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Labor Informality and Macroeconomic Volatility*

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Abstract

We examine the role of labor informality in shaping macroeconomic volatility in a small open economy. Using a DSGE model calibrated to Colombia, we focus on worker-level rather than firm-level informality. The model features heterogeneous households and a segmented labor market with formal and informal workers, incorporating wage rigidities and productivity differences. Our results show that higher informality amplifies the volatility of consumption and investment, which is consistent with the empirical evidence. The mechanism operates through the interaction of wage rigidities in the formal sector with lower productivity of informal workers. Quantitatively, the model accounts for a significant share of the observed link between informality and volatility. These findings highlight how labor market frictions magnify business cycle fluctuations in emerging economies.

JEL classification: E26, E32, J46, O17.
Keywords— DSGE, small open economy, informality, business cycles.

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Informalidad laboral y volatilidad macroeconómica*

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Resumen

En este trabajo, examinamos el papel de la informalidad laboral en la volatilidad macroeconómica en una economía pequeña y abierta. Para ello, utilizamos un modelo DSGE calibrado para Colombia en el que nos centramos en la informalidad a nivel de los trabajadores, en lugar de a nivel de las empresas. El modelo considera hogares heterogéneos y un mercado laboral segmentado, con trabajadores formales e informales, rigideces salariales y diferencias de productividad. Los resultados muestran que una mayor informalidad aumenta la volatilidad del consumo y la inversión, lo que concuerda con la evidencia empírica. Este efecto se produce a través de la interacción entre las rigideces salariales del sector formal y la menor productividad de los trabajadores informales. Cuantitativamente, el modelo explica una parte significativa de la relación observada entre la informalidad y la volatilidad. Estos resultados ponen de manifiesto cómo las fricciones del mercado laboral amplifican las fluctuaciones del ciclo económico en las economías emergentes.

Clasificación JEL: E26, E32, J46, O17.
Palabras clave— DSGE, economía pequeña y abierta, informalidad, ciclos de los negocios.

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1 Introduction

Informal economic activities play a substantial role in the global economy, with emerging and developing countries exhibiting a much higher prevalence than advanced economies. These activities encompass a wide range of market-based transactions that take place outside formal registration, often reflecting firms' and workers' attempts to avoid taxes and labor market regulations in environments with weak law enforcement (Dix-Carneiro et al., 2021). Labor market institutions, such as firing costs and minimum wages, have been identified as key drivers of informality in Latin American countries (Heckman & Pages, 2000).

Recent estimates indicate that more than half of the world's labor force, approximately two billion workers, is engaged in informal employment, underscoring the scale of this phenomenon (Bonnet et al., 2019; Elgin et al., 2021). For instance, Elgin et al. (2021) estimate that the informal economy accounts for about 35 percent of GDP in low- and middle-income countries, compared with roughly 15 percent in advanced economies. Regional evidence reinforces these contrasts: Latin America and sub-Saharan Africa display the highest levels of informality, whereas Europe and East Asia exhibit substantially lower rates. Moreover, Ohnsorge and Yu (2022) document cases in which the informal sector represents up to 60 percent of GDP and more than 90 percent of total employment in developing regions. These stark disparities suggest that the macroeconomic effects of informality are especially pronounced in emerging markets, where lower productivity, greater exposure to external shocks, weaker public finances, and limited access to social insurance amplify its economic relevance. For a comprehensive review of the causes and consequences of informality, see Ulyssea (2020).

Given the pervasive scale of informality, particularly in emerging markets, where its macroeconomic relevance is greatest, it is natural to ask how informal activity shapes aggregate fluctuations. Informality is often viewed as a shock absorber in emerging economies, cushioning downturns by reallocating workers displaced from the formal sector. A large empirical literature supports this view: informal employment tends to expand when formal employment contracts, providing an alternative source of income during recessions (Coşkun, 2022; Fernández & Meza, 2015; Loayza & Rigolini, 2011).

Nevertheless, a growing body of evidence, including the new stylized facts we document, points in the opposite direction, linking higher levels of informality to greater macroeconomic volatility (Horvath, 2018b; Restrepo-Echavarria, 2014). Using data from 60 emerging and developed economies over the period 1990–2020, we find statistically and economically significant relationships between informality and aggregate fluctuations. Consumption volatility relative to GDP increases with informality, with a correlation of 0.36, while investment volatility displays an even stronger correlation of 0.42. For example, an increase in informality from 18% to 53% is associated with 25% higher consumption volatility and 24% higher investment volatility. We also document a strong positive correlation between inflation and informality (0.46).

At the same time, existing studies show that higher informality is associated with lower volatility in employment (Lama & Urrutia, 2011; Leyva & Urrutia, 2020) and reduced volatility in unemployment (Horvath & Yang, 2022). Taken together, these findings challenge the conventional view of informality as a stabilizing force. Instead, they raise a central puzzle: if informality buffers workers at the individual level and dampens labor market fluctuations, why does it amplify aggregate volatility? Through which mechanisms does informality magnify, rather than attenuate, macroeconomic fluctuations?

We address these questions and resolve the puzzle by developing a DSGE model for a small open economy that incorporates three empirically grounded features of labor markets in emerging economies.[1] Crucially, we focus on worker-level informality, distinguishing between formal and informal workers and the rigidities they face, rather than modeling it at the firm level. First, we model worker-level informality through heterogeneous households: high-skilled formal workers with access to financial markets and low-skilled workers who supply both formal and informal labor but face borrowing constraints. This structure is consistent with the strong empirical evidence we document linking informality to financial exclusion. Second, we introduce sector-specific

[1] We embed these features in a standard small open economy DSGE framework, in which the domestic good is homogeneous and substitutable for the foreign good, and international financial integration takes place through bond trade. Our approach builds on the emerging market business cycle literature (García-Cicco et al., 2010; Schmitt-Grohé & Uribe, 2003) and the monetary policy framework of Galí and Monacelli (2005), while simplifying by assuming homogeneous goods across countries and incomplete markets.

wage rigidities, with formal wages adjusting more slowly than informal wages. Third, we allow formal and informal workers to differ in their productivity.

These features generate a novel mechanism through which informality amplifies macroeconomic volatility. Following productivity shocks, wage rigidities in the formal sector lead to sharp adjustments in labor demand and income. In particular, firms expand their demand for formal low-skilled and high-skilled labor more than proportionally and increase aggregate production. In response, low-skilled households reallocate labor between formal and informal activities; however, because they are hand-to-mouth, they cannot smooth consumption intertemporally. Meanwhile, high-skilled households with access to financial markets primarily adjust through savings and investment decisions, thereby amplifying investment volatility. Consequently, while informality may locally buffer employment in response to shocks, its interaction with formal sector wage rigidities and limited consumption-smoothing capacity ultimately magnifies aggregate demand volatility. When calibrated to Colombia, a representative emerging economy with persistently high levels of informality, the model quantitatively accounts for approximately 36% of the observed relationship between informality and consumption volatility and 60% of the relationship between informality and investment volatility documented in the cross-country data.

To clarify the mechanisms through which informality affects macroeconomic volatility, we conduct a set of robustness exercises that isolate the drivers of the differences between high and low-informality economies. Although the model is recalibrated to match the same aggregate targets under lower informality, most parameter changes independently lead to lower consumption volatility, indicating that the results are not driven by a single modeling assumption. Two channels are particularly relevant. Lower informality is associated with a reduced productivity of informal labor, which shifts adjustment toward more productive formal employment. Following a positive productivity shock, this amplifies firms' labor demand and output responses, especially in the presence of wage rigidities. At the same time, the higher disutility of high-skilled labor, required to maintain its employment share, limits short-run labor adjustments and shifts the response toward capital accumulation. As a result, the output rises more gradually, and investment volatility increases in this specific case. Together, these mechanisms highlight how labor composition and factor complementarities shape the relationship between informality and macroeconomic volatility. We also find that the qualitative results (higher informality correlated with higher volatility) are robust to different sources of fluctuations in the model: productivity, discount factors, and foreign interest rates.

This contribution addresses a key gap in the theoretical literature. While DSGE models have explored labor market frictions (Gomez Ospina, 2023; Horvath & Yang, 2022), financial frictions (Granda, 2015; Mitra, 2013), and monetary policy effectiveness (Alberola & Urrutia, 2020; Gomez Ospina, 2023; Yépez, 2025), these mechanisms are rarely integrated simultaneously. More importantly, most frameworks model firm-level informality or lack supply side segmentation between formal and informal workers facing different productivity, wage rigidities and financial access. Our worker-level approach captures how households substitute between formal and informal labor in response to shocks, which is a key mechanism for explaining why informality amplifies rather than dampens volatility.

As an additional insight into monetary policy transmission, extending the model to include nominal rigidities shows that inflation becomes more volatile in economies with greater informality, which matches the empirical evidence. This results from supply- and demand-side effects resulting from worker heterogeneity observed in the data and built in the model. On the supply side, informal workers face more flexible wages, which make the marginal costs more volatile. On the demand side, aggregate consumption is more volatile because of the financial constraints faced by informal workers. These findings provide new insights into the debate on the effectiveness of monetary policy in the literature[2].

The remainder of this paper is organized as follows. Section 2 presents the empirical evidence on informality and the business cycle in Colombia. Section 3 describes the theoretical model and outlines the parameterization process. Section 4 reports the main results. Section 5 concludes.

[2]While Alberola and Urrutia (2020) argue that informality weakens policy by increasing the sacrifice ratio, Yépez (2025) finds the opposite

2 Empirical Evidence

Previous research has documented significant correlations between the level of informality in an economy and key macroeconomic variables. Horvath (2018a) and Restrepo-Echavarria (2014) identified a positive correlation between informality and the relative volatility of consumption to output. More recently, Horvath and Yang (2022) explore labor market dynamics, finding a negative correlation between unemployment volatility and informality as a percentage of GDP, but a positive correlation between informality and the cyclical correlation of unemployment with GDP for the period 1980-2018.

In this section, we update these empirical facts and expand them to include investment, inflation, and financial inclusion using a broader dataset covering 60 emerging and developed countries from 1990–2020.[3] This dataset draws on information from the World Bank, International Monetary Fund (IMF), Organization for Economic Cooperation and Development (OECD), and Bank for International Settlements (BIS). As a measure of informality, we use the indirect and dynamic estimate proposed by Elgin et al. (2021), who estimate informality as a percentage of GDP based on a general equilibrium model in which households endogenously optimize the time allocated to the formal and informal sectors.

