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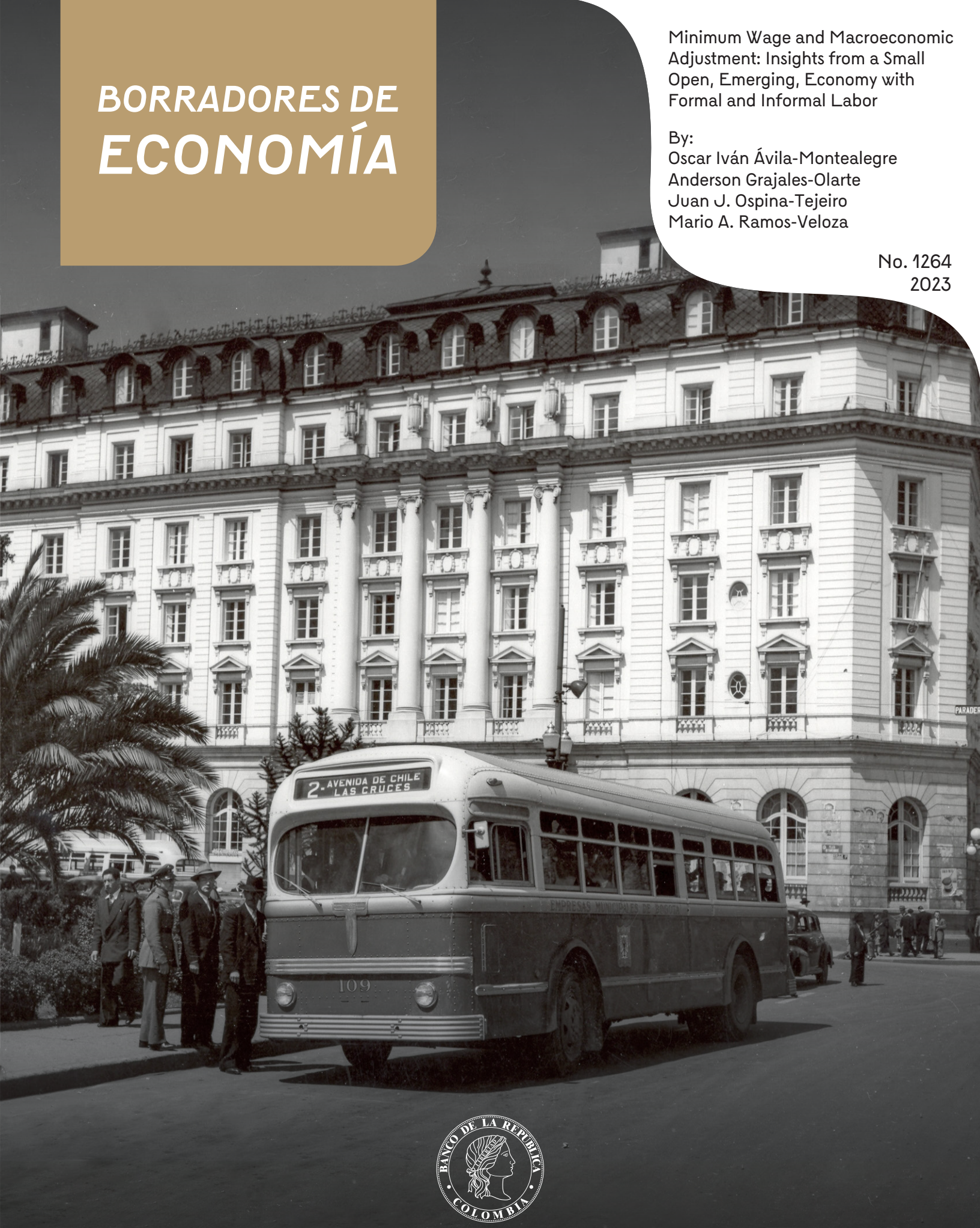

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Minimum Wage and Macroeconomic Adjustment: Insights from a Small Open, Emerging, Economy with Formal and Informal Labor*

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Abstract

We examine the adjustment of a small, open, emerging market economy (SOEME) to an unexpected increase in the minimum wage using an extended New-Keynesian SOE model that incorporates heterogeneous households, a flexible production structure, and a minimum wage rule. We calibrate the model for Colombia and find that an unexpected increase in the minimum wage has significant effects on the low-skilled labor market, and weaker impacts on inflation and the policy interest rate. The rise in the minimum wage increases production costs and prompts the substitution of formal low-skilled labor with informal workers and machinery, resulting in reduced output, increased inflation, and higher policy interest rates. We also observe that the minimum wage influences the transmission of productivity, demand, and monetary shocks, leading to a more persistent impact on macroeconomic variables, and a less efficient monetary policy to control inflation. Our findings suggest that the minimum wage has important macroeconomic implications, and affects emerging market economies through different channels than in developed economies.

JEL classification: E13, E50, J31, J46.
***Keywords*—** DSGE model, minimum wage, informal labor markets, monetary policy, heterogeneous agents.

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Salario mínimo y ajuste macroeconómico: lecciones de una economía emergente, pequeña y abierta con trabajo formal e informal

Resumen

En este artículo estudiamos el ajuste macroeconómico de una economía emergente pequeña y abierta ante un cambio inesperado en el salario mínimo. Para ello, construimos un modelo neo-keynesiano de economía pequeña y abierta con hogares heterogéneos, una estructura de producción con distintos tipos de trabajo y de capital, y una regla de ajuste del salario mínimo que responde a la inflación y productividad laboral pasadas, así como a choques inesperados. Tras calibrar el modelo para Colombia encontramos que un aumento inesperado del salario mínimo tiene efectos significativos sobre la producción y el empleo, y efectos moderados sobre la inflación y la tasa de política monetaria. En particular, observamos que el choque incrementa los costos de contratar mano de obra formal no calificada, la cual es sustituida por trabajadores informales y maquinaria. A pesar de esta sustitución, los mayores costos generan una contracción de la actividad económica, acompañada por un incremento en la inflación y en la tasa de política monetaria. Por otra parte, encontramos que la existencia de una regla de ajuste del salario mínimo afecta la transmisión de choques convencionales (productividad, demanda y política monetaria), aumentando su persistencia y reduciendo la efectividad de la política monetaria. Estos resultados son relevantes para economías emergentes en las que la política de salario mínimo tiene una mayor incidencia en el mercado laboral.

Clasificación JEL: E13, E50, J31, J46

Palabras clave: modelo de equilibrio general dinámico y estocástico, salario mínimo, mercado laboral informal, política monetaria, agentes heterogéneos.

1 Introduction

What are the macroeconomic effects of the minimum wage in a small, open, emerging economy? Recent studies on the general equilibrium effects of the minimum wage have focused on developed economies (see Šauer (2018), Glover (2019), and Glover, Mustre-del-Rıo, et al. (2021)), mainly the United States, which is usually modeled as a closed economy with no informal labor. These studies have provided important insights into the macroeconomic effects of minimum wages and its interaction with monetary policy, finding that higher labor costs push firms to demand higher labor effort, which enhances productivity and dampens the negative effects of higher wages, as in Šauer (2018), and that the monetary policy stance can determine whether higher wages cause an expansion or contraction of economic activity, as in Šauer (2018) and Glover (2019). Despite the relevance of these results, they may not be directly applicable to developing economies, where the minimum wage plays a larger role in the economic structure, the economy is better characterized as small and open, and the labor market has higher levels of informality.

This study answers this question from the perspective of a typical small, open, and emerging economy. We follow a two-step approach. First, we analyze how increasing the minimum wage affects the main macroeconomic aggregates. We then study how the presence of a minimum wage affects the propagation of standard shocks. Our results suggest that informality and capital accumulation in machines play an important role in macroeconomic adjustment; the former mechanism is not present (or relevant) in developed economies. We also find that the minimum wage increases the persistence of traditional shocks and reduces the effectiveness of monetary policy to control inflation.

Table 1: Minimum wage, EMEs and DEs.

	EMEs	DEs	Colombia
Workers receiving minimum wage	19.8%	9.0%	15.7%
Informality	69.5%	7.8%	58.1%
Urban informality	59.8%	7.3%	51.0%
Rural informality	78.8%	9.7%	84.5%
Average years between minimum wage changes	4.0	2.0	1.0
Minimum wage as a percentage of median wage	67%	55%	90%
Minimum wage as a percentage of mean wage	45%	41%	54%

Notes: Informal employment is not covered by social security, income taxes, or labor regulations. The average frequency of minimum wage changes for DEs is influenced by European countries, which typically revise their minimum wages at least every other year. In contrast, the United States has a longer adjustment period (around six years or more).
Sources: ILO (2020), ILO STAT Database, OECD. Own calculations.

A key distinguishing factor between emerging and developed economies that affects the transmission of minimum wage shocks is the fraction of workers that is affected by the wage policy -directly and indirectly-. Using information from the International Labor Organization (ILO), Table 1 reports some labor market measures that show the relative importance of the minimum wage in EMEs and DEs. We find that, on average, the percentage of workers earning the minimum wage in EMEs is twice the value of DEs. In other words, a larger fraction of workers and -therefore- of the labor cost is directly affected by the minimum wage. On the other hand, the share of informal workers is much larger in EMEs than in DEs (70% vs 8%). High informality may be associated with lower wages for informal workers, since -by definition- they are not covered by labor regulations and are exposed to earn wages below the minimum wage. In accordance with Lemos (2004), Mora and Muro (2017), and L. Arango and L. Flórez (2021) labor informality may partly be the result of the minimum wage itself, since a higher minimum wage creates a barrier to formality. The presence of informality creates an additional mechanism of adjustment that is more relevant in EMEs than in DEs. As the minimum wage increases, firms can substitute low-productive workers (earning the minimum wage), for cheaper informal workers, or for machines through automation (Lordan and Neumark, 2018; Eckardt, 2022). Finally, the higher importance of the minimum wage in EMEs is confirmed by the Kaitz ratio using both the median and the mean wages as reference.

In this study, we examine the macroeconomic effects of the minimum wage in a typical small, open, and emerging economy. To this end, we propose a TANK-SOE model with formal and informal labor that considers some of the characteristics of EMEs. Our model considers two households that differ in their skills (high and low), access to financial markets, and ownership of capital and firms, as well as a flexible production structure that allows for substitution between low-skilled labor (formal and informal) and machinery and more complementarity with high-skilled labor and other types of capital (e.g., buildings). We also assume that low-skilled formal labor is directly affected by a minimum wage rule that evolves according to past inflation and past labor productivity. The remaining characteristics of the model are typical of SOE-NK literature.

