_t} \frac{Y_{I,t}^W}{L_{I,t}} = W_{I,t} + HC_{I,t} - E_t (\rho_{t,t+1} HC_{I,t+1} (1 - \sigma_{I,t+1}))$$

which refer to 3.13 and 3.15 in the main text.

Wage Bargaining

Formal and informal sector wages are determined by the Nash bargaining solution described as 3.19 in the text:

$$V_{F,t} - V_{U,t} = \frac{\lambda_{F,t}}{1 - \lambda_{F,t}} (1 - \tau_F) J_{F,t} \quad (\text{B.11})$$

$$V_{I,t} - V_{U,t} = \frac{\lambda_{I,t}}{1 - \lambda_{I,t}} J_{I,t} \quad (\text{B.12})$$

The utility gain of an unemployed worker from getting hired in the formal sector is given by $(V_{F,t} - V_{U,t})$. Inserting 3.16 and 3.18 from the main text in B.11, results in the following:

$$\begin{aligned} (V_{F,t} - V_{U,t}) &= (1 - \tau_F) W_{F,t} - W_{U,t} \\ &\quad + E_t \left\{ \rho_{t,t+1} \left[-(1 - \sigma_{F,t+1}) p(H_{I,t+1}) \right] V_{I,t+1} \right\} \\ &\quad + E_t \left\{ \rho_{t,t+1} \left[(1 - \sigma_{F,t+1}) - p(H_{F,t+1}) (1 - \sigma_{F,t+1}) \right] V_{F,t+1} \right\} \\ &\quad - E_t \left\{ \rho_{t,t+1} \left[(1 - \sigma_{F,t+1}) (1 - p(H_{F,t+1}) - p(H_{I,t+1})) \right] V_{U,t+1} \right\} \end{aligned}$$

Rearranging terms helps us write the above equation as:

$$\begin{aligned} (V_{F,t} - V_{U,t}) &= (1 - \tau_F) W_{F,t} - W_{U,t} \\ &\quad + E_t \left\{ \rho_{t,t+1} \left[(1 - \sigma_{F,t+1}) \right] (V_{F,t+1} - V_{U,t+1}) \right\} \\ &\quad - E_t \left\{ \rho_{t,t+1} \left[p(H_{I,t+1}) (1 - \sigma_{F,t+1}) \right] (V_{I,t+1} - V_{U,t+1}) \right\} \\ &\quad - E_t \left\{ \rho_{t,t+1} \left[p(H_{F,t+1}) (1 - \sigma_{F,t+1}) \right] (V_{F,t+1} - V_{U,t+1}) \right\} \end{aligned}$$

Inserting B.11 and B.12 in the equation above results in the following:

$$\begin{aligned} \frac{\lambda_{F,t}}{1 - \lambda_{F,t}} (1 - \tau_F) J_{F,t} &= (1 - \tau_F) W_{F,t} - W_{U,t} \quad (\text{B.13}) \\ &\quad + (1 - \tau_F) E_t \left\{ \rho_{t,t+1} \left[(1 - \sigma_{F,t+1}) (1 - p(H_{F,t+1})) \right] \frac{\lambda_{F,t+1}}{1 - \lambda_{F,t+1}} J_{F,t+1} \right\} \\ &\quad - E_t \left\{ \rho_{t,t+1} \left[p(H_{I,t+1}) (1 - \sigma_{F,t+1}) \right] \frac{\lambda_{I,t+1}}{1 - \lambda_{I,t+1}} J_{I,t+1} \right\} \end{aligned}$$