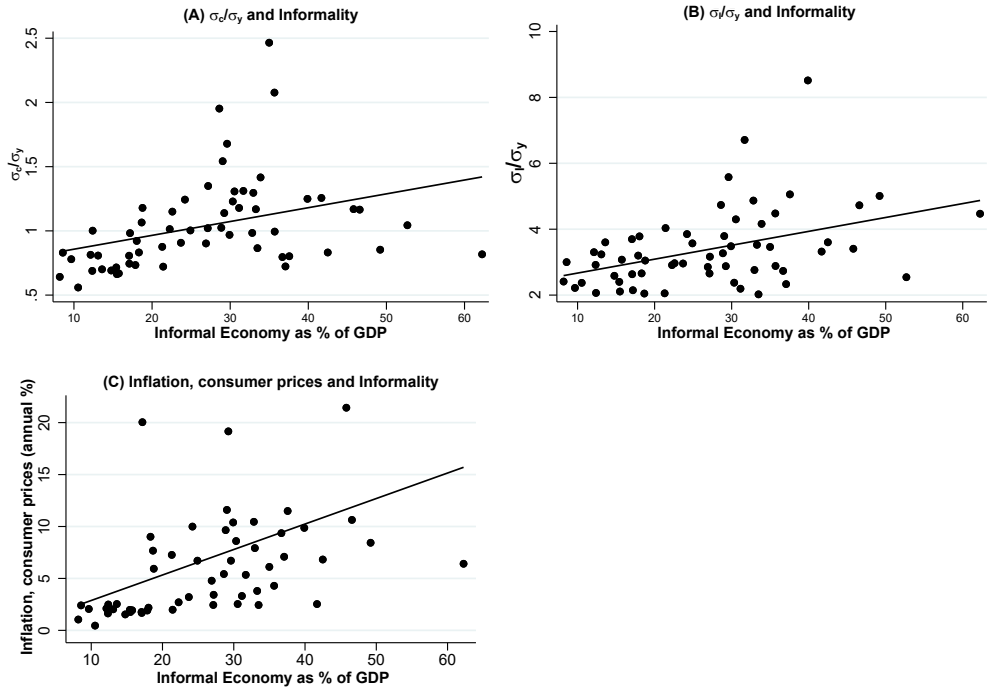
As shown in Figure 1, high informality is correlated with higher volatility in consumption, investment, and inflation. We find a positive correlation of 0.36 between informality and consumption volatility relative to output volatility (Panel A). This indicates that economies with higher levels of informality experience greater volatility in consumption. For instance, Peru, with an informality level of 53%, shows 25% higher relative consumption volatility than Indonesia, which has an informality level of 18%. This greater volatility is also evident in investment, where we identify a positive correlation of 0.42 with informality (Panel B). Thus, economies such as Sweden and Norway, with informality levels close to 18%, report relative investment volatility that is, on average, 24% higher than that of countries such as Austria and Japan, where informality averages only 9%. Additionally, we find a strong positive correlation of 0.46 between informality and annual inflation (Panel C). For example, Ecuador, with 29% informality, experienced an average inflation rate of 19% during the period considered, almost 12 pp higher than that of India, which had 21% informality. All of these correlations are statistically significant at the 5% level, according to 10,000 bootstrap replications.[4] It is important to note that our model successfully replicates these stylized facts.

Finally, we highlight the correlation between informality and financial inclusion, which justifies our decision to model informal households as households without access to financial markets, and which will turn out to be key for the model to produce the above empirical facts. Figure 2 shows the significant negative correlations between these variables. Specifically, we observe a correlation of -0.28 between private-sector credit and informality (Panel A), as well as a correlation of -0.30 with the percentage of people over the age of 15 who have some form of credit with a bank or other financial institution (Panel D). This relationship is notably stronger when measuring demand deposits as a percentage of GDP (-0.63, Panel B) and the percentage of people over 15 who have an account at a financial institution (-0.75, Panel C). In the latter case, for example, while 99% of adults in Denmark (17% informality) have a bank account, only 28% of adults in Bolivia (62% informality) do. This trend persists, even in countries with similar levels of development. Spain (22% informality) has a financial inclusion rate of 93%, which is lower than Denmark's. All of these correlations with financial inclusion variables are significant at the 5% level.

[3] Data is taken from the World Bank Informal Economy Database: https://data360.worldbank.org/en/dataset/WB_INFECDB.

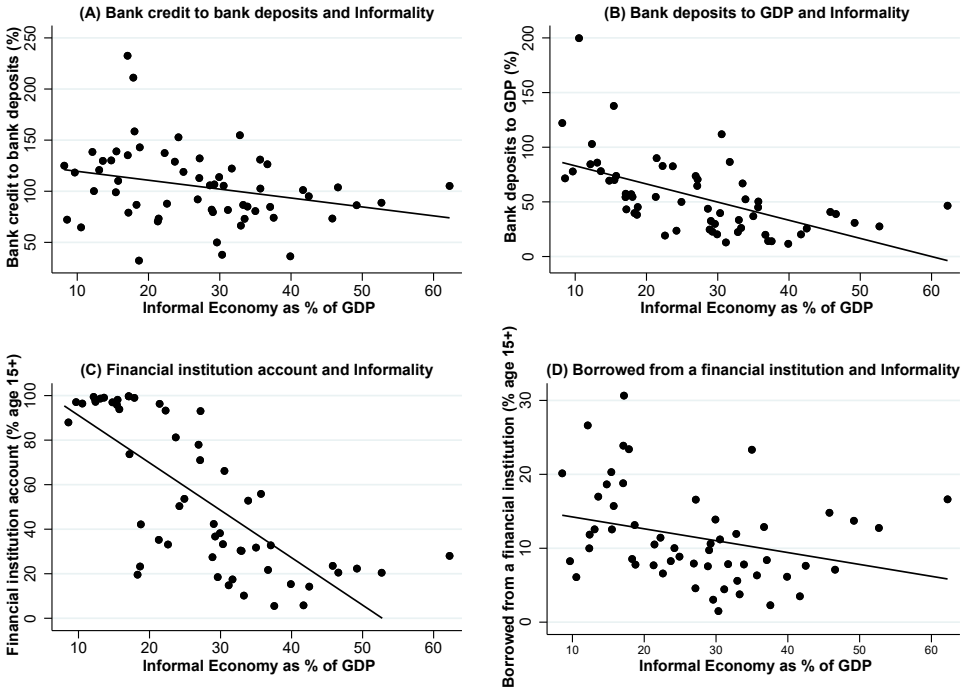
[4] Table B.1 in Appendix B shows the correlation values, their p-values, and the estimated slope of the line for each of the relationships mentioned.

Figure 1: Informality and macroeconomic variables



Notes: The figure shows the correlation between different stylized facts related to some macroeconomic variables and the level of informality. It also shows the regression line associated with this correlation. The sample period covers 1990 to 2020 on an annual basis.
Panel (A): Final consumption expenditure includes private and public expenditures on final goods and services. Panel (B), gross fixed capital formation. Panel (C), Inflation as measured by the consumer price index.
Sources: World Bank national accounts data, BIS, IMF, OECD and national accounts data files.

Figure 2: Informality and access to financial markets



Notes: The figure shows the correlation between different measures of access to financial markets and the level of informality. It also shows the regression line associated with the correlation. The sample period covers 1990 to 2020 on an annual basis.
Panel (A), the financial resources provided to the private sector by domestic money banks as a share of total deposits. Domestic money banks comprise commercial banks and other financial institutions that accept transferable deposits such as demand deposits. Total deposits include demand, time, and saving deposits in deposit money banks. Panel (B), the total value of demand, time and saving deposits at domestic deposit money banks as a share of GDP. Deposit money banks include commercial banks and other financial institutions that accept transferable deposits, such as demand deposits. Panel (C), the percentage of respondents with an account at a bank, credit union, another financial institution, or the post office, including respondents who reported having a debit card. Panel (D), the percentage of respondents who report borrowing any money from a bank, credit union, microfinance institution, or another financial institution such as a cooperative in the past 12 months.
Sources: World Bank national accounts data, BIS, IMF, OECD and national accounts data files.

3 Model

To study how informality affects macroeconomic volatility and the channels through which this occurs, we develop a general equilibrium model of a small open emerging economy that incorporates key features of labor informality. Taken together, these features distinguish our framework from the existing literature. Specifically, we introduce two types of heterogeneous households that differ in their access to financial markets and firm ownership, consistent with the empirical correlation documented in the previous section.

On the production side, firms employ three types of labor, each characterized by potentially different productivity levels, payroll tax rates, and degrees of wage rigidity. High-skilled households supply labor that is always formal and therefore subject to labor regulations and payroll taxation. Low-skilled households, by contrast, can work either formally or informally, with informal employment not subject to income taxation. Moreover, wages in the formal sector—both for high- and low-skilled workers—are allowed to be more rigid than informal wages, reflecting the presence of labor market regulations such as minimum wages and firing costs (Heckman & Pages, 2000; Leyva & Urrutia, 2020). Differences along these dimensions between formal and informal employment are central to the model's ability to replicate the empirical patterns observed in the data.

The remaining model structure is standard. The economy produces a homogeneous good that is substitutable for the good produced abroad, and stationarity is ensured by a debt-elastic interest rate. Following the emerging market business cycle literature (García-Cicco et al., 2010; Schmitt-Grohé & Uribe, 2003), the substitutability of the domestic good and the exogenous foreign interest rate allow the model to close through net exports without explicitly modeling exports and imports. Unlike Galí and Monacelli (2005), we initially abstract from monetary policy and exchange rate regimes by assuming that domestic and foreign goods are homogeneous, which simplifies the nominal and real exchange rate dynamics. Finally, in line with Schmitt-Grohé and Uribe (2003), we depart from complete markets and assume that households trade only a non-contingent international bond. A complete list of the model equations is provided in Appendix C.

3.1 Households

3.1.1 High-Skilled Household:

Households are divided into two groups: high-skilled/high-productivity (N) and low-skilled/low-productivity $(1-N)$. High-skilled households differ from low-skilled households in several dimensions. First, they supply highly productive formal labor $\left(h_t^H\right)$. Second, they own firms and receive the associated profits $\left(\Pi_t^d\right)$. Third, they hold capital (k_t) and undertake investment decisions (i_t). In addition, they consume $\left(c_t^H\right)$ and have access to foreign financial markets (b_t^*). A complete list of the model variables is provided in Appendix D. Low-skilled households are hand-to-mouth workers and supply both formal and informal labor.

The representative high-skilled household maximizes the present value of its utility

$$\max_{c_t^H, h_t(l), b_t^*, i_t, k_t} \mathbb{E}_0 \sum_{t=0}^{\infty} N\beta^t \left(\frac{(c_t^H)^{1-\sigma}}{1-\sigma} - \psi^H \frac{(h_t^H(l))^{1+\nu^H}}{1+\nu^H} \right)$$

subject to the aggregate budget constraint and capital law of motion, including quadratic adjustment costs:

$$P_t^c(c_t^H + i_t) + s_t P^* b_t^* = W_t^H h_t^H(l) + R_t k_{t-1} + (1 + i_{t-1}^*) s_t P^* b_{t-1}^* + \Pi_t^d, \tag{1}$$

$$i_t = k_t - (1-\delta)k_{t-1} + \frac{\phi_K}{2}(k_t - k_{t-1})^2, \tag{2}$$

$$i_t^* = i^* + (e^{\phi_b\left(B_t^Y - B_{ss}^*\right)} - 1) \tag{3}$$

$$B_t^Y = \frac{s_t P^* B_t}{GDP_t^{ann}} \tag{4}$$

$$GDP_t^{ann} = \sum_{s=0}^{3} GDP_{t-s} \tag{5}$$

where P_t^c denotes the price of the domestic final good, P^* the (exogenous) price of foreign goods expressed in foreign currency, s_t the nominal exchange rate, i_t^{nom} and i_t^* the returns on domestic and foreign assets, W_t^H the nominal wage rate of high-skilled labor, and R_t the return to capital. Labor is differentiated and indexed by l. This assumption makes it possible to introduce wage rigidities through a labor aggregator (or "packer") that combines different labor varieties. Given the demand for each variety, the representative household chooses the corresponding wage, subject to wage adjustment costs, to maximize utility. Based on this setup, we first derive the demand for labor varieties and then determine the optimal wage.