We calibrate the model for Colombia, a typical small, open, emerging economy with a large informal sector (Table 1), and an explicit rule of adjustment for the minimum wage, which takes into account past inflation and past labor productivity growth. According to the ILO, informality in Colombia is approximately 60%, and the minimum wage is relatively high (90% of the median wage). Characteristics that make Colombia an appropriate country for studying the macroeconomic effects of minimum wage.

At first glance, the minimum wage shock appears to have a similar effect on the economy as a negative productivity shock: output falls, inflation rises, and the central bank responds by increasing its nominal interest rate. However, we observe a different reactions of the production factors. For instance, in response to higher minimum wages, firms demand less low-skilled formal workers and substitute them with informal labor and machines. The remaining factors of production, capital in buildings and high-skilled labor, are affected by higher production costs and the general equilibrium effects that modify the decisions of firms and high-skilled households. Quantitatively, we find significant effects on the labor market for low-skilled workers and investment, moderate effects on Gross Domestic Product (GDP) and aggregate consumption, and minor effects on inflation and monetary policy. These small effects on nominal variables and aggregate economic activity are the result of a small transmission of the shock to the marginal cost due to substitution forces and an initial low share of formal low-skilled workers in aggregate labor costs.

Some of our findings for a typical EME are consistent with those in the existing literature, while others differ. Šauer (2018) examines the macroeconomic impacts of raising the minimum wage in the U.S., concluding that a higher minimum wage increases income and consumption of low-skilled workers, in spite of generating more unemployment for this group, but has negligible effects on inflation and the main macroeconomic aggregates. In this paper, the effort channel is a key mechanism for the transmission of minimum wage shocks. In response to higher labor costs, firms demand greater effort from workers, leading to higher productivity and lower inflation. Our study reveals that for a typical EME, the aggregate macroeconomic effects are also small and concentrated on low-skilled labor (formal and informal). However, we find that the impact on low-skilled consumption is time-dependent. In the short run, it increases as firms find it difficult to substitute for formal low-skilled labor. Over time, firms reduce their demand for formal low-skilled labor and substitute it with informal labor and machines. This substitution reduces the income of low-skilled households, whose consumption falls during the transition to the long run, this drop in consumption/income for low-skilled families are consistent with the empirical evidence presented by L. Arango, Ávila-Montealegre, et al. (2022).

In a simplified version of our model with no capital in machinery, we find that low-skilled consumption increases in the short and long run after a minimum wage increase; under this setup, firms substitute low-skilled formal workers for informal labor, and low-skilled income and consumption do not fall. In this case, we also observe that the contractionary effects of increasing the minimum wage are smaller, and the policy can reduce income and consumption inequality. In an alternate scenario, we consider an economy with no informal labor; in this case, all the substitution goes through machinery and total employment falls more, causing low-skilled income to drop even further, and magnifying the negative effects of the minimum wage. These results show that both machinery and informality are important adjustment mechanisms in our model.

Regarding the interaction of the minimum wage with conventional shocks, our results suggest that the minimum wage increases the persistence of macroeconomic responses and that most adjustments in the labor market are through quantities rather than wages. We also find that monetary policy becomes less effective in controlling inflation in the short run because of the rigidities created by the minimum wage. This result is consistent with Glover (2019), who finds that, for the U.S, the presence of a minimum wage mitigates the impact of a policy rate shock on inflation. Glover (2019) also studies the interaction between the minimum wage and the zero lower bound (ZLB) in the U.S. finding that, away from the ZLB the macroeconomic effects of increasing the minimum wage depend on the monetary policy stance. If the central bank maintains a hawkish stance, the increase in the minimum wage is contractionary. However, if the stance is dovish, then the effect is expansionary. Consistent with the variety of rules of adjustment that exist worldwide, we analyze how our results change when we consider alternative rules. Our results are qualitatively consistent; however, some rules add more volatility to the business cycle.

The remainder of this paper is organized as follows. Section 2 provides an overview of the methods used to set minimum wages in several countries, including an analysis of the actors involved, the frequency of adjustments, and the factors considered in minimum wage revisions. Section 3 introduces the structure of our model. Section 4 details the calibration approach and parameter values specific to the Colombian economy. In Section 5, we examine both the direct and indirect effects of minimum wage changes on the labor market and macroeconomic variables by analyzing the dynamics following an unexpected minimum wage increase. In this section, we assess the impact of the minimum wage on the persistence of macroeconomic responses to demand, productivity, and monetary policy shocks. Finally, Section 6 presents a summary of our main findings and their implications for policy.

2 Minimum Wage Adjustment Around the World

Minimum wage policy was introduced in New Zealand in 1984 to protect vulnerable workers.[1] Since then, it has spread around the world, with variations in the frequency of changes, the rules of adjustment, and the sectors and regions covered. It was first outlined in the International Labour Organization (ILO) Minimum Wage Fixing Convention Number 131, held in 1970 (ILO, 1970). By 2023, 187 nations had implemented minimum wage policies following the recommendations of the ILO Convention. The mechanisms for setting the minimum wage vary considerably from country to country; however, the ILO porposes the involvement of labor market actors and governments so that the interests of workers and employers are considered, and the value of the minimum wage represents a balance between them. This involvement varies from country to country; in some countries, minimum wages are set unilaterally by public authorities. In others, governments define its value after consulting with labor market actors. Finally, some countries have a tripartite process in which minimum wages are set through the joint participation (or bargaining) of the government, employers and workers.

Irrespective of the involvement of labor actors, the adjustment of the minimum wage takes into account additional factors such as its coverage in terms of sectors, occupations, educational level, regions, and the frequency of change. Approximately 48% of countries with minimum wage systems opt for a single, universally applicable national minimum wage. This approach seeks to ensure wage protection for all workers and emphasizes meeting the needs of workers and their families, regardless of sector or firm size. However, differences in the cost of goods and services across regions within a country pose challenges. Additionally, regional disparities in labor market conditions, with some areas experiencing robust economic activity and low unemployment while others face sluggish growth and higher unemployment rates, may call for or result in regional wage differentials, (L. Arango and L. Flórez, 2021). To accommodate these variations, some countries, such as Brazil, the Russian Federation, and the United States, have adopted a hybrid approach that combines a national minimum wage floor with provisions for higher regional rates.

With regard to the frequency of adjustments, Article 4 of Convention No. 131 suggests a periodic revision. In practice, the rate of inflation is an important variable to consider, since the purchasing power of workers receiving a fixed minimum wage erodes as prices increase. Indexation of the current wage to past inflation is intended to keep the wage constant in real terms and to guarantee the purchasing power of minimum wages. However, indexation introduces inertia, which becomes an obstacle to reducing the current rate of inflation and represents an additional concern for monetary policy. Sudden and large adjustments in minimum wages affect hiring decisions by increasing uncertainty about labor costs. To mitigate these concerns, some countries have introduced explicit requirements for periodic reviews of the minimum wage. In most cases, these reviews are conducted either annually or biennially. Some countries use yearly adjustments to provide predictability and gradual transitions, complemented by more frequent revisions when inflation exceeds a predetermined threshold. In France, for example, the minimum wage increases automatically when the annual inflation rate exceeds 2%. In addition to inflation, some countries include other macroeconomic variables in their adjustment decisions, such as labor productivity, economic growth and the unemployment rate. According to the ILO, 134 countries adjusted their minimum wages at least once every three to five years between 2010 and 2019.

Some countries adjust their minimum wage according to an explicit rule ILO (2016). In Brazil, for instance, wages are adjusted every four years, taking into account past inflation and economic growth. Similarly, Costa Rica follows an adjustment rule that considers expected inflation, economic growth, and deviations between actual inflation and inflation expectations. In Colombia, the minimum wage is adjusted every year through a negotiation process between unions, the private sector and the government. This process, which takes place in December, takes into account the sum of observed inflation and the change in labor productivity as a floor for the increase in the minimum wage. If the bargaining process fails, the government adjusts the minimum wage by decree, while respecting the aforementioned floor. Malaysia follows a more complex rule that includes socioeconomic indicators such as poverty line income, median wage, productivity growth, consumer inflation, unemployment rate. The adjustment varies by region. In France, the minimum wage is adjusted every January and considers the evolution of the CPI and the increase in the purchasing power of blue-collar workers. Finally, the Netherlands adjusts the minimum wage twice a year (January and July) based on changes in the weighted average of collectively agreed wages.

In summary, in several countries, the adjustment of the minimum wage is periodic but not necessarily regular, and some countries have a defined mechanism that includes the views of labor market actors, such as unions, firms, and the government. Some minimum wage adjustments are made by considering the evolution of economic variables such as inflation, economic growth, and productivity to ensure that the purchasing power of agents and the share of labor are kept constant. Additionally, in some countries, labor market variables such as the unemployment rate or wages can be considered in the adjustment..

[1] https://www.ilo.org/global/topics/wages/minimum-wages/definition/WCMS_439071/lang--en/index.htm

3 Model

We develop a general equilibrium model to study the effects of the minimum wage on macroeconomic variables in a small open emerging economy. Our model includes both high- and low-productivity workers. Low-productivity workers are employed in both the formal and informal sectors. In the formal sector, low-productivity workers earn the minimum wage, while in the informal sector they are paid below the minimum wage. Our model also distinguishes between two types of capital: machinery, which serves as a substitute for low-productivity labor, and buildings, which complement labor. The minimum wage serves as a reference for other wages and is determined by a rule that takes into account price inflation and productivity. The central bank uses a Taylor rule to determine the policy rate.

3.1 Households

Households are divided into two groups: high-skilled/high-productivity $\left(N^H\right)$ and low-skilled/low-productivity $\left(N^L\right)$. High-skilled households have several characteristics that distinguish them from their low-skilled counterparts. First, they offer a highly productive form of formal labor $\left(h_t^H\right)$. Second, they own firms and receive the profits generated by these firms (Π_t). Third, they own two types of capital: machinery (k_t^m) and buildings $\left(k_t^b\right)$.[2] High-skilled households consume $\left(c_t^H\right)$, and invest in both types of capital $\left(i_t^m \text{ and } i_t^b\right)$. Additionally, high-skilled households have access to both domestic and foreign financial markets, b_t and a_t^f, respectively.