Similarly, the utility gain of an unemployed worker from getting hired in the informal sector is given by $(V_{I,t} - V_{U,t})$. Inserting 3.17 and 3.18 from the text, and rearranging terms results

in:

$$\begin{aligned}
(V_{I,t} - V_{U,t}) &= W_{I,t} - W_{U,t} \\
&+ E_t \left\{ \rho_{t,t+1} [(1 - \sigma_{I,t+1})] (V_{I,t+1} - V_{U,t+1}) \right\} \\
&- E_t \left\{ \rho_{t,t+1} [p(H_{F,t+1}) (1 - \sigma_{I,t+1})] (V_{F,t+1} - V_{U,t+1}) \right\} \\
&- E_t \left\{ \rho_{t,t+1} [p(H_{I,t+1}) (1 - \sigma_{I,t+1})] (V_{I,t+1} - V_{U,t+1}) \right\}
\end{aligned}$$

Inserting B.11 and B.12 in this equation:

$$\begin{aligned}
\frac{\lambda_{I,t}}{1 - \lambda_{I,t}} J_{I,t} &= W_{I,t} - W_{U,t} \tag{B.14} \\
&+ E_t \left\{ \rho_{t,t+1} [(1 - \sigma_{I,t+1}) (1 - p(H_{I,t+1}))] \frac{\lambda_{I,t+1}}{1 - \lambda_{I,t+1}} J_{I,t+1} \right\} \\
&- (1 - \tau_F) E_t \left\{ \rho_{t,t+1} [p(H_{F,t+1}) (1 - \sigma_{I,t+1})] \frac{\lambda_{F,t+1}}{1 - \lambda_{F,t+1}} J_{F,t+1} \right\}
\end{aligned}$$

Inserting $J_{F,t} = HC_{F,t}$ in B.13 derives the formal sector wage:

$$\begin{aligned}
\frac{\lambda_{F,t}}{1 - \lambda_{F,t}} (1 - \tau_F) HC_{F,t} &= (1 - \tau_F) W_{F,t} - W_{U,t} \tag{B.15} \\
&+ (1 - \tau_F) E_t \left\{ \rho_{t,t+1} [(1 - \sigma_{F,t+1}) (1 - p(H_{F,t+1}))] \frac{\lambda_{F,t+1}}{1 - \lambda_{F,t+1}} HC_{F,t+1} \right\} \\
&- E_t \left\{ \rho_{t,t+1} [p(H_{I,t+1}) (1 - \sigma_{F,t+1})] \frac{\lambda_{I,t+1}}{1 - \lambda_{I,t+1}} HC_{I,t+1} \right\}
\end{aligned}$$

Rearranging terms in B.15 gives us the expression for the formal sector wage rate given by 3.20 in the text:

$$\begin{aligned}
W_{F,t} (1 - \tau_F) &= \frac{\lambda_{F,t}}{1 - \lambda_{F,t}} (1 - \tau_F) HC_{F,t} + W_{U,t} \\
&- (1 - \tau_F) E_t \left\{ \rho_{t,t+1} \left[\frac{\lambda_{F,t+1}}{1 - \lambda_{F,t+1}} (1 - \sigma_{F,t+1}) (1 - p(H_{F,t+1})) HC_{F,t+1} \right] \right\} \\
&+ E_t \left\{ \rho_{t,t+1} \left[\frac{\lambda_{I,t+1}}{1 - \lambda_{I,t+1}} (1 - \sigma_{F,t+1}) p(H_{I,t+1}) HC_{I,t+1} \right] \right\}
\end{aligned}$$

Similarly, for informal sector wages we derive:

$$\begin{aligned} \frac{\lambda_{I,t}}{1-\lambda_{I,t}} HC_{I,t} &= W_{I,t} - W_{U,t} \\ &+ E_t \left\{ \rho_{t,t+1} [(1-\sigma_{I,t+1})(1-p(H_{I,t+1}))] \frac{\lambda_{I,t+1}}{1-\lambda_{I,t+1}} HC_{I,t+1} \right\} \\ &- (1-\tau_F) E_t \left\{ \rho_{t,t+1} [p(H_{F,t+1})(1-\sigma_{I,t+1})] \frac{\lambda_{F,t+1}}{1-\lambda_{F,t+1}} HC_{F,t+1} \right\} \end{aligned} \quad (\text{B.16})$$