The real exchange rate is defined as

$$rer_t = s_t \frac{P^*}{P_t^c}. \tag{6}$$

Assuming that domestic and foreign goods are homogeneous and that the law of one price holds, we have that *rer* equals one. In other words, domestic and final goods have the same price once they are expressed in the same currency. From the first-order conditions of the high-skilled household, we find the high-skilled the Euler equations for capital and domestic and foreign bonds:

$$(c_t^H)^{-\sigma} = P_t^c \lambda_t^H \tag{7}$$

$$\lambda_t^H P_t^c \left[1 + \phi_K \left(k_t - k_{t-1}\right)\right] = \mathbb{E}_t \lambda_{t+1}^H \beta P_{t+1}^c \left[1 - \delta + \phi_K \left(k_{t+1} - k_t\right) + \frac{R_{t+1}}{P_{t+1}^c}\right] \tag{8}$$

$$\lambda_t^H s_t P^* = \mathbb{E}_t \lambda_{t+1}^H \beta s_{t+1} P^* (1 + i_t^*). \tag{9}$$

The aggregate levels of high-skilled consumption, high-skilled labor supply, capital, investment, and foreign bonds can be found by multiplying the individual levels by the mass of households N.

3.1.2 Labor packer

For the wage-setting problem, we follow Galí and Monacelli (2005), who assumes a household with l members, each supplying a differentiated labor service, who are perfectly insured within the family. He then pairs this with l labor unions responsible for wage setting in market l. Given this setup, we introduce a labor packer or union that combines different types of labor into a composite labor good that is then supplied to firms at a nominal wage rate W_t^H. This setup is symmetric for the three types of labor in the model: high-skilled, formal, and informal low-skilled.

We first consider the problem of the competitive labor packing firm and then return to the household's optimization problem. In particular, the representative labor packer maximizes profits by choosing across labor varieties according to:

$$\max_{h_t^H(l)} W_t^H \left(\int_0^1 h_t^H(l)^{\frac{\theta_H - 1}{\theta_H}} dl \right)^{\frac{\theta_H}{\theta_H - 1}} - \int_0^1 W_t^H(l) h_t^H(l) dl.$$

From the F.O.C with respect to $h_t^H(l)$ we obtain the optimal demand for labor varieties:

$$h_t^H(l) = \left(\frac{W_t^H}{W_t^H(l)} \right)^{\theta_H} h_t^H. \tag{10}$$

3.1.3 Rotemberg wage adjustment

Consistent with extensive empirical evidence indicating that formal wages exhibit less volatility than informal wages, the model incorporates nominal wage rigidities à la Rotemberg (1982) to capture this asymmetry in the wage dynamics. This specification allows us to represent that wages in the formal sector respond more slowly to

aggregate shocks than the greater flexibility observed in the informal sector.[5] In this regard, the model assumes that households face quadratic adjustment costs when changing wages. This cost is paid in units of the final good and makes wages less flexible in the short run. Following Born and Pfeifer (2020), the adjustment cost can be expressed as

$$\Upsilon_t^H = \frac{\phi^H}{2}\left(\frac{W_t^H(l)}{W_{t-1}^H(l)} - 1\right)^2. \tag{11}$$

We can then rewrite the household's optimization problem after substituting the optimal labor demand from the labor aggregator, equation (10), and focus exclusively on the wage decision. From the first-order condition, we obtain the *New Keynesian Wage Phillips Curve*:

$$\begin{aligned}\left(h_t^H\right)^{1+\nu^H}\frac{\psi_h\theta_H}{W_t^H\lambda_t^H} = (\theta_H-1)h_t^H + \phi^H\left(\frac{W_t^H}{W_{t-1}^H}-1\right)\frac{1}{W_{t-1}^H}p_t^d q_t^d \\ - \mathbb{E}_t\beta\frac{U_c(c_{t+1}^H,h_{t+1}^H)}{U_c(c_t^H,h_t^H)}\left[\phi^H\left(\frac{W_{t+1}^H}{W_t^H}-1\right)\frac{W_{t+1}^H}{(W_t^H)^2}p_{t+1}^d q_{t+1}^d\right].\end{aligned} \tag{12}$$

As shown by Keen and Wang (2007) and Born and Pfeifer (2020), Rotemberg and Calvo wage-setting are equivalent up to a first-order approximation, which is sufficiently accurate for the type of analysis we conduct.

A defining characteristic of labor informality is the lack of formal employment contracts. As noted by International Monetary Fund (2023), individual income volatility is substantial, with a large share of workers experiencing significant income fluctuations each year. This volatility is particularly severe among informal workers, significantly increasing their risk of falling into poverty. In addition, informal workers are more likely to work part-time than formal workers, both in mixed and fully formal households, especially among women. As found by Gomes et al. (2019), formal employment is covered by labor regulations and social security; there are typically higher job security and lower volatility in earnings.

These features suggest that wages in the informal sector are considerably more flexible than those in the formal sector. Consistent with this view, Munro (2011) emphasize that informal sector jobs typically operate outside formal regulatory frameworks, implying the absence of written employment agreements and limited legal contract enforcement in many developing economies. Moreover, Vanek et al. (2014) document that temporary employment—closely related to informality—is associated with shorter job duration, weaker access to employer-provided benefits, and greater exposure to earnings fluctuations due to unpredictable working hours. Such employment arrangements are frequently associated with lower pay.

3.1.4 Low-Skilled Household

Low-skilled households represent a mass of $1-N$, face borrowing constraints, and lack access to financial markets, in line with the evidence presented in Section 2. Consequently, their only income comes from labor. These hand-to-mouth households consume $\left(c_t^L\right)$ and supply formal labor $\left(h_t^F\right)$, earning $\left(W_t^F\right)$ and informal labor $\left(h_t^I\right)$, earning $\left(W_t^I\right)$. This specification captures the link between the two types of labor in low-skilled households by reflecting the mobility between the formal and informal sectors. This is consistent with the main features of a standard two-sector model used to analyze the effects of the minimum wage, as shown by Gramlich (1976) and Mincer (1976). The representative low-skilled household maximizes the present value of its utility,

$$\max_{c_t^L,h_t^I(l),h_t^F(l)} \mathrm{E}_0\sum_{t=0}^{\infty}\beta^t\left[\frac{\left(c_t^L\right)^{1-\sigma}}{1-\sigma} - \psi^I\frac{\nu^I}{1+\nu^I}\left(h_t^I(l)\right)^{\frac{1+\nu^I}{\nu^I}} - \psi^F\frac{\nu^F}{1+\nu^F}\left(h_t^F(l)\right)^{\frac{1+\nu^F}{\nu^F}}\right],$$

[5] Several studies show that wages in the informal sector are significantly more volatile than those in the formal sector. This phenomenon occurs in both developed and emerging countries, but the disparity is considerably more pronounced in emerging economies, which tend to have larger informal labor markets (Aleksynska et al., 2023; Baltagi et al., 2013; Bargain & Kwenda, 2014; Engbom et al., 2022). Multiple institutional factors explain this volatility. Informal economies typically operate with lax or nonexistent employment contracts and lack legal minimum wages and collective labor protection agreements such as unions. These agreements usually stabilize wages in the formal sector.

subject to its budget constraint,

$$P_t^c c_t^L \leq W_t^I h_t^I(l) + W_t^F h_t^F(l) + \frac{P_t^c T_t}{1-N}. \tag{13}$$

As in the previous case, we consider labor packers for low-skilled formal and informal labor. The Phillips curves are isomorphic to Equation 12. The aggregate consumption and labor supply functions for low-skilled households are equal to the mass of low-skilled households times the corresponding variable. Finally, aggregate consumption is the sum of high- and low-skilled consumption:

$$C_t = C_t^H + C_t^L. \tag{14}$$

3.2 Firms: Domestic producers

We divide the production process into two steps. First, a continuum of firms operating under monopolistic competition uses capital and labor to produce heterogeneous domestic inputs and decide over prices. Then, a competitive firm aggregates heterogeneous inputs into a domestic homogeneous intermediate good that is later used for the production of final goods: consumption, investment, and net exports. Given this production structure, we initially solve the final goods optimization problem to determine the demand for heterogeneous goods. Then, given the demand for intermediates, we solve the optimization problem of heterogeneous producers.

3.2.1 Domestic goods Aggregator: Final goods production

A competitive representative firm aggregates domestic heterogeneous inputs into a homogeneous good that is later used for consumption, investment, and net exports. The optimization problem is as follows:

$$\max_{q_t^d(j)} P_t^d \left(\int_0^1 q_t^d(j)^{\frac{\eta^d-1}{\eta^d}} \right)^{\frac{\eta^d}{\eta^d-1}} - \int_0^1 P_t^d(j) q_t^d(j).$$

where the aggregation technology is given by $q_t^d = \left(\int_0^1 q_t^d(j)^{\frac{\eta^d-1}{\eta^d}} \right)^{\frac{\eta^d}{\eta^d-1}}$

From the F.O.C, we obtain the relative demand for variety (l):

$$q_t^d(l) = \left(\frac{P_t^d}{P_t^d(l)} \right)^{\eta^d} q_t^d. \tag{15}$$

The market-clearing condition for domestic goods is as follows:

$$q_t^d = C_t + I_t + NX_t + \Upsilon_t^H + \Upsilon_t^F + \Upsilon_t^I. \tag{16}$$

3.2.2 Producers of domestic heterogeneous inputs

A representative firm operating under monopolistic competition chooses capital and different types of labor to produce a differentiated good and sets its output price, considering the demand it faces as given. To characterize firm decisions, we derive factor demands, marginal costs, and optimal pricing rules.

The firm solves the following cost-minimization problem:

$$\min_{k_{t-1}(j), l_t^H(j), l_t^F(j), l_t^I(j)} R_t k_{t-1}(j) + (1+\tau_t^H) W_t^H l_t^H(j) + (1+\tau_t^F) W_t^F l_t^F(j) + W_t^I l_t^I(j) \tag{17}$$

subject to the production technology

$$q_t^d(j) = A_t \left(k_{t-1}(j)\right)^{\alpha} \left(l_t(j)\right)^{1-\alpha}, \tag{18}$$

where A_t denotes total factor productivity (TFP). TFP is the only source of uncertainty in the model and follows an AR(1) process,

$$A_t = (A_{ss})^{1-\rho_a}(A_{t-1})^{\rho_a}(1+\varepsilon_t^A), \tag{19}$$

with ε_t^A denoting a productivity shock. Capital and labor are combined through a Cobb–Douglas production function, with capital predetermined at $t-1$.

Labor aggregation. Labor input $l_t(j)$ is an aggregate of heterogeneous labor types, represented by a nested CES structure. At the lowest level, low-skilled labor $l_t^L(j)$ aggregates informal and formal labor.

$$l_t^L(j) = \left[\theta^L \left(l_t^I(j)\right)^{\frac{\eta^L-1}{\eta^L}} + (1-\theta^L)\left(l_t^F(j)\right)^{\frac{\eta^L-1}{\eta^L}}\right]^{\frac{\eta^L}{\eta^L-1}}, \tag{20}$$

where $\eta^L > 1$ implies that formal and informal labor are substitutes, allowing firms to adjust to informality when formal labor costs increase.

At the next level, total labor combines low- and high-skilled labor:

$$l_t(j) = \left[\theta \left(l_t^L(j)\right)^{\frac{\eta-1}{\eta}} + (1-\theta)\left(l_t^H(j)\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{21}$$

where $\eta < 1$ implies complementarity between low- and high-skilled labor. As a result, $l_t(j)$ does not correspond to total employment but rather to a non-linear aggregation of heterogeneous labor inputs.

Given this production structure and the assumptions on labor supply, the model features no unemployment; all labor adjustments occur along the intensive margin.