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

$$\max_{c_t^H, h_t^H, b_{t+1}, a_{t+1}^f, i_t^b, i_t^m, k_{t+1}^b, k_{t+1}^m} E_0 \sum_{t=0}^{\infty} \beta^t e^{Z_t} \left[\frac{\left(c_t^H\right)^{1-\sigma}}{1-\sigma} - \psi_H \frac{\nu_H}{1+\nu_H} \left(h_t^H\right)^{\frac{1+\nu_H}{\nu_H}} \right],$$

where $Z_t = \rho_Z Z_{t-1} + \epsilon_t^Z$ represents a demand shock, subject to the intertemporal budget constraint

$$P_t \left(c_t^H + i_t^b + i_t^m\right) + a_{t+1}^f + b_{t+1} \leq b_t R_{t-1} + \Phi_{t-1} R_{t-1}^f a_t^f + W_t^H h_t^H + R_t^b k_t^b + R_t^m k_t^m + \frac{\Pi_t}{N^H},$$

the adjustment cost of investment in buildings and in machinery,

$$k_{t+1}^q \leq i_t^q + (1-\delta^q) k_t^q - \frac{\phi_q}{2} \left(\frac{i_t^q}{i_{t-1}^q} - 1 \right)^2, q \in \{b, m\},$$

and the debt elastic interest rate,

$$\Phi_t = \Phi\left(A_t^f\right) = \widetilde{\phi} + \phi_a \left(\frac{A_t^f}{Y_t} - \frac{A_{ss}^f}{Y_{ss}} \right),$$

where Y_t and A_t^f denote output and the aggregate foreign asset, respectively.[3]

After normalizing the F.O.C. by P_t we find the marginal rate of substitution between consumption and labor,

$$\psi_H \left(h_t^H\right)^{\frac{1}{\nu_H}} = w_t^H (c_t^H)^{-\sigma},$$

the Euler equations for domestic and foreign bonds,

$$\left(c_t^H\right)^{-\sigma} = \beta e^{Z_{t+1} - Z_t} \frac{\left(c_{t+1}^H\right)^{-\sigma} R_t}{\pi_{t+1}},$$

$$\left(c_t^H\right)^{-\sigma} = \beta e^{Z_{t+1} - Z_t} \frac{\left(c_{t+1}^H\right)^{-\sigma} R_t^f \Phi_t}{\pi_{t+1}},$$

capital in machinery and buildings,

$$\mu_t^q = \beta e^{Z_{t+1} - Z_t} \left(\left(c_{t+1}^H\right)^{-\sigma} r_{t+1}^q + \mu_{t+1}^q (1-\delta^q) \right) \text{ for } q \in \{b, m\},$$

[2] Subsection 3.2 discusses the importance of considering both forms of capital.

[3] The subscript ss denotes the steady state value of the variable.

and the corresponding two types of investment,

$$\left(c_t^H\right)^{-\sigma} = \mu_t^q \left[1 - \phi_q \left(\frac{i_t^q}{i_{t-1}^q} - 1\right) \frac{1}{i_{t-1}^q}\right] + \beta \left[\mu_{t+1}^q e^{Z_{t+1}-Z_t} \phi_q \left(\frac{i_{t+1}^q}{i_t^q} - 1\right) \frac{i_{t+1}^q}{\left(i_t^q\right)^2}\right] \text{ for } q \in \{b, m\},$$

where $w_t^H = W_t^H/P_t$, $r_t^b = R_t^b/P_t$, $r_t^m = R_t^m/P_t$, and $\pi_t = P_t/P_{t-1}$.

Low-skilled households face borrowing constraints and lack access to financial markets. As a result, their only income comes from labor. These hand-to-mouth households consume $\left(c_t^L\right)$ and offer their labor force both in the formal sector $\left(h_t^F\right)$, where they earn the minimum wage $\left(W_t^F\right)$, and in the informal sector $\left(h_t^I\right)$, where they earn a market wage below the minimum wage $\left(W_t^I\right)$.[4] The representative low-skilled household maximizes the present value of its utility,

$$\max_{c_t^L, h_t^I, h_t^F} E_0 \sum_{t=0}^{\infty} \beta^t e^{Z_t} \left[\frac{\left(c_t^L\right)^{1-\sigma}}{1-\sigma} - \psi_I \frac{\nu_I}{1+\nu_I} \left(h_t^I\right)^{\frac{1+\nu_I}{\nu_I}} - \psi_F \frac{\nu_F}{1+\nu_F} \left(h_t^F\right)^{\frac{1+\nu_F}{\nu_F}}\right],$$

subject to its budget constraint,

$$P_t c_t^L \leq W_t^I h_t^I + W_t^F h_t^F + \frac{P_t T_t}{N^L},$$

where T_t are transfers from the government.

From the normalized F.O.C., we find the marginal rates of substitution between consumption and labor (formal and informal),

$$\phi_I \left(h_t^I\right)^{\frac{1}{\nu_I}} = \left(c_t^L\right)^{-\sigma} w_t^I, \text{ and}$$

$$\phi_F \left(h_t^F\right)^{\frac{1}{\nu_F}} = \left(c_t^L\right)^{-\sigma} w_t^F,$$

where $w_t^I = W_t^I/P_t$ and $w_t^F = W_t^F/P_t$.

Macroeconomic aggregates can be defined as follows: Consumption is the sum of the consumption of each representative household multiplied by the number of households of each type, $C_t = N^H c_t^H + N^L c_t^L$. Investment in buildings and machinery is given by $I_t^b = N^H i_t^b$ and $I_t^m = N^H i_t^m$, respectively, because low-skilled households do not make investment decisions. Domestic demand is given by $D_t = C_t + I_t^b + I_t^m$. The aggregate labor supply for high-skilled, low-skilled formal, and low-skilled informal workers is defined as the total number of hours worked: $E_t^H = N^H h_t^H$, $E_t^F = N^L h_t^F$, and $E_t^I = N^L h_t^I$, respectively. Total employment reflects the total hours worked in the economy: $E_t = E_t^F + E_t^I + E_t^H$.

3.2 Production

The final good sector is perfectly competitive. It combines a continuum of differentiated intermediate goods ($Y_t(j)$ with $j \in [0, 1]$) into the final good (Y_t). This firm maximizes its profits according to

$$\max_{Y_t(j)} P_t Y_t - \int_0^1 P_t(j) Y_t(j) dj,$$

where,

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{\xi-1}{\xi}} dj\right)^{\frac{\xi}{\xi-1}}$$

is the production technology of the final good, $P_t(j)$ and P_t are the prices of the jth intermediate good and the aggregate price, respectively. From the F.O.C., we find that the demand for input j depends on its relative price and the aggregate demand for domestic goods,

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\xi} Y_t,$$

[4] This specification captures the link between the two types of labor in low-skilled households by reflecting 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, for example, by Gramlich (1976) and Mincer (1976).

and that the aggregate price index for domestic goods is an average of the prices of the heterogeneous set of inputs,

$$P_t = \left[\int_0^1 P_t(j)^{1-\xi} dj\right]^{\frac{1}{1-\xi}}.$$

Domestic production of the homogeneous good is allocated to consumption, investment, and net exports $Y_t = D_t + NX_t$.

Each intermediate good is produced by a monopolistically competitive firm. The firm faces a Cobb-Douglas production function and makes both static and dynamic decisions. Regarding the static decisions, each firm j minimizes its costs by choosing its optimal demand for capital in machinery, capital in buildings, and for each type of labor: high-skilled formal, low-skilled formal, and low-skilled informal. The firm's optimization problem is given by:

$$\min_{K_t^b(j),K_t^m(j),L_t^H(j),L_t^I(j),L_t^F(j)} \tau_t w_t^H L_t^H(j) + w_t^I L_t^I(j) + \tau_t w_t^F L_t^F(j) + r_t^b K_t^b(j) + r_t^m K_t^m(j),$$

where τ_t is a tax levied on the wages of high-skilled and low-skilled formal workers, subject to the technology

$$Y_t(j) = A_t \left(K_t^b(j)\right)^{\alpha} \left(L_t(j)\right)^{1-\alpha}, \tag{1}$$

where total factor productivity follows $A_t = \rho_a A_{t-1} + \epsilon_t^A$, being ϵ_t^A a productivity shock, and $K_t^b(j)$ is the demand for capital in buildings which complements labor demand, $L_t(j)$.

Labor demand for each firm j ($L_t(j)$) is a nested CES function that aggregates the three types of labor and machinery. The CES structure provides enough flexibility to capture different substitution and complementarity effects among these inputs, which allows us to better capture the dynamics after a minimum wage shock. This structure is defined as:

$$L_t^L(j) = \left[\theta_L \left(L_t^I(j)\right)^{\frac{\eta_L - 1}{\eta_L}} + (1-\theta_L)\left(L_t^F(j)\right)^{\frac{\eta_L - 1}{\eta_L}}\right]^{\frac{\eta_L}{\eta_L - 1}}, \tag{2}$$

$$L_t^m(j) = \left[(1-\theta_m)\left(L_t^L(j)\right)^{\frac{\eta_m - 1}{\eta_m}} + \theta_m \left(K_t^m(j)\right)^{\frac{\eta_m - 1}{\eta_m}}\right]^{\frac{\eta_m}{\eta_m - 1}}, \text{ and} \tag{3}$$

$$L_t(j) = \left[\theta \left(L_t^m(j)\right)^{\frac{\eta - 1}{\eta}} + \left(1-\theta\right)\left(L_t^H(j)\right)^{\frac{\eta - 1}{\eta}}\right]^{\frac{\eta}{\eta - 1}}. \tag{4}$$

The structure of labor demand and its various levels of aggregation deserve further examination. At the lowest level, the demand for low-skilled labor, $L_t^L(j)$, consists of the demand for low-skilled informal and low-skilled formal labor. These two types of labor are substitutes, giving firms the option of employing informal labor at wages below the minimum wage at the expense of formal labor in response to minimum wage increases (Eq. (2)). At the intermediate level, the demand for the factor *labor-machinery*, $L_t^m(j)$, is composed of the demands for low-skilled labor and machinery capital. These two inputs are also substitutes, allowing firms to choose automation in response to minimum wage increases (Eq. (3)). At the highest level, the demand for labor, $L_t(j)$, is a combination of the *labor-machinery* factor and the demand for high-skilled labor. Unlike the other levels of aggregation, these two inputs are complementary (Eq. (4)).