and rearranging terms in B.16 gives us the informal sector wage rate equation given in the text as 3.21:

$$\begin{aligned} W_{I,t} &= \frac{\lambda_{I,t}}{1-\lambda_{I,t}} HC_{I,t} + W_{U,t} \\ &- E_t \left\{ \rho_{t,t+1} \left[\frac{\lambda_{I,t+1}}{1-\lambda_{I,t+1}} (1-\sigma_{I,t+1})(1-p(H_{I,t+1})) HC_{I,t+1} \right] \right\} \\ &+ (1-\tau_F) E_t \left\{ \rho_{t,t+1} \left[\frac{\lambda_{F,t+1}}{1-\lambda_{F,t+1}} (1-\sigma_{I,t+1}) p(H_{F,t+1}) HC_{F,t+1} \right] \right\} \end{aligned}$$

Solution to Retailer Price Setting Problem

To solve the retailers' profit maximization problem described in the text, we establish the associated Lagrangian for the retailer j_s in each sector s as follows:

$$\mathcal{L}_s^R = E_t \sum_{k=0}^{\infty} \rho_{t,t+k} (1-\delta_s)^k \left\{ \begin{aligned} &\left(\frac{P_{F,t}(j_F)}{P_t} - MC_{F,t}^W \right) \left(\frac{P_{F,t}(j_F)}{P_{F,t}} \right)^{-\varepsilon_{F,t}} (Q_{F,t}^d + Q_t^x) \\ &- \frac{\phi_F^{adj}}{2} \left(\frac{P_{F,t}(j_F)}{\pi(P_{F,t-1}(j_F))} - 1 \right)^2 (Q_{F,t}^d + Q_t^x) \end{aligned} \right\}$$

Above $MC_{F,t}^W = P_{F,t}^W/P_t$ is the real marginal cost in period t .

Differencing the above equation with respect to $P_{F,t}(j_F)$ yields the following first order condition:

$$(1-\delta_s) \left\{ \begin{aligned} &\frac{1}{P_t} \left(\frac{P_{F,t}(j_F)}{P_{F,t}} \right)^{-\varepsilon_{F,t}} Q_{F,t}^d - \varepsilon_{F,t} \left(\frac{1}{P_{F,t}} \right) \left(\frac{P_{F,t}(j_F)}{P_t} - MC_{F,t}^W \right) \left(\frac{P_{F,t}(j_F)}{P_{F,t}} \right)^{-\varepsilon_{F,t}-1} Q_{F,t}^d \\ &+ \frac{1}{P_t} \left(\frac{P_{F,t}(j_F)}{P_{F,t}} \right)^{-\varepsilon_{F,t}} Q_t^x - \varepsilon_{F,t} \left(\frac{1}{P_{F,t}} \right) \left(\frac{P_{F,t}(j_F)}{P_t} - MC_{F,t}^W \right) \left(\frac{P_{F,t}(j_F)}{P_{F,t}} \right)^{-\varepsilon_{F,t}-1} Q_t^x \\ &- \phi_F^{adj} \left(\frac{1}{\pi(P_{F,t-1}(j_F))} \right) \left(\frac{P_{F,t}(j_F)}{\pi(P_{F,t-1}(j_F))} - 1 \right) (Q_{F,t}^d + Q_t^x) \\ &+ \rho_{t,t+1} \phi_F^{adj} \left(\frac{1}{P_{F,t}(j_F)} \right)^2 \left(\frac{P_{F,t+1}(j_F)}{\pi} \right) \left(\frac{P_{F,t+1}(j_F)}{\pi(P_{F,t}(j_F))} - 1 \right) (Q_{F,t+1}^d + Q_{t+1}^x) \end{aligned} \right\} = 0$$