Factor demands and marginal cost. Solving the firm's problem yields the demand for capital and each labor type, as well as the firm's marginal cost, $MC_t(j)$. In equilibrium, the marginal costs are identical across firms, implying common factor demands and prices. Hence, we drop firm index j. The first-order conditions are as follows:

$$R_t = \mu_t \alpha \frac{q_t^d}{K_{t-1}}, \tag{22}$$

$$(1+\tau_t^H)W_t^H = \mu_t(1-\alpha)\frac{q_t^d}{l_t}\left(\frac{l_t}{l_t^H}\right)^{\frac{1}{\eta}}(1-\theta), \tag{23}$$

$$(1+\tau_t^F)W_t^F = \mu_t(1-\alpha)\frac{q_t^d}{l_t}\left(\frac{l_t}{l_t^L}\right)^{\frac{1}{\eta}}\theta(1-\theta^L)\left(\frac{l_t^L}{l_t^F}\right)^{\frac{1}{\eta^L}}, \tag{24}$$

$$W_t^I = \mu_t(1-\alpha)\frac{q_t^d}{l_t}\left(\frac{l_t}{l_t^L}\right)^{\frac{1}{\eta}}\theta\theta^L\left(\frac{l_t^L}{l_t^I}\right)^{\frac{1}{\eta^L}}, \tag{25}$$

$$MC_t = \frac{1}{A_t}\left(\frac{R_t}{\alpha}\right)^{\alpha}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}, \tag{26}$$

where μ_t is the Lagrange multiplier on the production constraint and equals the marginal cost.

Labor cost indices. The unit labor cost indices implied by the nested CES structure are

$$W_t^L = \left[(\theta^L)^{\eta^L}(W_t^I)^{1-\eta^L} + (1-\theta^L)^{\eta^L}\left((1+\tau_t^F)W_t^F\right)^{1-\eta^L}\right]^{\frac{1}{1-\eta^L}}, \tag{27}$$

$$W_t = \left[\theta^{\eta}(W_t^L)^{1-\eta} + (1-\theta)^{\eta}\left((1+\tau_t^H)W_t^H\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{28}$$

Pricing and profits. Given the marginal cost, the firm sets its price according to a constant markup rule:

$$P_t^d = MC_t \frac{\eta^d}{\eta^d - 1}. \tag{29}$$

Total profits are given by

$$\Pi_t^d = P_t^d q_t^d - MC_t q_t^d. \tag{30}$$

Trade balance. Finally, in aggregate equilibrium, the real trade balance equals the change in net foreign assets:

$$NX_t = rer_t \left(B_t^* - B_{t-1}^* (1 + i_{t-1}^*) \right). \tag{31}$$

3.3 Model Parametrization

We set the parameter values using a combination of literature for Colombia (González et al., 2011), international evidence (Behar, 2025; Chen, 2020; Krusell et al., 2000; Whalen & Reichling, 2017), and moment matching. Table 1 lists the parameter values and their sources. To calibrate the model, we solve a system of equations that includes the steady state (Appendix E), normalization conditions, and the targeted moments. This results in a final set of 13 equations that could not be solved analytically because of the dimensionality of the model. Seven of these equations represent the core variables of the model, whereas the remaining equations are associated with the targets.[6] Table 2 lists the targets from the data and the associated calibrated parameters.

Before adjusting the model to the data, we classified Colombian workers into three categories considered in the model: highly skilled formal workers, low-skilled formal workers, and low-skilled informal workers. We made this classification based on their labor income relative to the minimum wage using data from the Colombian Household Survey (GEIH) from 2010 to 2019.[7] In particular, we define high-skilled formal workers as those with earnings above 1.1 times the minimum hourly wage, low-skilled formal workers as those with earnings between 0.9 and 1.1 times the minimum hourly wage, and the remainder as low-skilled informal workers. According to these computations, the mass of high-skilled households (N) corresponds to 52%.[8]

It is important to note that in Colombia, as in other Latin American countries, employment with earnings below the minimum wage is not fully penalized and may not even be illegal. On the one hand, some jobs are performed in sectors such as agriculture, construction, and retail trade, where the value added is relatively low, there are many small and unregistered firms (with no law enforcement), and self-employment is abundant. For this segment of the economy, the minimum wage and other constraints are obstacles for firms to hire formal workers. On the other hand, there are higher-productivity firms that are registered, formal, comply with legal requirements, pay their workers at least the minimum wage, and contribute to social security (SS). This situation creates a duality or segmentation of the labor market, as formal jobs protected by regulations coexist with informal and low productivity jobs. In fact, the fraction of workers earning less than the minimum wage varies from 20% in Chile to 60% in Ecuador. Our calibration for Colombia is consistent with this observation.

Using the data from GEIH, we also calibrate the relative productivity between formal and informal low-skilled workers according to the observed wage thresholds; thus, $\left(\theta^L\right)$ yields a wage ratio of 2.24 for low-skilled workers.[9] Here, we use the productive definition of informality, which defines informal firms and workers

[6] We use MATLAB's *fsolve* function to obtain the solution numerically. Notably, this calibration process ensures precise alignment to all specified targets.

[7] The National Administrative Department of Statistics (DANE) conducts the GEIH, a continuous household survey that examines employment, income, hours worked, and other labor market-related variables. The survey started in July 2006 and replaced the Continuous Household Survey (ECH), which ran from 2001 to June 2006.

[8] We define minimum wage earners using a range because workers surveyed in the GEIH may report the wage they receive instead of the wage stated in their contract. This discrepancy may be explained by social security deductions and subsidies.

[9] Daza and Gamboa (2013) find that formal workers (with similar characteristics than informal ones) earn between 30 to 60 percent more, on average, than informal workers.

according to their productive characteristics, such as being low productivity or unskilled (see Fields (1990) and Perry (2007)).

We set the disutility of high-skilled labor $\left(\psi^H\right)$ to match a labor income share (of total labor income) of 17% for low-skilled households. We also calibrate the employment shares of low-skilled workers: 10% for formal and 40% for informal workers. To match these targets, we use the relative productivity of high- and low-skilled labor and the disutility of low-skilled labor $\left(\psi^I\right)$. The remaining parameters of the production function are the capital share (α) and total factor productivity, A. These values are chosen to match a GDP of 1 in the long run and an investment-to-GDP ratio of 22%. This calibration algorithm perfectly matches the long-run ratios.

For the long-run equilibrium, we assume that domestic and foreign prices are equal to one, that is, $P^c = P^* = 1$, net foreign debt is 50% of annual GDP $(B^*_{ss} = 50\%)$. The labor tax rate is consistent with the average values observed in Colombia: $\tau^H = 11\%, \tau^F = 8\%$. Finally, the capital adjustment cost parameter is chosen such that investment is 2.6 times as volatile as GDP, and the wage rigidities for high-skilled labor and formal low-skilled labor are set to 50, which is equivalent to a wage rigidity of around a year. In the case of informal wages, we consider no rigidities. This assumption is in line with empirical evidence regarding the lack of contracts in informal markets.

Table 1: Parameters. Description of parameters, values and sources.

Parameter	Definition	Value	Source
σ	Intertemporal elast. subs	2.0	Glover (2019)
β	Discount factor	0.99	González et al. (2011)
δ	Depreciation of K	0.0125	González et al. (2011)
ρ^A	TFP persistence	0.98	González et al. (2011)
ν^H	High-skilled Labor elasticity	1.0	Glover (2019)
$\nu_F = \nu_I$	Low-skilled labor elasticity	2.0	Behar (2025)
η	EoS L^L vs L^H	0.8	Krusell et al., 2000
η^L	EoS L^I vs L^F	1.70	Behar (2025) and Krusell et al. (2000)
ϕ^H	Wage rigidity H	50	Keen and Wang, 2007
ϕ^F	Wage rigidity F	50	Keen and Wang, 2007
ϕ^I	Wage rigidity I	0	Normalization
η^d	EoS intermediates	5	González et al. (2011)
η^H	EoS H	6	Smets and Wouters (2007)
η^I	EoS F	6	Smets and Wouters (2007)
η^F	EoS I	6	Smets and Wouters (2007)
P^c	Long run price	1.0	Normalization
P^*	Long run foreign price	1.0	Normalization
B^*_{ss}	Net foreign assets LR	-0.50	Data
τ^H	Labor taxes H	11%	Ministry of Health
τ^F	Labor taxes F	8%	Ministry of Health
ϕ_b	Debt-elastic interest rate	-0.001	Schmitt-Grohé and Uribe (2003)
ϕ_K	Capital adjustment cost	0.2	Calibration

Note: EoS stands for Elasticity of Substitution

4 Results

In this section, we analyze how the level of informality shapes the transmission of total factor productivity (TFP) shocks and the volatility of key macroeconomic aggregates and labor market outcomes. We organize

Table 2: Targeted moments and calibrated parameters.

Target	Value	Parameter	Definition	Value
GDP	1.0	A	Productivity	0.286
I/GDP	0.22	α	Capital share	0.386
w^F/w^I	2.24	θ^L	Productivity L_F vs L_I	0.48
Low skill labor income share	0.17	$\psi^I = \psi^F$	Disutility of low-skilled labor	0.028
Employment share I	0.4	θ	Productivity L^H vs L^L	0.13
Employment share F	0.1	ψ^H	Disutility of high-skilled labor	0.022

the analysis into three parts. First, to illustrate the basic mechanisms embedded in the model, we compute impulse response functions to a 1% TFP shock. In our setup, domestic productivity shocks are the sole source of volatility. We then construct a counterfactual economy with a lower level of informality and compare its outcomes with those of the benchmark. In particular, we simulate two model configurations to obtain theoretical moments, placing particular emphasis on the volatilities of consumption and investment. Finally, we assess the robustness of our findings to the modeling assumptions, calibration choices, and alternative shock specifications. All simulations are performed using Dynare Adjemian et al. (2011).

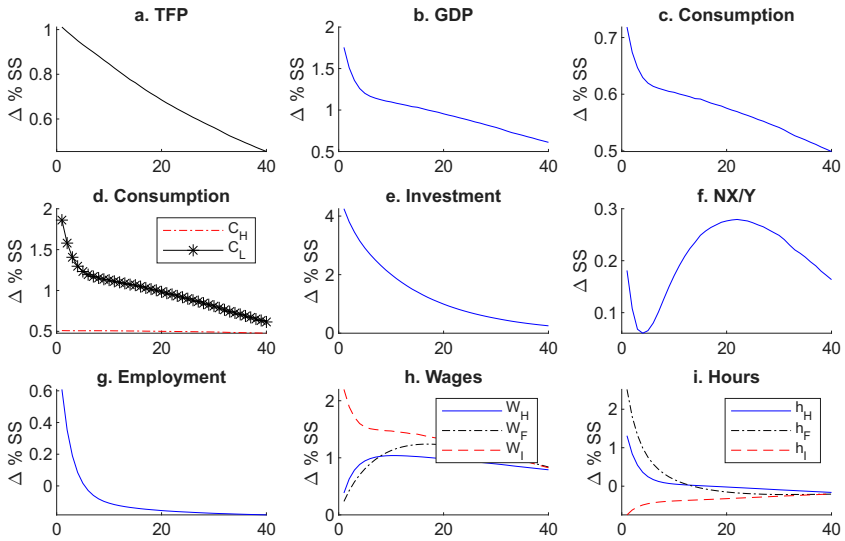
4.1 Benchmark Economy: Response to a productivity shock

As reported in Figure 3, a transitory 1% increase in total factor productivity raises total output by more than 1%. This amplification arises from the stronger demand for high-skilled and formal low-skilled labor (Panels h and i), driven by wage rigidities. Higher TFP increases the marginal product of labor, pushing both wages and hours upward. However, because formal wages adjust sluggishly, hours respond more strongly, leading to a more-than-proportional increase in the production.