From the normalized F.O.C. we find the relative demand of factors as a function of their relative prices,

$$\frac{w_t^m}{\tau_t w_t^H} = \frac{\theta}{1-\theta}\left(\frac{L_t^H}{L_t^m}\right)^{\frac{1}{\eta}},$$

$$\frac{w_t^I}{\tau_t w_t^F} = \frac{\theta_L}{1-\theta_L}\left(\frac{L_t^F}{L_t^I}\right)^{\frac{1}{\eta_L}},$$

$$\frac{r_t^m}{w_t^L} = \frac{\theta_m}{1-\theta_m}\left(\frac{L_t^L}{K_t^m}\right)^{\frac{1}{\eta_m}} \text{ and,}$$

$$\frac{L_t}{K_t^b} = \frac{(1-\alpha)}{\alpha}\frac{r_t^b}{w_t}.$$

We also obtain the aggregate factor prices,

$$w_t = \left(\theta^{\eta}\left(w_t^m\right)^{1-\eta} + (1-\theta)^{\eta}\left(\tau_t w_t^H\right)^{1-\eta}\right)^{\frac{1}{1-\eta}},$$

$$w_t^m = \left((1-\theta_m)^{\eta_m}\left(w_t^L\right)^{1-\eta_m} + \theta_m^{\eta_m}\left(r_t^m\right)^{1-\eta_m}\right)^{\frac{1}{1-\eta_m}},$$

$$w_t^L = \left(\theta_L^{\eta_L}\left(w_t^I\right)^{1-\eta_L} + (1-\theta_L)^{\eta_L}\left(\tau_t w_t^F\right)^{1-\eta_L}\right)^{\frac{1}{1-\eta_L}}$$

and the real marginal cost

$$mc_t = \frac{1}{A_t}\left(\frac{\alpha}{r_t^b}\right)^{\alpha}\left(\frac{1-\alpha}{w_t}\right)^{1-\alpha}.$$

The dynamic optimization of intermediate firms is related to their price decisions. We adopt the framework proposed by Calvo (1983), in which intermediate firms set their prices to maximize the present value of profits given the expected demand for their products. In each period, a firm has an exogenous probability, $1-\phi$, of being able to change its price. The remaining ϕ firms that are unable to change their prices in a given period apply indexation, adjusting their prices according to past inflation. The optimal decision for a firm that can change its price in period t is given by:

$$\max_{P_t(j)} E_t \sum_{k=0}^{\infty} (\beta\phi)^k \frac{U_{c,t+k}}{U_{c,t}}\left[\left(\frac{\pi_{t+k-1}^{1_k} P_t(j)}{P_{t+k}}\right)^{1-\xi} Y_{t+k} - mc_{t+k}\left(\frac{\pi_{t+k-1}^{1_k} P_t(j)}{P_{t+k}}\right)^{-\xi} Y_{t+k}\right],$$

where 1_k is an indicator function that takes the value of zero if $k=0$ and one otherwise. From the F.O.C

$$P_t(j) = \frac{\xi}{\xi-1}\frac{E_t\sum_{k=0}^{\infty}(\beta\phi)^k U_{c,t+k} mc_{t+k} P_{t+k}^{\xi} Y_{t+k}}{\sum_{k=0}^{\infty}(\beta\phi)^k U_{c,t+k} P_{t+k}^{\xi-1} Y_{t+k}}.$$

This equation implies that the optimal price of a firm that can change prices is given by

$$P_t^{\#} = \frac{\xi}{\xi-1}\frac{X_{1,t}}{X_{2,t}},$$

where,

$$X_{1,t} = U_{c,t} mc_t P_t^{\xi} Y_t + \beta\phi E_t X_{1,t+1}, \text{ and}$$

$$X_{2,t} = U_{c,t} P_t^{\xi-1} + \beta\phi E_t X_{2,t+1}.$$

By applying the law of large numbers to the continuum of firms, it can be demonstrated that aggregate prices may be expressed as a weighted average of optimal and lag prices, resulting from the optimal decision-making of individual firms,

$$P_t^{1-\xi} = (1-\phi)\left(P_t^{\#}\right)^{1-\xi} + \phi P_{t-1}^{1-\xi}.$$

After normalization we find the inflation rate,

$$\pi_t^{1-\xi} = (1-\phi)\left(\pi_t^{\#}\right)^{1-\xi} + \phi\pi_{t-1}^{1-\xi},$$

where,

$$\pi_t^{\#} = \frac{\xi}{\xi-1}\frac{x_{1,t}}{x_{2,t}}\pi_t,$$

$$x_{1,t} = C_t^{-\sigma} mc_t Y_t + \beta\phi E_t x_{1,t+1}\left(\frac{\pi_{t+1}}{\pi_t}\right)^{\xi} \text{ and,}$$

$$x_{2,t} = C_t^{-\sigma} Y_t + \beta\phi E_t x_{2,t+1}\left(\frac{\pi_{t+1}}{\pi_t}\right)^{\xi-1}.$$

Finally, due to price rigidities, total output in the economy is given by:

$$Y_t = \frac{\left(K_t^b\right)^{\alpha} L_t^{1-\alpha}}{v_t^p},$$

where v_t^p is the price dispersion:

$$v_t^p = \int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\xi} dj = (1-\phi)\left(\frac{\pi_t}{\pi_t^{\#}}\right)^{\xi} + \phi\left(\frac{\pi_t}{\pi_{t-1}}\right)^{\xi} v_{t-1}^p.$$

3.3 Minimum wage

As noted above, the model considers three types of workers. The wage and employment of high-skilled formal workers and low-skilled informal workers are determined by the equilibrium between supply and demand for their respective labor. In contrast, low-skilled formal workers are paid the minimum wage and therefore their employment level is determined by the demand for labor from firms.

The government sets changes in the nominal minimum wage $\left(\Delta W_t^F\right)$ according to a rule that takes into account inflation and productivity dynamics $(\Delta MP_{L,t-1})$, with some room for unexpected changes $\left(\epsilon_t^F\right)$. These changes are modeled as shocks which can be either permanent or transitory in nature,

$$\Delta W_t^F = \frac{W_t^F}{W_{t-1}^F} = \pi_{t-1}\Delta MP_{L,t-1}\left(1+\epsilon_t^F\right), \tag{5}$$

where

$$\Delta MP_{L,t} = \frac{(Y_t/Y_{t-1})}{(E_t/E_{t-1})}.$$

The rule in Eq. (5), which is commonly used in EMEs and particularly in Colombia, implies that changes in the nominal minimum wage are fully reflected in the real minimum wage.[5] Given this setup, the real minimum wage $\left(w_t^F\right)$ follows

$$w_t^F = w_{ss}^F + \Delta w_t^F,$$

where $\Delta w_t^F = \Delta W_t^F - \pi_t$. For the wage setting to be relevant, we assume that in the steady state, the real wage of formal low-skilled workers, w_{ss}^F, is higher than the real wage that would be determined by market clearing.

Consistent with empirical evidence on the lighthouse/beacon effect of the minimum wage in EMEs, including Colombia (Bell, 1997; Maloney and Mendez, 2004; Neumark, Schweitzer, and Wascher, 2004), we assume that there is a short-term transmission of minimum wage shocks to high-skilled wages as well as persistence in their adjustment. This distorts the competitive equilibrium of high-skill wages in the short-term, but ultimately ensures that the long-term equilibrium remains competitive. In particular, we consider that:

$$w_t^H = \left(w_{t-1}^H\right)^{\rho_H}\left(w_{t-1}^{H,market}\right)^{1-\rho_H}\left(\frac{w_t^F}{w_{t-1}^F}\right)^{\rho_F}, \tag{6}$$

where $w^{H,market}$ is the competitive equilibrium wage for high-skilled workers.

3.4 Policy institutions

On the policy side, the model considers two institutions: the central bank and the government. Regarding the central bank, we define a standard Taylor rule that depends on inflation and on the output gap,

$$log\left(\frac{R_t}{R}\right) = \rho_r log\left(\frac{R_{t-1}}{R}\right) + r_\pi log\left(\frac{\pi_{t+1}}{\pi}\right) + r_y log\left(\frac{4Y_t}{\sum_{s=1}^4 Y_{t-s}}\right) + \epsilon_r, \tag{7}$$

where $\sum_{s=1}^4 Y_{t-s}$ is the annual GDP. This specification of the output gap allows us to account for changes in the steady state that do not result in permanent gaps. This is particularly useful when analyzing the impact of permanent changes on the real minimum wage. On the fiscal side, we assume that the government maintains a balanced budget in each period, with tax revenues from the wages of high-skilled and formal low-skilled workers equaling the lump-sum transfers provided to low-skilled households.

$$\frac{T_t}{P_t} = (\tau_t - 1)\left(w_t^F L_t^F + w_t^H L_t^H\right).$$

[5] In Subsection 5.3 we explore the effects of alternative rules.

4 Parameters, Calibration, and Adjustment to the Colombian Business Cycle

We set the parameter values using a combination of literature for Colombia (González et al., 2011), international evidence (Whalen and Reichling, 2017; Krusell et al., 2000), and moment matching. Table 2 shows the parameter values and their sources. Before matching the model with the data, we categorize Colombian workers according to their labor income relative to the minimum wage, using data from the Colombian Household Survey (GEIH) from 2010 to 2019.[6] 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.[7] Given these thresholds, we calibrate the relative productivity between low-skilled and high-skilled workers (θ) to yield a wage ratio of 2.7, and the relative productivity between formal and informal low-skilled workers (θ_L) to yield a wage ratio of 2.24. We define the mass of high-skilled households $\left(N^H\right)$ as 52% consistent with the data, and set the disutility of low-skilled labor (ψ_I) to match a labor income share (of total labor income) of 17% for low-skilled households.

To define the initial level of the minimum wage (w_{min}), we target a level of low-skilled formal employment that is 10% below that of a competitive market. The remaining parameters in the production function are the share of capital in buildings (α) and the relative productivity of machinery (θ_m). These values are chosen to match an investment over GDP of 30% and a share of investment in machinery in total investment of 30%. It is important to note that our calibration algorithm perfectly matches the long-run ratios. For the long-run equilibrium, we assume that domestic and external inflation rates are zero, i.e., $\pi = \pi^f = 1$, total factor productivity is set to generate a GDP equal to one (normalization), net foreign debt is 50% of GDP $(A^f_{ss} = 50\%)$, and the risk premium and the labor tax rate are consistent with the average values observed in Colombia, $\Phi_{ss} = 1.0037$, and $\tau_{ss} = 1.2$, respectively. Finally, the adjustment cost of capital $(\psi_b$ and $\psi_m)$, the elasticity of the risk premium (ϕ_a), and the persistence and volatility of shocks are calibrated to replicate specific moments in the business cycle of the Colombian economy, (Table 3).