As all firms are identical, i.e. $P_{F,t}(j_F) = P_{F,t}$, we can write the above equation as:

$$(1 - \delta_s) \left\{ \begin{array}{l} \frac{1}{P_t} Q_{F,t}^d - \varepsilon_{F,t} \left(\frac{1}{P_{F,t}} \right) \left(\frac{P_{F,t}}{P_t} - MC_{F,t}^W \right) Q_{F,t}^d \\ + \frac{1}{P_t} Q_t^x - \varepsilon_{F,t} \left(\frac{1}{P_{F,t}} \right) \left(\frac{P_{F,t}}{P_t} - MC_{F,t}^W \right) Q_t^x \\ - \phi_F^{adj} \left(\frac{1}{\pi(P_{F,t-1})} \right) \left(\frac{P_{F,t}}{\pi(P_{F,t-1})} - 1 \right) (Q_{F,t}^d + Q_t^x) \\ + \rho_{t,t+1} \phi_F^{adj} \left(\frac{1}{P_{F,t}(j_F)} \right)^2 \left(\frac{P_{F,t+1}}{\pi} \right) \left(\frac{P_{F,t+1}}{\pi(P_{F,t})} - 1 \right) (Q_{F,t+1}^d + Q_{t+1}^x) \end{array} \right\} = 0$$

Using $Y_{F,t} = (Q_{F,t}^d + Q_t^x)$

$$(1 - \delta_s) \left\{ \begin{array}{l} \frac{1}{P_t} Y_{F,t} - \varepsilon_{F,t} \left(\frac{1}{P_{F,t}} \right) \left(\frac{P_{F,t}}{P_t} - MC_{F,t}^W \right) Y_{F,t} \\ - \phi_F^{adj} \left(\frac{1}{\pi(P_{F,t-1})} \right) \left(\frac{P_{F,t}}{\pi(P_{F,t-1})} - 1 \right) (Y_{F,t}) \\ + \rho_{t,t+1} \phi_F^{adj} \left(\frac{1}{P_{F,t}} \right)^2 \left(\frac{P_{F,t+1}}{\pi} \right) \left(\frac{P_{F,t+1}}{\pi(P_{F,t})} - 1 \right) (Y_{F,t+1}) \end{array} \right\} = 0$$

Rearranging terms:

$$(1 - \delta_s) \left\{ \begin{array}{l} \frac{1}{P_t} (1 - \varepsilon_{F,t}) Y_{F,t} + \varepsilon_{F,t} \left(\frac{1}{P_{F,t}} \right) MC_{F,t}^W Y_{F,t} \\ - \phi_F^{adj} \left(\frac{1}{\pi(P_{F,t-1})} \right) \left(\frac{P_{F,t}}{\pi(P_{F,t-1})} - 1 \right) (Y_{F,t}) \\ + \rho_{t,t+1} \phi_F^{adj} \left(\frac{1}{P_{F,t}} \right)^2 \left(\frac{P_{F,t+1}}{\pi} \right) \left(\frac{P_{F,t+1}}{\pi(P_{F,t})} - 1 \right) (Y_{F,t+1}) \end{array} \right\} = 0$$

Multiplying both sides by $P_{F,t}$:

$$(1 - \delta_s) \left\{ \begin{array}{l} \frac{P_{F,t}}{P_t} (1 - \varepsilon_{F,t}) Y_{F,t} + \varepsilon_{F,t} MC_{F,t}^W Y_{F,t} \\ - \phi_F^{adj} \left(\frac{\pi_{F,t}}{\pi} \right) \left(\frac{\pi_{F,t}}{\pi} - 1 \right) (Y_{F,t}) \\ + \rho_{t,t+1} \phi_F^{adj} \left(\frac{\pi_{F,t+1}}{\pi} \right) \left(\frac{\pi_{F,t+1}}{\pi} - 1 \right) (Y_{F,t+1}) \end{array} \right\} = 0$$