As formal income for low-skilled workers rises, hand-to-mouth households increase their consumption (Panel d) and reduce their supply of informal labor, generating a countercyclical response of informality, as in Leyva and Urrutia (2020). In turn, informal wages rise (panel h). These labor-supply adjustments lead to a decline in informal employment, while formal employment—both high- and low-skilled—expands, making formal workers relatively cheaper from the firm perspective. These employment and wage dynamics are consistent with the findings of Gomez Ospina (2023).

Investment reacts more strongly than consumption, as higher TFP and greater formal employment boost the demand for capital, generating a short-run increase in investment. High-skilled households, which smooth consumption intertemporally, reallocate resources toward investment and foreign bonds. Consequently, the economy temporarily lends to the rest of the world, leading to an increase in net exports (Panel f). Overall, the dynamics of these aggregates align with the standard results in the literature, such as those reported by Mendoza (1991).

Figure 3: Response to a 1% total productivity shock.



Note: The variables are plotted as percentage deviations from the steady state.

4.2 Effects of informality on short-run dynamics and macroeconomic volatility

To analyze the cyclical role of informality, we compare two economies: the benchmark economy presented in the previous subsection and a counterfactual economy with a lower degree of informality. In the counterfactual, informal labor constitutes 10% of the workforce, while the share of formal low-skilled labor increases from 10% to 40%. We also construct an alternative measure of informality, defined as the ratio of informal labor compensation to the GDP. This measure equals 10% in the benchmark economy and falls to 1.6% in the counterfactual model. Using these two economies, we conduct two exercises: (i) compare their impulse response functions (IRFs) to a TFP shock and (ii) simulate both economies to study their macroeconomic volatility.

To make the economies comparable, the counterfactual economy is recalibrated to match the benchmark's macroeconomic targets. Table 3 lists the resulting parameters. Achieving these targets in a low-informality environment requires, for example, lower relative productivity levels of low-skilled and informal labor, θ, θ^L. Likewise, matching the same employment shares calls for higher disutility parameters for low- and high-skilled labor, ψ^I, ψ^F, ψ^H. Finally, replicating the same level of aggregate output requires a higher level of TFP. Changing these parameters potentially affects the transmission mechanisms of a TFP shock.

Because these parameter changes may affect the transmission of a TFP shock, we evaluate robustness by comparing IRFs while varying one parameter at a time, allowing us to assess which specific parameter (or set of parameters) drives the results.

Table 3: Calibrated parameters

Parameter	Definition	High Informality	Low Informality
θ	Productivity L^H vs L^L	0.13	0.15
θ^L	Productivity L^F vs L^I	0.48	0.16
$\psi^I = \psi^F$	Informal labor disutility	0.028	7.14
ψ^H	High-skilled labor disutility	0.022	0.20
A_{ss}	TFP	0.29	0.54
α	Capital share	0.39	0.39

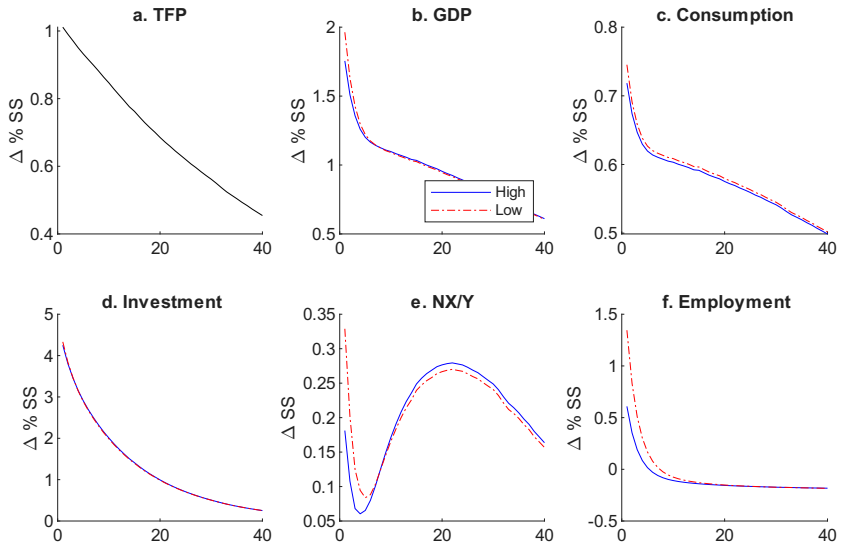
We start by comparing the IRFs to a 1% TFP shock. As shown in Figure 4, the qualitative effects of the shock are similar across both economies, implying that the transmission mechanisms described in the previous section remain valid. However, some quantitative differences emerge. For instance, output and consumption increase more in an economy with lower informality (Panels b and c). However, GDP increases relatively more in the low-informality economy.

One possible explanation for this result is the incidence of wage rigidities. By construction, the low-informality economy has a larger share of formal low-skilled labor that is directly subject to wage rigidity. As a larger fraction of total labor costs becomes rigid, firms respond to TFP shocks by increasing their demand for formal labor more aggressively. This mechanism is evident in Figure 5, which shows a stronger reaction of formal wages accompanied by an increase in formal employment. Although the increase in formal low-skilled employment is smaller in percentage terms, it is larger in absolute terms because this category accounts for 40% of total labor. This is clearly reflected in the overall employment response in Panel f. Through complementarity, high-skilled labor also expands slightly more in the low-informality economy, allowing the output to rise further.

In relative terms, although consumption increases more in the low-informality economy, its rise is smaller than the proportional increase in GDP, which may contribute to lower consumption volatility. Similarly, investment responds by roughly the same magnitude in both economies, implying that, relative to GDP, the change is smaller in the economy with lower informality. Finally, as shown in Panel 2 of Figure 5, informal labor is more countercyclical in the economy with lower informality.

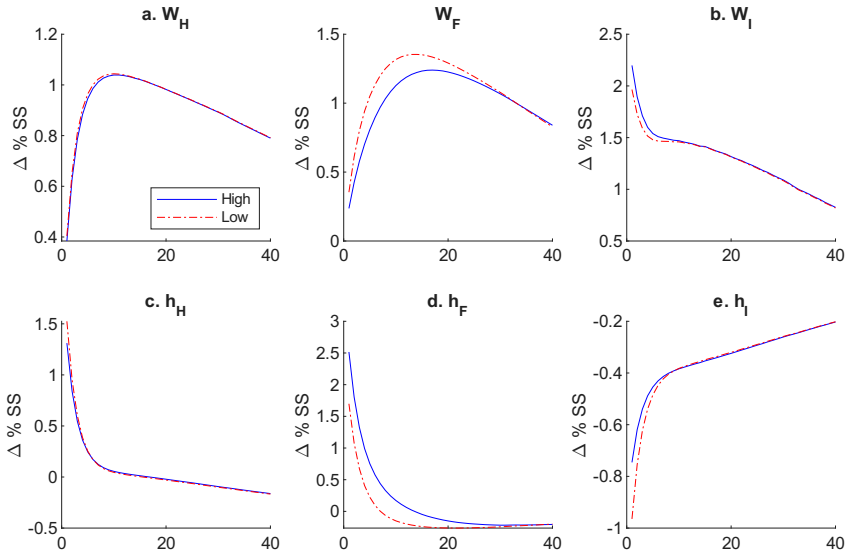
These results provide an initial approximation of the relationship between informality and macroeconomic volatility. To further explore the quantitative implications of labor informality for the relative fluctuations of GDP components, in the next section, we simulate the two economies and compare their cyclical properties.

Figure 4: Response of the main macroeconomic variables to a 1% TFP shock under different levels of informality



Note: Models with high and low informality. Variables are plotted as percentage deviations from the steady state.

Figure 5: Response of labor market variables to a 1% TFP shock under different levels of informality



Note: Variables are plotted as percentage deviations from the steady state.

4.3 Simulations

The presence of a formal–informal labor structure in most emerging markets affects not only the transmission of economic shocks but also the volatility of macroeconomic aggregates. In the formal labor market, wage rigidities imply that, after a shock, adjustment occurs primarily through employment, while wages respond more sluggishly; as a result, formal employment is more volatile than wages. In contrast, in the informal sector, both labor and wages adjust more flexibly. These labor market dynamics shape household income, particularly for hand-to-mouth consumers, and, in turn, influence aggregate volatility.

To analyze how the degree of labor informality affects macroeconomic volatility, we compare the simulated standard deviations of key macroeconomic and labor market variables in the two economies described in

the IRFs and Colombian data. For comparability, both simulated economies are subject only to TFP shocks with identical persistence and variance. Specifically, we run simulations for 100,000 periods and compute business-cycle moments using the last 400 observations (roughly ten years of data).[10] Following the empirical approach, we transform the simulated data by taking natural logarithms and extract the cyclical component using the Hodrick–Prescott filter.

A comparison of the volatilities is presented in Table 4. The upper panel highlights the main differences in informal employment and the share of informal wages across the two economies and Colombian data. Our benchmark model closely replicates these observed patterns. The lower panel reports the relative volatility of each variable, defined as the ratio of its standard deviation to that of the GDP. As shown in the table, higher levels of informality are associated with greater volatility in consumption and investment, but lower volatility in employment (EMP), consistent with our empirical findings and the broader literature. In particular, increasing informality by a factor of four in employment—or by a factor of six in labor compensation relative to GDP—raises the volatility of consumption and investment by 7% and 9%, respectively, while reducing employment fluctuations by half.

For consumption, this implies a slope of approximately 0.36, which corresponds to 33% of the coefficient reported in Figure 1 (approximately 1.08, see Appendix B). As shown in Appendix 4.4, this result relies on two key model assumptions: first, the possibility for hand-to-mouth agents to substitute between formal and informal labor, and second, the presence of wage rigidities. Regarding the first assumption, when hand-to-mouth agents supply only informal labor, consumption becomes more volatile; however, there are no differences in volatility across the two model versions. Thus, the ability of low-skilled households to smooth consumption by substituting between formal and informal labor is a key driver of the differences in consumption volatility. A similar outcome arises when wages are fully flexible, which reduces labor and income volatility and does not generate different slopes for the models with high and low levels of informality. In the case of investment, the estimated coefficient is also consistent with the data and represents approximately 59% of the empirical value (2.5 in the model versus 4.22 in the data).

Table 4: Comparison of volatility

	Model simulated		*Colombian*
	High Informality	Low Informality	*Data*
Share of informal employment	40%	10%	40%
Mass of informal wages/GDP	10%	1.6%	
Relative Volatility of cyclical variables			
Consumption (C)	0.44	0.41	1.04
Investment (I)	2.64	2.43	2.56
Employment (EMP)	0.36	0.71	0.66
High Skilled employment (h^H)	0.74	0.78	0.84
Low skilled Formal employment (h^F)	1.48	0.92	1.39
Low Skilled informal employment (h^I)	0.43	0.50	1.05

Note: We use quarterly data from 2000 to 2019 from the National Accounts and GEIH for Colombia. We compute the cyclical components of the variables using the HP filter with a $\lambda = 1600$.
Relative volatility is computed as the ratio of the standard deviation of the variable to the standard deviation of GDP.

To better understand how higher informality generates more volatility, we perform a series of robustness checks. Given that we re-calibrate the model to match the same targets for the low-informality economy, the reduction in volatility might come from one or more sources. To understand what explains the difference in the results, we change one parameter at a time and simulate the alternative economy. As reported in Table 5,

[10] We also compute the statistics using the theoretical moments, and the results are consistent.

with the exception of the relative productivity of total low-skilled labor, θ, all parameters generate a decline in the volatility of consumption under lower informality levels. In other words, most sources of variation in the low-informality setup point in the same qualitative direction, which provides some reassurance regarding the robustness of the results.