To analyze the business cycle properties of the model, we compare the standard stylized macroeconomic facts of the Colombian economy with those generated by the simulated model incorporating productivity, demand, and monetary policy shocks. Using quarterly data for Colombia from 2000 to 2019, we subtract the cyclical component of the log of GDP, consumption, investment, and the trade balance over GDP using a Hodrick-Prescott filter. With the cyclical components, we calculate the relative volatility of each variable with respect to GDP (cycle), and its correlation with GDP (cycle). To compare the results of the model with the data, we simulated the variables using the model and then applied the same logarithmic transformation and detrending procedure that we used for the data. Our results, presented in Table 4, show that the model reproduces the procyclicality of consumption and investment as well as the countercyclicality of the trade balance. Furthermore, the volatility of investment in the model closely matches that observed in the data. However, consumption and the trade balance are less volatile in the model than in the data.[8]

5 Results

We now explore the macroeconomic effects of the minimum wage through the lens of our calibrated DSGE model. We first analyze the effects of an unexpected and permanent increase in the nominal minimum wage, which, according to the Colombian adjustment rule, generates a permanent increase in the real minimum wage. We then analyze how the presence of the minimum wage and its adjustment rule affect the transmission of conventional shocks such as productivity, demand, and monetary policy. Finally, we examine how our results change when we consider alternative specifications for the model, and different adjustment rules for the minimum wage which resemble the rules of other countries.

[6] 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.

[7] We define minimum wage earners using a range of values because workers surveyed in the GEIH do not always report the wage stated in their contract. Instead, they may report the actual wage they receive, which may differ from the minimum wage. This discrepancy may be due to factors such as social security deductions, which reduce the actual wage, or transportation subsidies, which increase it. By using a range to define minimum wage earners, we are able to account for these variations and provide a more accurate representation of these workers.

[8] The real business cycle literature has emphasized the lower relative volatility of consumption in general equilibrium models (Garcia-Cicco, Pancrazi, and Uribe, 2010; Rebelo, 2005; Plotnikov, 2017).

Table 2: Parameters. Description of parameters, values and sources.

Parameter	Definition	Value	Source
σ	Intertemporal elast. subs	2.0	Glover (2019)
β	Discount factor	0.9878	González et al. (2011)
ν_H	High-skilled Labor elasticity	1.0	Glover (2019)
$\nu_{FL} = \nu_{IL}$	Low-skilled labor elasticity	2.0	Calibrated*
ψ_H	Disutility of high-skilled labor	1.0	Glover (2019)
$\psi_I = \psi_F$	Disutility of low-skilled labor	3.73	Calibrated
η	Elast. subs. L_x vs L_H	0.7	Krusell et al. (2000)
η_m	Elast. subs. L_L vs K_m	1.25	Calibrated*
η_L	Elast. subs. L_I vs L_F	1.50	Krusell et al. (2000)
α	Capital share	0.2537	Calibrated
θ	Productivity L_L vs L_H	0.3028	Calibrated
θ_L	Productivity L_{FL} vs L_{IL}	0.1586	Calibrated
θ_m	Productivity L_L vs K_m	0.3432	Calibrated
ϕ	Price rigidity	0.75	González et al. (2011)
ξ	Elast. subs. intermediates	12	González et al. (2011)
π	Long run inflation	1.0	Normalization
A^f_{ss}	Net foreign assets LR	-0.50	Data
Φ_{ss}	LR risk premium	1.0037	Data
ϕ_a	Risk premium elast. to debt	0.50	Calibrated*
ρ_r	Persistence R	0.70	González et al. (2011)
r_π	Taylor π	1.50	González et al. (2011)
r_y	Taylor y	0.25	Calibrated
w_{min}	LR real minimum wage	0.39	Calibrated
A	Productivity	1.0505	Calibrated
π^f_{ss}	LR foreign inflation	1.0	Normalization
τ_{ss}	Labor taxes	1.2	Data
ψ_b	Capital adjustment cost k_b	0.0025	Calibrated*
ψ_m	Capital adjustment cost k_m	0.0013	Calibrated*

* These parameters are adjusted to replicate business cycle moments. They do not affect the long run equilibrium.

5.1 Unexpected and permanent increase in the minimum wage

In this subsetion, we examine the macroeconomic response to an unanticipated increase of 100 basis points (1%) in the nominal minimum wage, which according to the Colombia's adjustment rule, generates a permanent deviation in the real minimum wage.[9] Figure 1 shows the response of the main macroeconomic variables of the model, including GDP, output gap, investment, consumption, labor market outcomes, inflation, and the monetary policy rate. At first glance, the minimum wage shock looks like a negative productivity shock: output falls (Panel a), a negative output gap opens (Panel b), inflation rises (Panel i), and the central bank responds by raising its nominal interest rate (Panel h). In other words, at the aggregate level, the minimum wage shock can be associated with a cost-push shock that increases the marginal cost of production and reduces economic activity. This perspective helps us understand the initial implications of such shocks on key macroeconomic variables.

Looking closely at the behavior of other variables, we observe differentiated effects on the factors of production. This differentiation allows us to unravel the intricate dynamics within the labor market following minimum wage shocks. For instance, in response to higher minimum wages, firms demand less low-skilled formal workers (Panel e) and substitute them with informal labor (Panel e) and machines (Panel c). Quantitatively, we find that the magnitude of the response of low-skilled formal labor depends on the time horizon. This time dependency reveals an important nuance in how labor

[9] Since the rule accounts for past inflation, any shock to the nominal minimum wage generates a permanent effect in the real minimum wage

Table 3: Parameter Values for Exogenous Processes

Shock	Persistence	Volatility
Total Factor Productivity (TFP)	0.0925	0.0025
Demand	0.75	0.001
Monetary Policy	0.9	0.0025

Table 4: Data vs. Model

Statistic	Data	Model
Standard deviations		
σ_y	0.01	0.01
σ_c/σ_y	0.93	0.62
σ_i/σ_y	5.43	5.34
$\sigma_{NX/y}/\sigma_y$	0.84	0.59
Correlations with (y)		
GDP (y)	1.0	1.0
Consumption (c)	0.68	0.91
Investment (i)	0.64	0.82
Net exports/GDP (nx/y)	-0.51	-0.44

markets adapt to minimum wage changes over the short and long run. In particular, we see that the decline is smaller in the short run than in the long run, a result consistent with the findings of Hurst et al. (2022). Capital accumulation and the presence of investment adjustment costs help explain the slow adjustment of formal low-skilled labor in the short run. Immediately after the shock, it is costly to put more resources into building new machinery, which limits the substitution of more expensive formal low-skilled labor for machinery. Over time, the adjustment costs become cheaper, and firms can fully substitute the right amount of labor for machinery. In this context, the transition from the short to the long run is crucial. During the transition to the long run, other frictions such as price rigidities disappear. This transition illustrates how the reduction in low-skilled formal labor in response to minimum wage shocks influences capital accumulation and investment dynamics. As a result, the short-run elasticity of labor demand is less than one, while in the long run it is closer to one.[10] These figures are similar in magnitude to the empirical evidence reported by Luis E Arango, Castellani, and Obando (2019) and Cardenas and Bernal (2003) for industrial employment in Colombia, who find that labor wage elasticity ranges between 0.7 and 1.4. However, it is essential to recognize that these elasticities, while similar, may exhibit variations due to the unique economic structure of emerging markets.

Regarding the informal labor market, we observe some temporal differences in the response of real wages, reflecting the complex relationship between labor supply and demand in the informal sector following a minimum wage shock (Panel f). For instance, in the short run, as firms substitute formal low-skilled workers for informal labor, the demand for the latter increases and wages rise by about 0.39%. During the transition, as low-skilled households see their income and consumption fall, they increase the supply of informal labor and push down wages; this phenomenon is known as the additional worker effect.[11] The remaining factors of production, capital in buildings and high-skilled labor, are affected by higher production costs and general equilibrium effects that modify the decisions of high-skilled households. Panel c shows how investment in buildings falls after the shock as firms reduce their demand for other factors that are more complementary to low-skilled labor and machinery. High-skilled households also reduce their investment in buildings and allocate more resources to capital in machinery (Panel c). With respect to high-skilled labor, hours barely change (Panel e), but wages increase on impact due to the transmission of the minimum wage shock. As the transmission disappears, the lower demand for this type of labor pushes wages down. This dynamic highlights the connection of labor markets across skill levels.

The minimum wage shock has important effects on household heterogeneity, especially on the consumption response

[10] We only consider the labor demand elasticity, since in the presence of relevant minimum wages the market is clear only through the demand equation.

[11] Evidence of the additional worker effect in Colombia is presented in Cardona-Sosa and Morales (2015), who showed that in the first six months after the primary breadwinner's job loss, spouses increase their labor force participation between 9% and 20%. Additionally, Luis Eduardo Arango, Parra, and Pinzón (2015) showed that participation increases six times more in recessions than in expansions, showing that during the business cycle the additional worker effect is higher than the discouraged worker effect.

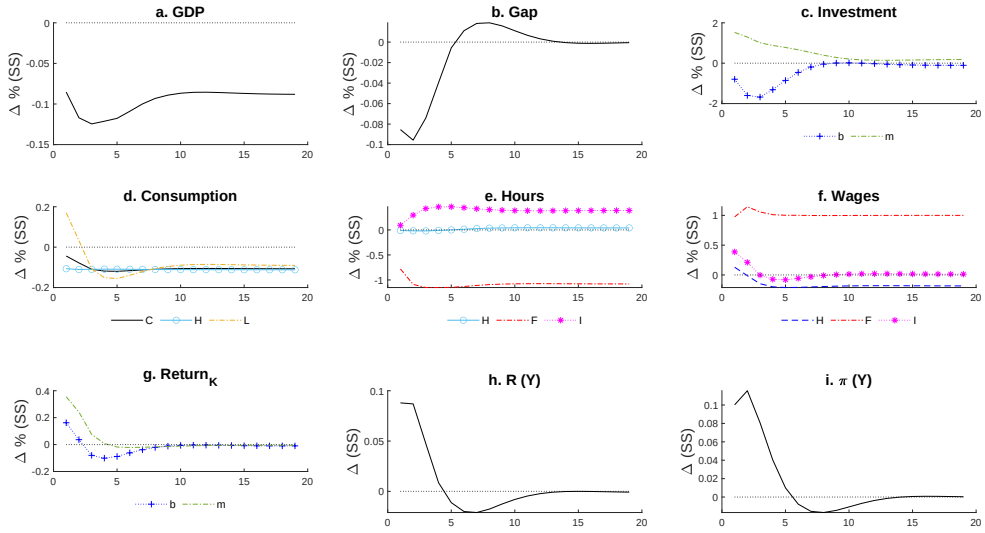

Figure 1: Impulse Response of Main Macroeconomic Aggregates to a 100 bp increase in the minimum wage.