Solving for $\frac{P_{F,t}}{P_t}$ yields:

$$\begin{aligned} \frac{P_{F,t}}{P_t} (\varepsilon_{F,t} - 1) (Y_{F,t}) &= \varepsilon_{F,t} MC_{F,t}^W (Y_{F,t}) - \phi_F^{adj} \left(\frac{\pi_{F,t}}{\pi} \right) \left(\frac{\pi_{F,t}}{\pi} - 1 \right) (Y_{F,t}) \\ &+ \rho_{t,t+1} \phi_F^{adj} \left(\frac{\pi_{F,t+1}}{\pi} \right) \left(\frac{\pi_{F,t+1}}{\pi} - 1 \right) (Y_{F,t+1}) \end{aligned}$$

Dividing both sides by $(\varepsilon_{F,t} - 1)(Y_{F,t})$ results in the price setting equation in the formal sector given as:

$$\begin{aligned} \frac{P_{F,t}}{P_t} &= \frac{\varepsilon_{F,t}}{(\varepsilon_{F,t} - 1)} MC_{F,t}^W - \frac{\phi_F^{adj}}{(\varepsilon_{F,t} - 1)} \left(\frac{\pi_{F,t}}{\pi} \right) \left(\frac{\pi_{F,t}}{\pi} - 1 \right) \\ &+ \rho_{t,t+1} \frac{\phi_F^{adj}}{(\varepsilon_{F,t} - 1)} \left(\frac{\pi_{F,t+1}}{\pi} \right) \left(\frac{\pi_{F,t+1}}{\pi} - 1 \right) \left(\frac{Y_{F,t+1}}{Y_{F,t}} \right) \end{aligned}$$

Similarly, the informal price equation is obtained as:

$$\begin{aligned} \frac{P_{I,t}}{P_t} &= \frac{\varepsilon_{I,t}}{(\varepsilon_{I,t} - 1)} MC_{I,t}^W - \frac{\phi_I^{adj}}{(\varepsilon_{I,t} - 1)} \left(\frac{\pi_{I,t}}{\pi} \right) \left(\frac{\pi_{I,t}}{\pi} - 1 \right) \\ &+ \rho_{t,t+1} \frac{\phi_I^{adj}}{(\varepsilon_{I,t} - 1)} \left(\frac{\pi_{I,t+1}}{\pi} \right) \left(\frac{\pi_{I,t+1}}{\pi} - 1 \right) \left(\frac{Y_{I,t+1}}{Y_{I,t}} \right) \end{aligned}$$

The above equations correspond to 3.35 for sector s in the main text.

Solution to Capital Producers Profit Maximization

The capital producer invests I_t such that its profit is maximized, where Q_t is the real price of capital, resulting in the following profit maximization problem described in the text:

$$\max_{I_t} Q_t \left(\frac{P_t^{Inv}}{P_t} I_t - \frac{\kappa}{2} \left(\frac{P_t^{Inv}}{P_t} \frac{I_t}{K_{t-1}} - \delta_K \right)^2 K_{t-1} \right) - \frac{P_t^{Inv}}{P_t} I_t$$

Differencing the above equation with respect to I_t results in the following first order condition:

$$[I_t] : Q_t \left[\frac{P_t^{Inv}}{P_t} - \kappa \left(\frac{P_t^{Inv}}{P_t} \frac{I_t}{K_{t-1}} - \delta_K \right) \frac{P_t^{Inv}}{P_t} \right] - \frac{P_t^{Inv}}{P_t} = 0$$

Rearranging terms gives us the supply of capital determined by:

$$Q_t = \left[1 - \kappa \left(\frac{P_t^{Inv}}{P_t} \frac{I_t}{K_{t-1}} - \delta_K \right) \right]^{-1}$$

which corresponds to the Tobin's Q 3.51 given in the text.

Optimal demand for domestic and imported investment goods is:

$$I_{F,t} = \alpha \left(\frac{P_{F,t}}{P_t^{Inv}} \right)^{-\eta} I_t \quad I_{f^*,t} = (1 - \alpha) \left(\frac{P_{f^*,t}}{P_t^{Inv}} \right)^{-\eta} I_t$$