Two parameters deserve additional attention. First, consider the relative productivity of informal low-skilled labor, denoted by θ^L. Compared to the benchmark economy, in the calibration with low informality, informal labor is substantially less productive (0.16 vs. 0.48). This implies that increasing informal labor has a smaller impact on total output, while formal low-skilled labor contributes more at the margin. When formal labor is relatively more productive, a positive TFP shock encourages firms to increase their demand for this type of labor. In the presence of wage rigidities, this demand effect becomes stronger, generating a larger output response relative to the benchmark case, as shown in Figure 4.

The second parameter is the disutility of high-skilled labor. The model is recalibrated to match the same employment share for high-skilled labor as in the benchmark economy. Since low- and high-skilled labor are complements, higher formal low-skilled employment increases the demand for high-skilled labor. To offset this effect, high-skilled households must supply less labor, which is achieved by assigning a higher disutility parameter. When the TFP shock occurs, firms raise their demand for both formal low-skilled and high-skilled labor. However, the latter is relatively harder to increase due to the higher disutility; therefore, total employment rises to a lesser extent, as reported in panel(f) of Figure 6. Consequently, firms increase their demand for capital more significantly, as shown in Panel (d) of the same figure. Notice that in this case, output does not increase as much on impact, but it increases more during the transition due to capital accumulation. Notably, this is the only case in which investment volatility moves in the opposite direction when informality is lower.

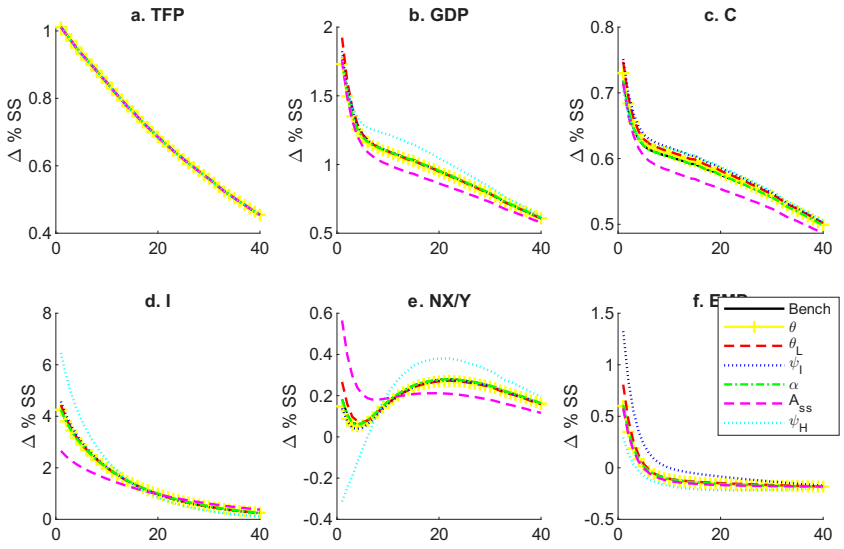


Figure 6: IRF from a TFP shock changing one parameter at a time.

In Appendix A we perform a series of robustness checks on the model, including alternative shocks and adding monetary policy to the model. Our qualitative results are consistent across the different specifications; however, the magnitudes change. In the next section, we extend our analysis to consider the sensitivity of our modeling assumptions.

Table 5: Standard deviations of variables under different model calibrations.

	Benchmark	θ	θ^L	ψ^I	α	A_{ss}	ψ^H	All
C	0.44	0.45	0.42	0.44	0.43	0.43	0.42	0.41
I	2.64	2.52	2.39	2.58	2.50	1.58	3.68	2.43
EMP	0.36	0.37	0.44	0.73	0.37	0.35	0.20	0.71
h^H	0.74	0.74	0.77	0.76	0.74	0.75	0.72	0.78
h^F	1.48	1.45	0.99	1.17	1.46	1.48	1.46	0.92
h^I	0.43	0.43	0.49	0.46	0.43	0.43	0.43	0.50

4.4 Sensitivity: Model Assumptions

In this section, we assess the importance of our modeling assumptions by examining how the baseline results change under alternative model specifications. Specifically, we consider several variations of the model: *(i)* a single-household economy (no hand-to-mouth agents); *(ii)* flexible wages (no adjustment costs); *(iii)* no low-skilled formal labor, where hand-to-mouth households supply only informal labor; *(iv)* the same rigidity in wages for the three agents; and *(v)* increasing wage rigidity for formal low-skilled labor and for high-skilled labor. In the first three cases, we recalibrated the model to match the same set of target moments. In the last two, recalibration is not necessary.

The results are presented in Table 6. Several findings are noteworthy. For instance, having only one agent reduces relative consumption volatility, as the representative household has access to financial markets and may borrow to smooth consumption after a negative shock. In this case, the additional volatility is absorbed by the investment. Regarding the strength of the relationship between volatility and informality, the qualitative results remain: both consumption and investment are more volatile (relative to GDP) in economies with higher levels of informality. However, quantitatively, the volatilities of consumption and investment are lower than in the benchmark case. Thus, introducing two types of agents not only improves the model's ability to match the magnitudes of relative volatilities but also the slopes of the volatility–informality relationships.

Columns three and four of Table 6 further highlight the relevance of our modeling assumptions. Under flexible wages, the relative volatilities of consumption and investment are identical in economies with high and low informality. This result underscores the importance of the interaction between wage rigidities and informality in explaining the changes in volatility observed in the data. Similarly, in a model with only informal low-skilled labor, low-skilled households lack a margin of adjustment through formal employment, and volatilities remain unchanged across different levels of informality.

As shown in columns four and five, heterogeneity in wage rigidities is a key channel driving the simulation results. When the model features fully flexible wages or when all wages share the same degree of rigidity (including informal wages), it fails to replicate the observed relationship between informality and macroeconomic volatility. Finally, the last column shows that the quantitative results are robust even when wages for formal low- and high-skilled labor are assumed to be more rigid, as in Born and Pfeifer, 2020.

In summary, incorporating two households—one of them hand-to-mouth—is crucial for capturing the magnitude of consumption volatility relative to GDP. Moreover, wage rigidities and the possibility of substituting between formal and informal low-skilled labor are key mechanisms for replicating the slopes of volatility–informality relationships.

5 Conclusions

This paper studies how labor informality shapes short-run dynamics and macroeconomic volatility in an emerging market economy. Using a dynamic model with formal and informal labor markets, heterogeneous households, and wage rigidities, we compare economies with high and low levels of informality that are otherwise calibrated to match the same aggregate targets. This strategy allows us to isolate the role of informality and its

Table 6: Relative Volatility under alternative model specifications

	Benchmark	One Agent	Flex W	No F	All Rigid	$\phi^{H,F} = 500$
			High-Informality			
C	0.44	0.31	0.56	0.47	0.4	0.42
I	2.64	3.91	3.67	2.83	2.43	2.79
EMP	0.36	0.56	0.16	0.31	0.83	0.44
h^H	0.74	0.80	0.04	0.70	0.78	0.9
h^F	1.48	1.31	0.34		0.93	1.62
h^I	0.43	0.09	0.34	0.34	0.87	0.45
			Low-Informality			
C	0.41	0.29	0.56	0.47	0.41	0.39
I	2.43	3.75	3.67	2.83	2.42	2.64
h^H	0.71	0.79	0.16	0.60	0.83	0.82
EMP	0.78	0.82	0.04	0.70	0.79	0.92
h^F	0.92	0.94	0.34		0.85	1.02
h^I	0.50	0.04	0.34	0.34	1.07	0.52

Relative volatility is computed as the ratio of the standard deviation of the variable to the standard deviation of GDP.

interaction with labor market frictions in driving cyclical outcomes.

Our impulse response analysis shows that the qualitative transmission of TFP shocks is similar across economies with different degrees of informality, but important quantitative differences emerge. Economies with lower informality display larger GDP responses to productivity shocks, reflecting the greater weight of formal labor subject to wage rigidity. In this environment, firms adjust more through employment than wages, amplifying labor demand—particularly for formal low-skilled workers—and, through complementarity, for high-skilled labor. Simultaneously, consumption and investment respond less than proportionally to GDP, suggesting a mechanism through which lower informality can dampen relative volatility.

The simulations confirmed and quantified these insights. Higher informality is associated with significantly greater volatility of consumption and investment relative to GDP. Increasing informality by a factor comparable to that observed in Colombian data raises consumption and investment volatility by economically significant magnitudes. The model can reproduce a substantial fraction of the empirical slopes linking informality to macroeconomic volatility, especially for investment, and a nontrivial share for consumption. These results highlight the importance of labor market composition—not only shock processes—in shaping aggregate fluctuations.

Our robustness exercises show that these findings are not driven by the choice of calibration. While changes in parameters such as productivity, labor disutility, or steady-state TFP affect the magnitudes, most reinforce the result that lower informality is associated with lower volatility. Two mechanisms are particularly important. First, the relative productivity of formal versus informal low-skilled labor strengthens the response of output to shocks when informality is low. Second, adjustments in the high-skilled labor supply interact with capital accumulation, affecting the dynamic path of output and investment.

The sensitivity analysis underscores the central role of the modeling assumptions. The presence of hand-to-mouth households is crucial for matching the level of consumption volatility observed in the data, while wage rigidities are essential for generating differences in volatility across economies with different levels of informality. The model fails to reproduce the observed relationship between informality and macroeconomic volatility when wages are fully flexible, when all wages share the same rigidity, or when low-skilled households can only work informally. In contrast, allowing low-skilled households to substitute between formal and informal jobs, together with heterogeneous wage rigidities, emerges as a key channel through which informality

amplifies aggregate fluctuations.

Overall, the results suggest that labor informality is a quantitively relevant determinant of macroeconomic volatility. Therefore, policies that reduce informality or alter its interaction with wage-setting institutions may have important stabilization effects beyond their well-known implications for productivity and fiscal capacity. Future research could extend this framework to study the joint role of informality and monetary or fiscal policy, as well as the implications of alternative shock structures and enforcement mechanisms in the labor market.

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A Robustness checks

We perform a series of robustness checks on the model, including alternative shocks and adding monetary policy to the model.

A.1 Alternative shocks

In this section, we analyze how the relative volatility of the main variables changes when two additional shocks are introduced into the model. In particular, we consider shocks to the discount factor and foreign interest rate. As in the benchmark case, we simulate the model with one shock at a time and assume shock deviations of 1% and persistence of 0.9.

As reported in Table A.1, the relative volatilities of consumption and investment increase under both shocks. However, consumption volatility responds more strongly to discount-factor shock, whereas investment volatility increases more with foreign interest rate shocks. Regarding the volatility–informality relationship, both shocks generate a steeper slope for consumption volatility than the benchmark case. For investment, the discount factor shock reduces the slope, while the interest rate shock increases it.

Given these results, if we combine the TFP shock with other shocks, we can explain a higher share of the consumption volatility-informality and investment volatility-informality relationships. In addition, we can get closer to the average level of consumption volatility observed in the data. With this in mind, we simulate the model by considering the three shocks simultaneously. To better match the empirical results, we consider TFP shocks with a standard deviation of 0.5%, discount factor shocks of 1%, and foreign interest rate shocks of 2%. The results of this simulation are reported in the last column of Table A.1. In this case, the slope for consumption volatility is 0.6, and the one for investment volatility is 2.74. In both cases, the slopes are closer to those of the data.

Given these results, combining the TFP shock with other shocks explains a larger share of the observed consumption and investment volatility–informality relationships. It also brings the average level of consumption volatility closer to the data. Therefore, we simulate the model with all three shocks simultaneously. To better match the empirical moments, we set the standard deviations to 0.5% for TFP shocks, 1% for discount-factor shocks, and 2% for foreign interest-rate shocks. The results (reported in the last column of Table A.1) imply a slope of 0.60 for consumption volatility and 2.74 for investment volatility. In both cases, the slopes move closer to those estimated from the data.