Note: The vertical axis shows the percentage difference with respect to the initial steady state except for the interest rate, R, and inflation, π (annualized absolute difference). H stands for High-skilled, F for formal low-skilled, I for informal, and L for low-skilled.

(Panel d). On the one hand, high-skilled households can smooth their consumption and reduce it permanently after the shock (-0.11%). On the other hand, hand-to-mouth consumers are affected by their current income and experience a more volatile consumption path. That said, on impact, the increase in the minimum wage has a positive effect on the consumption of low-skilled households(0.17%) and reduces consumption inequality. This aspect emphasizes how minimum wage adjustments can reverberate through the broader economy, affecting households differently and influencing consumption inequality. In the short run, firms have not fully substituted formal low-skilled labor, and the aggregate income of low-skilled households increases. As firms find other ways to produce using cheaper informal labor and machinery, low-skilled households see their income and consumption fall. During this transition, consumption becomes more volatile and falls in the long run relative to the initial equilibrium (-0.09%). Households partially compensate the drop in formal income by supplying more informal labor (Panel e).

To understand the aggregate effects on inflation, output, and the monetary policy response, we first compute the change in unit labor costs, defined as the wage bill divided by the total number of hours worked. This indicator gives us a sense of the change in the marginal cost of production, which is the main driver of inflation in New Keynesian models. On impact, we see that a 1% increase in the minimum wage translates into a 0.3% increase in labor costs. In the long run, the effect is approximately 0.1%. These relatively small magnitudes, together with the substitution of more expensive low-skilled formal labor with cheaper informal workers and machinery, help explain the small response on annual inflation (Panel i), the output gap (Panel b), and the monetary policy rate (Panel h). Quantitatively, GDP falls 0.09% on impact and in the long run, while the output gap is around -0.09%.

As a robustness check, in Appendix A we analyze how our results change when we consider different model specifications that are closer to the standard literature. In these three alternative specifications, we include a model in which there is only one type of capital (no machinery), a model in which there is only one household, and a model in which there is no informality. We find that the results are qualitatively consistent across the different versions of the model; however, their magnitudes are different. One of the versions that attracts our attention is the model with only one type of capital. Under this scenario, a higher minimum wage pushes firms to hire more informal workers, since they are the only available substitution option. Therefore, low-skilled households do not experience a drop in their income and their consumption increases, consistent with the results presented by Šauer (2018). As a result, aggregate consumption drop less (than in the other scenarios) and the contractionary effects on output and employment are smaller. Under this scenario we also observe a reduction in consumption inequality.

Finally, following the literature for developed economies (Šauer, 2018; Glover, 2019), in appendix B we analyze the macroeconomic effects of a transitory shock in the minimum wage. The results are qualitatively consistent with our benchmark case. However, the initial response of all the variables is different. For instance, investment in machinery increases less (1% vs 2%), while inflation and the monetary policy interest rate raise more. Under this scenario, firms know that the shock is transitory, and the minimum wage will eventually return to the same initial level. Therefore, they do not have the same incentives to invest in machinery and substitute a large fraction of their formal low-skilled labor. As a result, formal low-skilled labor falls by less than 1% on impact. Less substitution has an impact on short-run inflation, which increases more than in the benchmark case and causes the MP interest rate to react more. This comparison underlines how the presence of a minimum wage with its associated rigidity influences the responsiveness of the real interest rate to monetary policy shocks.

5.2 Minimum wage as a propagation mechanism of conventional shocks

In this section we analyze how the minimum wage and its adjustment rule affect the propagation of three conventional shocks: total factor productivity, aggregate demand, and monetary policy. In the three, cases we consider a 1% shock.[12] For comparison, we run an alternative model without labor market frictions (no minimum wage and no transmission to high-skilled wages). Figures 2 and 3 show the response of macroeconomic and labor market variables to a 1% productivity shock for the two versions of the model. In both cases, we see an expansion of economic activity and a decline in inflation, consistent with a positive supply shock that reduces the marginal cost of production and stimulates economic activity. Since the central bank is more sensitive to inflation than to the output gap, it lowers the policy rate. Comparing the macroeconomic effects in the two models, we find that the minimum wage affects the initial response and the persistence of the main variables. In particular, we observe that the initial decline in inflation is smaller with a minimum wage (due to wage rigidities), but it is more persistent. This behavior is similar for aggregate consumption, investment, output, and the policy rate. Regarding the labor market, we observe that in the economy with a minimum wage, most of the adjustment occurs through quantities and less through quantities, which is consistent with the rigidities imposed in the model.

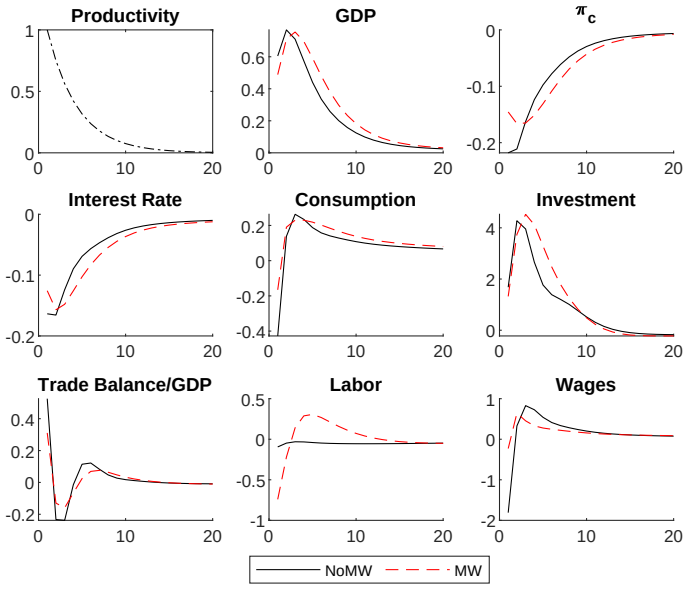

Figure 2: Impulse Response Functions to a 1% Total Factor Productivity (TFP) Shock.

Note: Except Trade Balance, variables are expressed in log deviations from the steady state.

In Figure 3 we plot the response of individual hours, wages, and consumption for the two models. Most of the results are quantitatively consistent, but the response of formal low-skilled workers differs significantly with and without a minimum wage. While in the former the productivity shock decreases employment, in the latter it increases. On the one

[12]For the TFP and demand shocks, we also consider a persistence of 75%. For the monetary policy shock the persistence remains as in the benchmark model.

hand, without labor market rigidities, the productivity shock reduces all wages on impact, causing a drop in the income of low-skilled workers, which pushes them to increase their formal and informal labor supply. On the other hand, given the minimum wage adjustment rule, a productivity shock increases labor productivity and pushes up the minimum wage. Higher labor costs reduce the demand for low-skilled labor in the short run. In both cases, as the productivity shock dissipates, the variables return to their initial steady state. Finally, we find that the minimum wage and its transmission to high-skilled wages have a positive effect on consumption for both high- and low-skilled households.

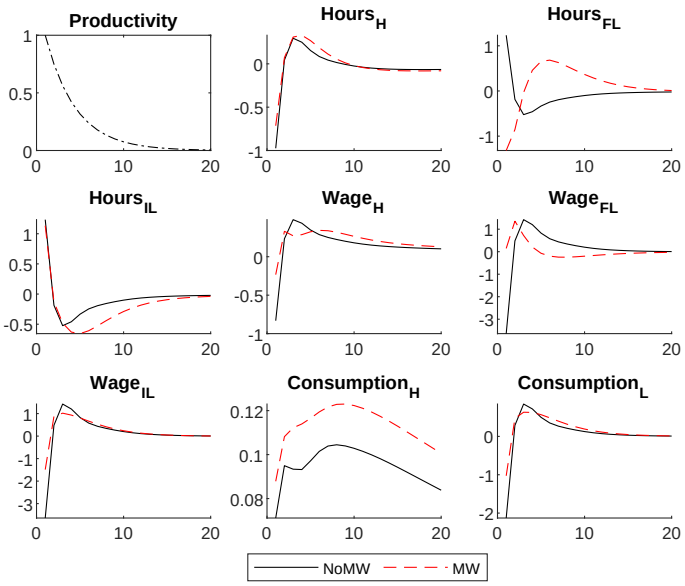

Figure 3: Impulse Response Functions to a 1% TFP Shock.

Note: All the variables are expressed in log deviations from the steady state.

We now analyze the effects of a positive demand shock that increases the willingness of high-skilled households to consume in the short run. By construction, this shock increases consumption, mainly of high-skilled workers, and reduces the resources assigned to investment both in buildings and in machinery (Figure 4). The higher demand for final goods also increases inflation in the short run, forcing the central bank to raise its interest rate. The fall in investment and the higher interest rate lead to a contraction in output. As in the previous case, we observe that the presence of the minimum wage and its adjustment rule increases the persistence of macroeconomic aggregates such as GDP, inflation, investment, and the nominal interest rate. In this regard, while inflation increases less on impact, it takes more time to return to the initial level, as a result of the behavior of labor costs.[13]

Finally, we consider a 1% monetary policy shock that raises the nominal and real interest rates. As Figure 5 shows, the existence of a minimum wage affects the transmission of monetary policy. In particular, we observe that the policy rate is less effective in reducing the inflation rate due to labor cost rigidities: a similar increase in the real interest rate has a smaller effect on inflation. As in the previous scenarios, macroeconomic aggregates take more time to return to their initial levels, a result consistent with the findings of Angel-Urdinola (2004). The other macroeconomic variables react as expected after a monetary policy shock: GDP, consumption and investment fall.

[13]Here it is important to remember that low-skilled households are hand-to-mouth and the shock does not affect them directly.

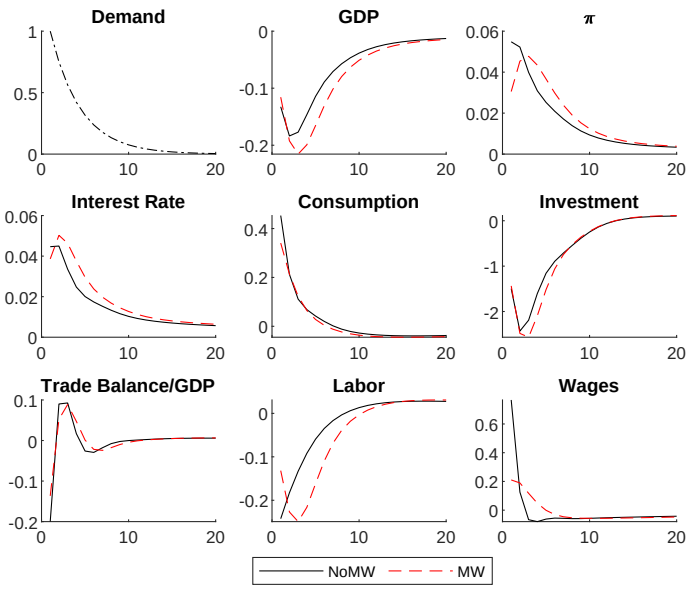

Figure 4: Impulse Response Functions to a 1% Demand Shock.

Note: Except Trade Balance, variables are expressed in log deviations from the steady state.

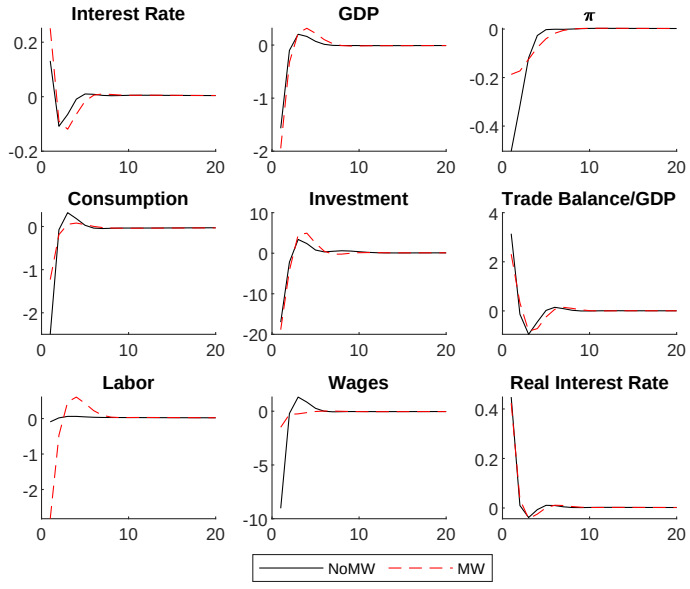

Figure 5: Impulse Response Functions to a 1% Monetary Policy Shock.

Note: Except Trade Balance, variables are expressed in log deviations from the steady state.

5.3 Macroeconomic effects under alternative rules of adjustment

In this section, we explore how alternative rules of adjustment affect the transmission of productivity, demand, and monetary policy shocks. As discussed in Section 2, the adjustment of the minimum wage may depend on several factors, including inflation, economic growth, productivity, and mean wage inflation. According to this evidence, we introduce four rules of adjustment that respond to:

i) past inflation combined with the change in the marginal product of labor (Eq. (5), our benchmark, discussed in Section 5),

ii) past inflation,

$$\Delta W_t^F = \frac{W_t^F}{W_{t-1}^F} = \pi_{t-1}\left(1+\epsilon_t^F\right), \tag{8}$$

iii) past inflation combined with past economic growth,

$$\Delta W_t^F = \frac{W_t^F}{W_{t-1}^F} = \pi_{t-1}\Delta Y_{L,t-1}\left(1+\epsilon_t^F\right), \text{ and} \tag{9}$$

iv) past inflation combined with the average growth rate of real wages

$$\Delta W_t^F = \frac{W_t^F}{W_{t-1}^F} = \pi_{t-1}\Delta w_{t-1}\left(1+\epsilon_t^F\right). \tag{10}$$

These four rules of adjustment address different objectives, however, all have implicitly the purpose of maintaining the purchasing power of low-skilled workers. Besides maintaining the purchasing power, the rule described by equation (9) seeks to re-distribute the gains of economic growth, while the rule from equation (5) compensates for changes in the marginal product of labor. Finally, rule in Eq. (10) ensures that changes in the minimum wage reflect the dynamics of other wages in the economy.

With these set of rules we compare the behavior of transitory shocks to total factor productivity, demand, and monetary policy (figures 6 to 8). In general we find that the results are qualitatively similar for all the rules, however the magnitudes and persistence of the shocks are different depending on the rule. For instance, after a productivity shock, Figure 6, we find that under the rules that adjust only for past inflation and for nominal wage growth, some variables (GDP, investment, inflation and the policy interest rate) have a higher response during the initial quarters. For these two rules the adjustment of the minimum wage is smaller on impact, and it does not dampen the positive effects of the TFP shock. It is important to notice that when the minimum wage is adjusted according to past wages growth we observe an additional volatility in labor and investment. In the case of a demand shock, Figure 7, we observe that the same rules (past inflation and past wage growth) have a higher effect on GDP, inflation, labor, and the monetary policy interest rate. These effects can be explained by the higher response of wages after the shock. Finally, for the monetary policy shock we observe similar effects for all of the rules, with some minimal differences in the magnitudes, Figure 8.

Our results suggest that the choice of the minimum wage adjustment rule is not critical to the effects of monetary policy shocks. Macroeconomic variables react similarly to a monetary policy shock, both quantitatively and qualitatively, regardless of the applied adjustment rule. Essentially, our simulations reveal that the economy's response remains qualitatively consistent across different rules. However, the nature of a shock plays a crucial role in determining its quantitative response. Specifically, shocks to productivity or minimum wage induce greater volatility under a rule that allows wage inflation. However, responses to monetary policy shocks showed no discernible differences.

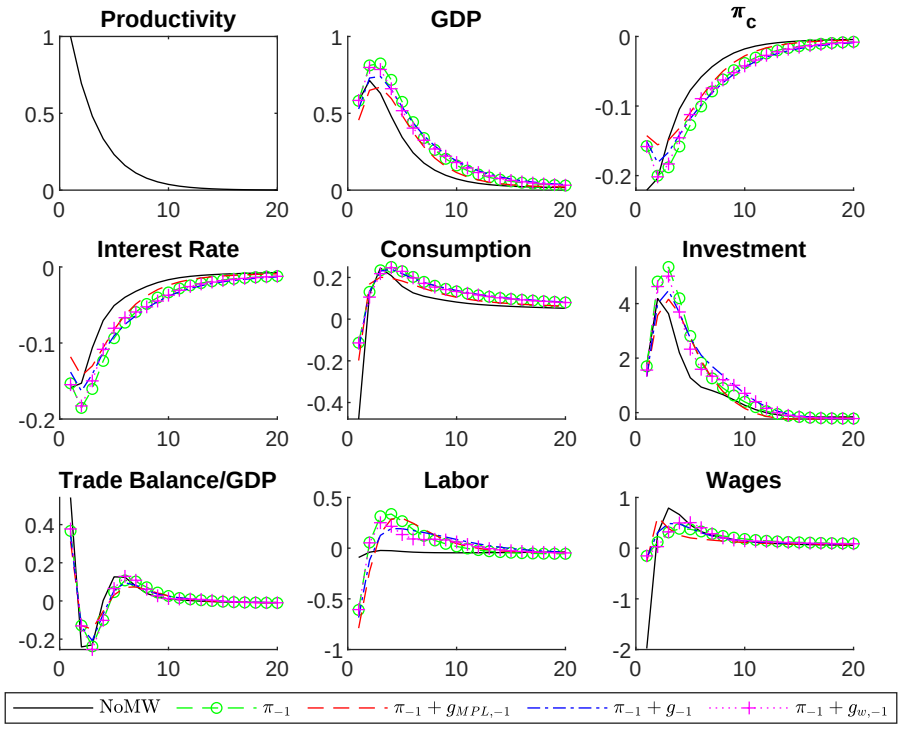

Figure 6: Impulse Response Functions to a 1% Total Factor Productivity (TFP) Shock.

Alternative minimum wage rules. Except Trade Balance, variables are expressed in log deviations from the steady state.

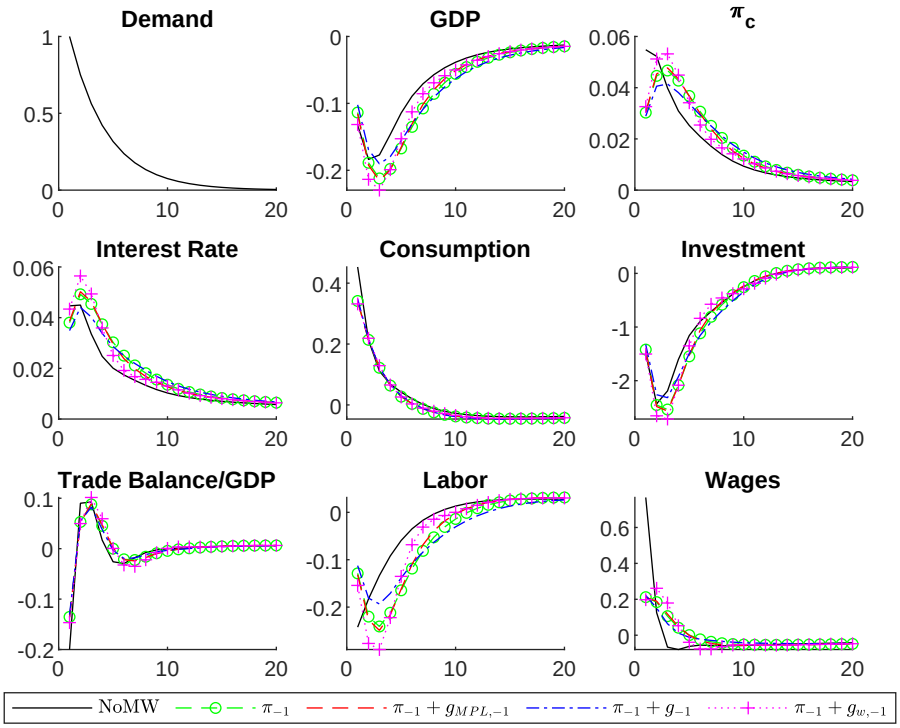

Figure 7: Impulse Response Functions to a 1% Demand Shock.

Alternative minimum wage rules. Except Trade Balance, variables are expressed in log deviations from the steady state.