Table A.1: Simulation results (HP-filter). Std relative to GDP Std

	TFP	Discount Factor (DF)	R^*	All
		High-Informality		
C	0.44	1.94	1.33	0.7
I	2.64	3.52	24.91	3.18
EMP	0.36	0.89	0.55	0.43
h^H	0.74	1.85	1.14	0.87
h^F	1.48	1.48	1.15	1.5
h^I	0.43	0.45	0.42	0.43
		Low-Informality		
C	0.41	1.83	1.24	0.65
I	2.43	3.39	23.43	2.95
h^H	0.71	1.15	0.75	0.76
EMP	0.78	1.79	1.12	0.89
h^F	0.92	0.81	0.66	0.93
h^I	0.50	0.50	0.47	0.5

A.2 Informality and Monetary Policy

Finally, we extend our benchmark model to include price rigidities in the production of domestic goods and a central bank that responds to a Taylor rule according to the following equation:

$$i_t^{nom} = \left(i_{t-1}^{nom}\right)^{\rho^I} \left(i_{ss}^{nom}\right)^{1-\rho^I} \left(\frac{P_{t+1}^c}{P_{ss}^c}\right)^{\phi_\pi} (1+\varepsilon_t^i) \tag{32}$$

Including monetary policy modifies the optimization problem of high-skilled households, who can now access a domestic bond that is in zero net supply. The new optimization problem implies an additional Euler equation with respect to domestic bonds as follows:

$$\lambda_t^H = \mathbb{E}_t \beta * \lambda_{t+1}^H * \frac{P_t^c}{P_{t+1}^c}(1+i_t^{nom}) \tag{33}$$

Finally, domestic producers face price rigidities, which modify the optimality condition for domestic prices. The resulting Phillips curve is as follows:

$$MC_t \theta^d \frac{1}{P_t^d} = (\theta^d - 1) + \tag{34}$$
$$\phi_q \left(\frac{P_t^d}{P_{t-1}^d} - 1\right) \frac{P_t^d}{P_{t-1}^d} - \mathbb{E}_t \beta \frac{U_{c,t+1}}{U_{c,t}} \phi_q \left(\frac{P_{t+1}^d}{P_t^d} - 1\right) \left(\frac{P_{t+1}^d}{P_t^d}\right)^2 \frac{q_{t+1}^d}{q_t^d}$$

where ϕ_q is the price adjustment cost. With this version of the model, and assuming the following values for the additional parameters $\rho^i = 0.75$, $\phi_q = 50$ and $\phi_\pi = 1.25$.

As in the benchmark comparison, we simulate the model under two alternative calibrations—high and low informality—considering only the productivity shocks. We also examine the implications of inflation volatility. As reported in Table A.2, the main findings from the baseline scenario are confirmed: consumption and investment are more volatile relative to GDP in a more informal economy. Moreover, we find that inflation is more volatile under high informality, consistent with the empirical evidence presented in Section 2.

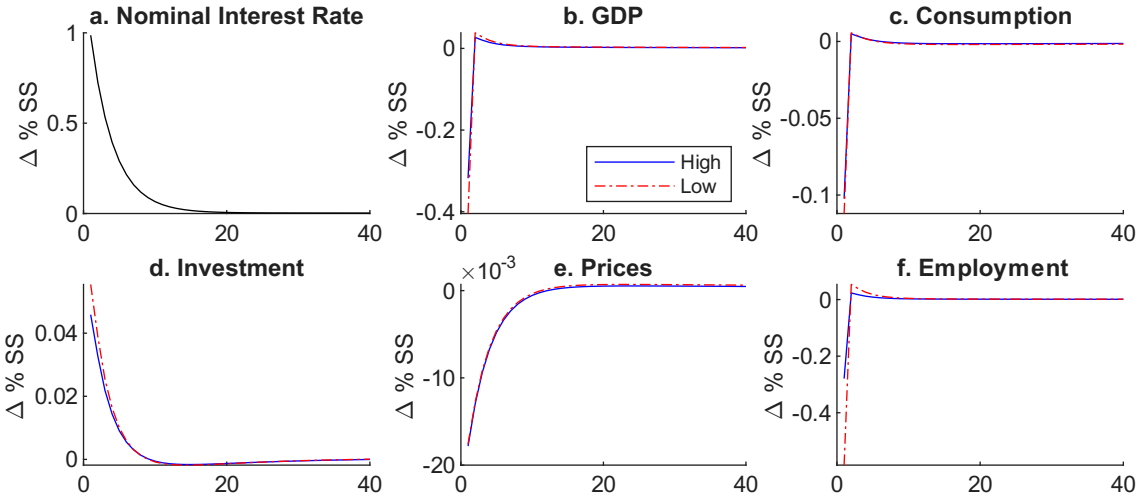
Table A.2: Relative volatility with Monetary Policy.

	High Informality	Low Informality
C	0.456	0.435
I	3.032	2.884
EMP	0.270	0.567
h^H	0.574	0.620
h^F	1.251	0.751
h^I	0.408	0.465
π	0.028	0.026

Relative volatility is computed as the ratio of the standard deviation of the variable to the standard deviation of GDP.

Finally, if we compute the impulse response function of a monetary policy shock, we find that the contractionary effect of increasing the policy rate is stronger in economies with lower informality, as shown in Figure A.1, while the effect on prices appears similar across economies. Intuitively, with lower informality, a larger share of marginal costs is affected by wage rigidity, which implies a stronger adjustment in total employment, as shown in Panel (f). This decline in employment reduces household income and, consequently, leads to a larger decrease in consumption. These results are consistent with those of Yépez (2025).

Figure A.1: Response to a Monetary Policy shock



B Some stylized facts of informality. Emerging and advanced economies

Table B.1 shows the correlations, corresponding p-values, and estimated slope coefficients for each of the relationships between the level of informality and the stylized facts of the macroeconomic variables shown in Figure 1, as well as for the relationships between the level of informality and access to financial markets shown in Figure 2. The level of informality as a percentage of GDP is between zero and one $(0-1)$. The p-values for these correlations were calculated using a bootstrapping procedure with 10,000 repetitions, ensuring a robust inference that does not rely on asymptotic distribution assumptions.

Table B.1: Macroeconomic relations and access to financial markets, and informality

Relationship with informality	**Correlation**	**Correlation p-value**	**Slope of the line**
σ_C/σ_Y	0.3553	0.0000	1.0768
σ_I/σ_Y	0.4203	0.0000	4.2169
Inflation (%)	0.4607	0.0000	0.1878
Bank credit to bank deposits (%)	−0.2774	0.0030	−0.8708
Bank deposits to GDP (%)	−0.5641	0.0000	−1.659
Financial institution accounts (%)	−0.7499	0.0000	−2.1301
Borrowed from a financial institution (%)	−0.2987	0.0160	−0.1607

C Full Model

$$P_t^c(c_t^H + i_t) + s_t P^* b_t^* = W_t^H h_t^H(l) + R_t k_{t-1} + (1 + i_{t-1}^*) s_t P^* b_{t-1}^* + \Pi_t^d, \tag{1}$$

$$P_t^c c_t^L = W_t^I h_t^I + W_t^F h_t^F + \frac{P_t^c T_t}{1-N} \tag{2}$$

$$i_t = k_t - (1-\delta)k_{t-1} + \frac{\phi_K}{2}(k_t - k_{t-1})^2, \tag{3}$$

$$i_t^* = i^* + (e^{\phi_b(B_t^Y - B_{ss}^*)} - 1) \tag{4}$$

$$B_t^Y = \frac{s_t P^* B_t}{GDP_t^{ann}} \tag{5}$$

$$GDP_t^{ann} = \sum_{s=0}^{3} GDP_{t-s} \tag{6}$$

$$rer_t = s_t \frac{P^*}{P_t^c}. \tag{7}$$

$$rer_t = 1 \tag{8}$$

$$(c_t^H)^{-\sigma} = P_t^c \lambda_t^H \tag{9}$$

$$\lambda_t^H P_t^c [1 + \phi_K (k_t - k_{t-1})] = \mathbb{E}_t \lambda_{t+1}^H \beta P_{t+1}^c \left[1 - \delta + \phi_K (k_{t+1} - k_t) + \frac{R_{t+1}}{P_{t+1}^c}\right] \tag{10}$$

$$\lambda_t^H s_t P^* = \mathbb{E}_t \lambda_{t+1}^H \beta s_{t+1} P^* (1 + i_t^*) \tag{11}$$

$$(c_t^L)^{-\sigma} = P_t^c \lambda_t^L \tag{12}$$

$$\begin{aligned}(h_t^H)^{1+\nu^H} \frac{\psi_h \theta_H}{W_t^H \lambda_t^H} &= (\theta_H - 1) h_t^H + \phi^H \left(\frac{W_t^H}{W_{t-1}^H} - 1\right) \frac{1}{W_{t-1}^H} p_t^d q_t^d \\ &\quad - \mathbb{E}_t \beta \frac{U_c(c_{t+1}^H, h_{t+1}^H)}{U_c(c_t^H, h_t^H)} \left[\phi^H \left(\frac{W_{t+1}^H}{W_t^H} - 1\right) \frac{W_{t+1}^H}{(W_t^H)^2} p_{t+1}^d q_{t+1}^d\right]\end{aligned} \tag{13}$$

$$\begin{aligned}(h_t^F)^{1+\nu^F} \frac{\psi_F \theta_F}{W_t^F \lambda_t^L} &= (\theta_F - 1) h_t^F + \phi^F \left(\frac{W_t^F}{W_{t-1}^F} - 1\right) \frac{1}{W_{t-1}^F} p_t^d q_t^d \\ &\quad - \mathbb{E}_t \beta \frac{U_c(c_{t+1}^L, , h_{t+1}^I, h_{t+1}^F)}{U_c(c_t^L, h_t^F)} \left[\phi^F \left(\frac{W_{t+1}^F}{W_t^F} - 1\right) \frac{W_{t+1}^F}{(W_t^F)^2} p_{t+1}^d q_{t+1}^d\right]\end{aligned} \tag{14}$$

$$\begin{aligned}(h_t^I)^{1+\nu^I} \frac{\psi_I \theta_I}{W_t^I \lambda_t^L} &= (\theta_I - 1) h_t^I + \phi^I \left(\frac{W_t^I}{W_{t-1}^I} - 1\right) \frac{1}{W_{t-1}^I} p_t^d q_t^d \\ &\quad - \mathbb{E}_t \beta \frac{U_c(c_{t+1}^L, h_{t+1}^I, h_{t+1}^F)}{U_c(c_t^L, h_t^I, h_{t+1}^F)} \left[\phi^I \left(\frac{W_{t+1}^I}{W_t^I} - 1\right) \frac{W_{t+1}^I}{(W_t^I)^2} p_{t+1}^d q_{t+1}^d\right]\end{aligned} \tag{15}$$

$$C_t^H = Nc_t^H, \tag{16}$$
$$K_t = Nk_t, \tag{17}$$
$$I_t = Ni_t, \tag{18}$$
$$B_t^* = Nb_t^* \tag{19}$$
$$L_t^H = Nh_t^H \tag{20}$$
$$C_t^L = (1-N)c_t^L, \tag{21}$$
$$L_t^I = (1-N)h_t^I, \tag{22}$$
$$L_t^F = (1-N)h_t^F \tag{23}$$
$$C_t = C_t^H + C_t^L. \tag{24}$$
$$q_t^d = C_t + I_t + NX_t + \Upsilon_t^H + \Upsilon_t^F + \Upsilon_t^I. \tag{25}$$
$$R_t = \mu_t \alpha \frac{q_t^d}{K_{t-1}}, \tag{26}$$
$$(1+\tau_t^H)W_t^H = \mu_t(1-\alpha)\frac{q_t^d}{l_t}\left(\frac{l_t}{l_t^H}\right)^{\frac{1}{\eta}}(1-\theta), \tag{27}$$
$$(1+\tau_t^F)W_t^F = \mu_t(1-\alpha)\frac{q_t^d}{l_t}\left(\frac{l_t}{l_t^L}\right)^{\frac{1}{\eta}}\theta(1-\theta^L)\left(\frac{l_t^L}{l_t^F}\right)^{\frac{1}{\eta^L}}, \tag{28}$$
$$W_t^I = \mu_t(1-\alpha)\frac{q_t^d}{l_t}\left(\frac{l_t}{l_t^L}\right)^{\frac{1}{\eta}}\theta\theta^L\left(\frac{l_t^L}{l_t^I}\right)^{\frac{1}{\eta^L}}, \tag{29}$$
$$MC_t = \frac{1}{A_t}\left(\frac{R_t}{\alpha}\right)^{\alpha}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}, \tag{30}$$
$$MC_t = \mu_t \tag{31}$$
$$W_t = \left[\theta^{\eta}(W_t^L)^{1-\eta} + (1-\theta)^{\eta}\left((1+\tau_t^H)W_t^H\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{32}$$
$$W_t^L = \left[(\theta^L)^{\eta^L}(W_t^I)^{1-\eta^L} + (1-\theta^L)^{\eta^L}\left((1+\tau_t^F)W_t^F\right)^{1-\eta^L}\right]^{\frac{1}{1-\eta^L}}, \tag{33}$$

$$P_t^d = MC_t\frac{\eta^d}{\eta^d - 1}. \tag{34}$$
$$\Pi_t^d = P_t^d q_t^d - MC_t q_t^d. \tag{35}$$
$$P_t^c = P_t^d \tag{36}$$
$$P_t^i = P_t^d \tag{37}$$
$$EMP_t = Nh_t^H + (1-N)(h_t^F + h_t^I) \tag{38}$$
$$NX_t = -(1+i_{t-1}^*)s_t P^* B_{t-1}^* + s_t P^* B_t^* \tag{39}$$
$$NXY_t = \frac{NX_t}{GDP_t} \tag{40}$$
$$\Upsilon_t^H = \frac{\phi^H}{2}\left(\frac{W_t^H}{W_{t-1}^H} - 1\right)^2 \tag{41}$$
$$\Upsilon_t^F = \frac{\phi^F}{2}\left(\frac{W_t^F}{W_{t-1}^F} - 1\right)^2 \tag{42}$$
$$\Upsilon_t^I = \frac{\phi^I}{2}\left(\frac{W_t^I}{W_{t-1}^I} - 1\right)^2 \tag{43}$$

D Model Variables

Households

High-skilled households (mass = N):

- c_t^H: consumption of high-skilled household
- $h_t^H(l)$: high-skilled labor supply of variety l
- h_t^H: aggregate high-skilled labor supply
- k_t: capital holdings
- i_t: investment
- b_t^*: foreign bond holdings
- Π_t^d: firm profits received
- λ_t^H: Lagrange multiplier (marginal utility of wealth)

Aggregate variables:

- $C_t^H = Nc_t^H$
- $K_t = Nk_t$
- $I_t = Ni_t$
- $B_t^* = Nb_t^*$
- $L_t^H = Nh_t^H$

Low-skilled households (mass = $1-N$):

- c_t^L: consumption
- $h_t^F(l)$: formal low-skilled labor supply of variety l
- $h_t^I(l)$: informal low-skilled labor supply of variety l
- λ_t^L: Lagrange multiplier

Aggregate variables:

- $C_t^L = (1-N)c_t^L$
- $L_t^F = (1-N)h_t^F$
- $L_t^I = (1-N)h_t^I$

Aggregate consumption:

$$C_t = C_t^H + C_t^L$$

Wages and Labor Packers

- $W_t^H(l)$: wage for high-skilled variety l
- W_t^H: aggregate high-skilled wage
- $W_t^F(l)$: wage for formal low-skilled labor variety l
- W_t^F: aggregate formal low-skilled wage
- $W_t^I(l)$: wage for informal low-skilled labor variety l
- W_t^I: aggregate informal low-skilled wage
- $\Upsilon_t^H, \Upsilon_t^F, \Upsilon_t^I$: Rotemberg wage adjustment costs

Firms

- $q_t^d(j)$: output of differentiated good j
- q_t^d: aggregate domestic output
- $P_t^d(j)$: price of variety j
- P_t^d: aggregate price index for domestic goods
- $l_t^H(j), l_t^F(j), l_t^I(j)$: labor inputs by type in firm j
- $l_t^L(j)$: composite low-skilled labor input
- $l_t(j)$: composite total labor input
- $k_{t-1}(j)$: capital input
- A_t: total factor productivity
- MC_t: marginal cost
- μ_t: Lagrange multiplier (shadow cost in firm's problem)
- Π_t^d: profits

Production Aggregators

- W_t^L: wage index for low-skilled labor (formal + informal)
- W_t: wage index for total labor (high + low)

Prices, Interest Rates, and Exchange Rate

- P_t^c: price of domestic final goods
- P^*: foreign price (exogenous, foreign currency)
- s_t: nominal exchange rate
- $rer_t = s_t \frac{P^*}{P_t^c}$: real exchange rate
- i_t^{nom}: domestic nominal interest rate
- i_t^*: foreign nominal interest rate
- R_t: return to capital

Trade and External Sector

- B_t^*: aggregate foreign asset position
- NX_t: real trade balance
- $B_t^Y = \dfrac{s_t P^* B_t}{GDP_t^{ann}}$: debt-to-GDP ratio
- GDP_t^{ann}: annual GDP

Shocks

- ε^A: productivity shock

E Steady State

We solve the system of equations for the following variables $k, c^H, W^H, c^L, W^F, W^I, NX$ and the parameters $\theta, \theta^L, \psi^I, A_{ss}, \alpha, \psi^H$

$$P^c = 1.0 \tag{1}$$
$$P^d = P^c \tag{2}$$
$$rer = 1 \tag{3}$$
$$s = \frac{rer \cdot P^c}{P^*_{ss}} \tag{4}$$
$$K = Nk \tag{5}$$
$$i = \delta k \tag{6}$$
$$I = Ni \tag{7}$$
$$C^H = Nc^H \tag{8}$$
$$C^L = (1-N)c^L \tag{9}$$
$$C = C^H + C^L \tag{10}$$
$$\lambda^H = \frac{c^{H-\sigma}}{P^c} \tag{11}$$
$$h^H = \left(\frac{\lambda^H W^H \left(\frac{\theta^H - 1}{\theta^H} \right)}{\psi^H} \right)^{\frac{1}{\nu^H}} \tag{12}$$
$$\lambda^L = \frac{c^{L-\sigma}}{P^c} \tag{13}$$
$$h^I = \left(\frac{\lambda^L W^I \left(\frac{\theta^I - 1}{\theta^I} \right)}{\psi^I} \right)^{\frac{1}{\nu^I}} \tag{14}$$
$$h^F = \left(\frac{\lambda^L W^F \left(\frac{\theta^F - 1}{\theta^F} \right)}{\psi^F} \right)^{\frac{1}{\nu^F}} \tag{15}$$
$$L^H = Nh^H \tag{16}$$
$$L^I = (1-N)h^I \tag{17}$$
$$L^F = (1-N)h^F \tag{18}$$
$$L^L = \left(\theta^L {L^I}^{\frac{\eta^L - 1}{\eta^L}} + (1-\theta^L) {L^F}^{\frac{\eta^L - 1}{\eta^L}} \right)^{\frac{\eta^L}{\eta^L - 1}} \tag{19}$$
$$L = \left(\theta {L^L}^{\frac{\eta - 1}{\eta}} + (1-\theta) {L^H}^{\frac{\eta - 1}{\eta}} \right)^{\frac{\eta}{\eta - 1}} \tag{20}$$
$$P^i = P^d \tag{21}$$

$$R = P^i \left(\frac{1}{\beta} - (1-\delta) \right) \tag{22}$$

$$R^* = \frac{1}{\beta} - 1 \tag{23}$$

$$W^L = \left((\theta^L)^{\eta^L} W^{I\,1-\eta^L} + (1-\theta^L)^{\eta^L} \left((1+\tau^F) W^F \right)^{1-\eta^L} \right)^{\frac{1}{1-\eta^L}} \tag{24}$$

$$W = \left(\theta^{\eta} W^{L\,1-\eta} + (1-\theta)^{\eta} \left((1+\tau^H) W^H \right)^{1-\eta} \right)^{\frac{1}{1-\eta}} \tag{25}$$

$$MC = \frac{1}{A^{ss}} \left(\frac{R}{\alpha} \right)^{\alpha} \left(\frac{W}{1-\alpha} \right)^{1-\alpha} \tag{26}$$

$$\mu = MC \tag{27}$$

$$T = \tau^H W^H N h^H + \tau^F W^F (1-N) h^F \tag{28}$$

$$\Upsilon^d = 0 \tag{29}$$

$$q^d = C + I + \Upsilon^d + NX \tag{30}$$

$$GDP = q^d P^d \tag{31}$$

$$GDP^{ann} = 4 \cdot GDP \tag{32}$$

$$B^* = B^*_{ss} \frac{GDP^{ann}}{sP^*_{ss}} \tag{33}$$

$$\Pi^d = q^d (P^d - MC) \tag{34}$$

$$NXY = \frac{NX}{GDP} \tag{35}$$

$$EMP = N h^H + (1-N)(h^F + h^I) \tag{36}$$

Equations to solve:

$$R = \mu\alpha\frac{q^d}{K} \tag{37}$$

$$(1+\tau^H)W^H = \mu(1-\alpha)\frac{q^d}{L}\left(\frac{L}{L^H}\right)^{1/\eta}(1-\theta) \tag{38}$$

$$(1+\tau^F)W^F = \mu(1-\alpha)\frac{q^d}{L}\left(\frac{L}{L^L}\right)^{1/\eta}\theta(1-\theta^L)\left(\frac{L^L}{L^F}\right)^{1/\eta^L} \tag{39}$$

$$W^I = \mu(1-\alpha)\frac{q^d}{L}\left(\frac{L}{L^L}\right)^{1/\eta}\theta\theta^L\left(\frac{L^L}{L^I}\right)^{1/\eta^L} \tag{40}$$

$$P^d = \frac{\theta^d}{\theta^d-1}MC \tag{41}$$

$$NX = -R^* sP^*_{ss}B^* \tag{42}$$

$$P^c c^L = W^I h^I + W^F h^F + \frac{T}{(1-N)} \tag{43}$$

$$Emp^{I,share} = \frac{(1-N)h^I}{(1-N)(h^I+h^F)+Nh^H} \tag{44}$$

$$Emp^{F,share} = \frac{(1-N)h^F}{(1-N)(h^I+h^F)+Nh^H} \tag{45}$$

$$\frac{W^H h^H N}{W^H h^H N + W^F h^F(1-N) + W^I h^I(1-N)} = Mass^H \tag{46}$$

$$\frac{I}{GDP} = I^{share} \tag{47}$$

$$GDP = 1 \tag{48}$$

$$\frac{W^F}{W^I} = gap^F \tag{49}$$

Where $Emp^{I,share}, Emp^{F,share}, Mass^H, I^{share}, gap^F$ are targets from the data.