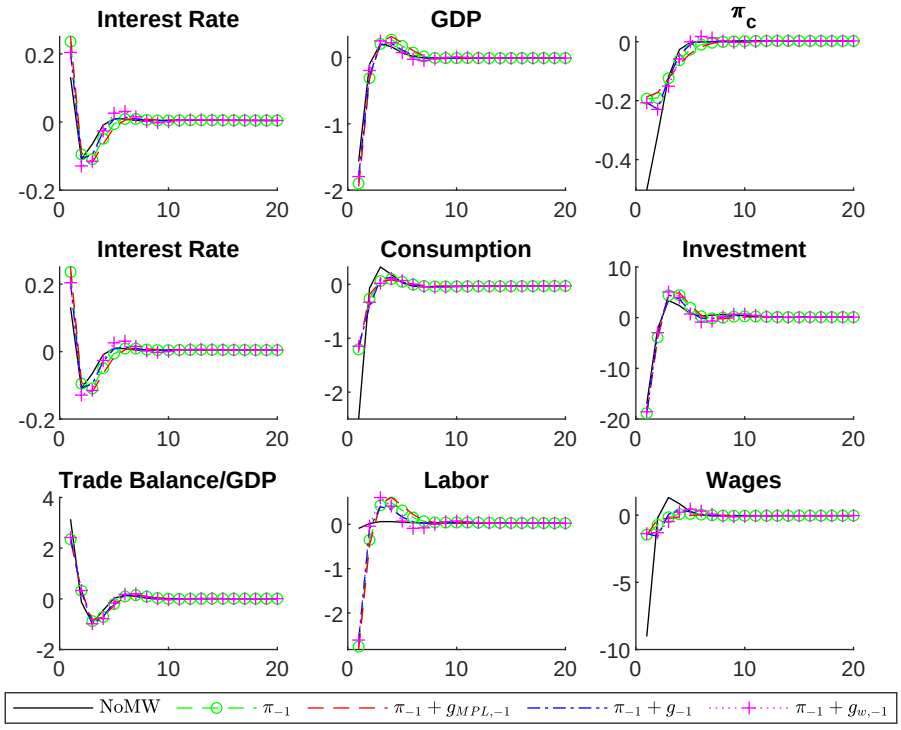

Figure 8: Impulse Response Functions to a 1% Monetary Policy Shock.

Alternative minimum wage rules. Except Trade Balance, variables are expressed in log deviations from the steady state.

6 Conclusions

This paper studies the macroeconomic effects of the minimum wage in a typical small, open, emerging economy and complements the existing literature, which focuses mainly on developed economies. Several characteristics of emerging economies make the minimum wage more relevant and potentially more disruptive than in developed economies. These include higher levels of informality, lower labor productivity, and higher minimum wages relative to the median wage. To study the effects of the minimum wage in emerging economies, we extend a New Keynesian small open economy model to incorporate some characteristics of emerging markets, such as labor informality, "hand-to-mouth" consumers, a flexible production structure that includes different types of labor and capital, and a minimum wage for low-skilled formal workers. We calibrate the model for Colombia, a typical emerging economy with high informality and a prominent minimum wage institution.

First, we analyze the response to an unexpected minimum wage shock. We find that the increase has a significant effect on the labor market for low-skilled workers, both formal and informal. The shock reduces the demand for low-skilled formal workers earning the minimum wage, who are substituted by informal workers and machines. This substitution cushions the negative impact on economic activity and only a moderate contraction in output is observed. The consumption response of low-skilled workers is time-dependent. In the short run, an increase in the minimum wage has a positive effect on their consumption due to labor market rigidities that make it difficult for firms to substitute low-skilled formal workers. However, as these frictions diminish, low-skilled workers are replaced and their incomes fall, leading to a contraction in their consumption in the long run. We observe a small response in terms of inflation and monetary policy.

Second, we examine the macroeconomic response to traditional shocks such as productivity, demand, and monetary policy. Our results suggest that the minimum wage increases the persistence of macroeconomic responses and that most labor market adjustments occur through quantities rather than wages. We also find that monetary policy is less effective in controlling inflation in the short run due to the rigidities created by the minimum wage.

Finally, we explore whether the effects of shocks change under alternative minimum wage adjustment rules. The response of the economy is qualitatively similar under alternative rules; however, the nature of the shock is important for analyzing the quantitative response. While a productivity, demand, or minimum wage shock generates higher volatility under the rule that accounts for wage inflation, there is no difference in the responses of the variables to the monetary policy shock. Thus, the adjustment rule can play an important role depending on the nature of the shock; while there is no difference for a monetary policy shock, the volatility of the responses depends on the rule.

Our research highlights the macroeconomic implications of minimum wage policies in emerging economies. We find that the effects of the minimum wage on key macroeconomic variables, as well as the channels through which it operates in emerging economies, differ from those documented in studies focused on developed countries. Our findings have important implications for policymakers in emerging economies considering minimum wage increases or changes in their adjustment rules.

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A Appendix: Sensitivity

We explore how our main results change when we modify some of the model assumptions, that are more consistent with standard models of real business cycles. In particular, we consider four scenarios that include: *i.* no machines (only one type of capital - buildings), ii. no informal labor (low-skilled households only offer formal labor), and iii. only one type of household with three types of labor. In all cases we re-calibrate the model to target the same moments, Table A.1 reports the calibrated parameters for each alternative version of model.

Table A.1: Calibrated Parameters. Alternative Models.

Parameter	Benchmark	NoK_x	No Infor.	One HH
$\psi_I = \psi_F$	3.73	4.30	3.44	0.69
α	0.25	0.39	0.25	0.25
θ	0.30	0.14	0.29	0.29
θ_L	0.16	0.16	N/A	0.25
θ_m	0.34	N/A	0.33	0.40
w_{min}	0.39	0.39	0.39	0.19
A	1.05	0.67	1.08	0.63

Figure A.1 shows the results of the main macroeconomic variables for the benchmark model and the alternative scenarios. As we can see, all the specifications are qualitatively consistent for the main macroeconomic aggregates (GDP, consumption, employment, policy interest rate and inflation), however, the magnitudes differ across scenarios. On the one hand, when low-skilled workers can only offer one type of labor, the increase in the minimum wage pushes firms to substitute formal low-skilled workers for machinery, which investment increases sharply. Due to the impossibility to increase their labor supply, low-skilled households see their employment and income fall. As a result, the contractionary effects of rising the minimum wage are magnified in this scenario. We also observe that the limited options of substitution generates an additional increase in wages, inflation and the policy interest rate. When we allow low-skilled households to offer informal labor, their drop in income forces them to increase the informal labor supply, which pushes informal wages down and dampens the inflationary effects of the policy. On the other hand, when we only consider one type of capital, the contractionary effects of the minimum wage increase are reduced. Under this scenario, higher formal low-skilled wages pushes firms to hire more informal workers, and low-skilled households do not experience a drop in income after the shock. As a result, low-skilled consumption increases and the drop in aggregate consumption is smaller (than in the other scenarios). This relatively higher demand causes output and employment to fall less. For the remaining scenario, we consider only one type of household that offers three different types of labor: formal high-skilled, formal low-skilled, and informal low-skilled. In this case, the representative household can perfectly smooth consumption and can adjust its labor supply decisions. Relative to the benchmark scenario consumption and employment fall less cause a smaller reduction in GDP.

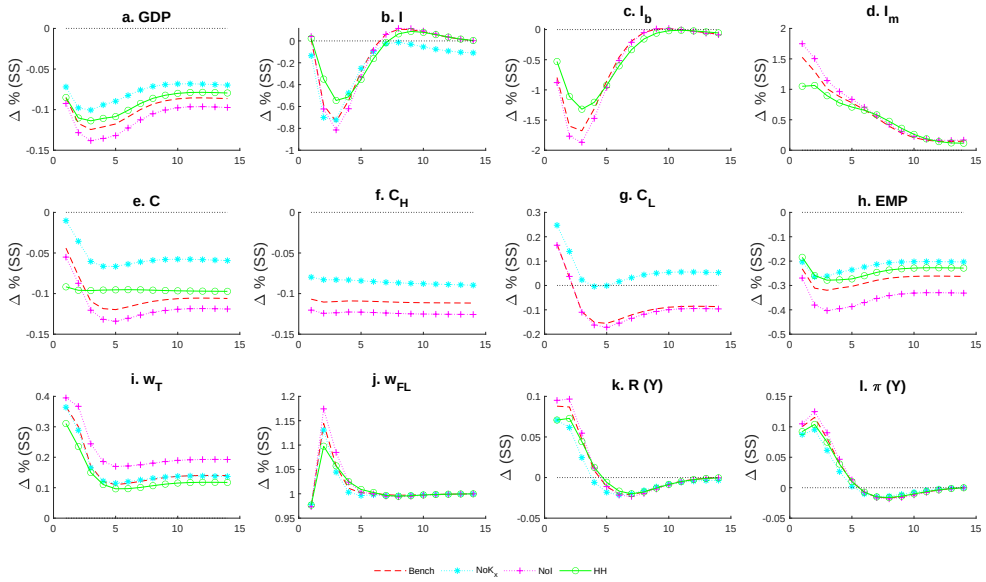

Figure A.1: Impulse Response of Main Macroeconomic Aggregates to a 100 bp increase in the minimum wage.

The vertical axis shows the percentage difference with respect to the initial steady state except for the interest rate, R, and inflation, π (absolute difference - annualized). Bench stands for the benchmark model, NoK_x for a model without machines, NoI for a model without informality, and HH for a model with only one household.

B Appendix: Transitory

Following the literature for developed economies (Šauer, 2018; Glover, 2019), in this section we analyze the macroeconomic effects of a transitory shock in the minimum wage. For this, we consider the the real minimum wage does not adjust according to past inflation and labor productivity, and it is only affected by a transitory shock that follows and AR1 process. The remaining structure of the model stays the same. As seen in FigureB.1 the results are qualitatively consistent with our benchmark case. However, the initial response of all the variables is different. For instance, investment in machinery increases less (1% vs 2%), while inflation and the monetary policy interest rate raise more. Under this scenario, firms know that the shock is transitory, and the minimum wage will eventually return to the same initial level. Therefore, they do not have the same incentives to invest in machinery and substitute a large fraction of their formal low-skilled labor. As a result, formal low-skilled labor falls less than 1% on impact. Less substitution has an impact on short-run inflation, which increases more than in the benchmark case, and causes the MP interest rate to react more.

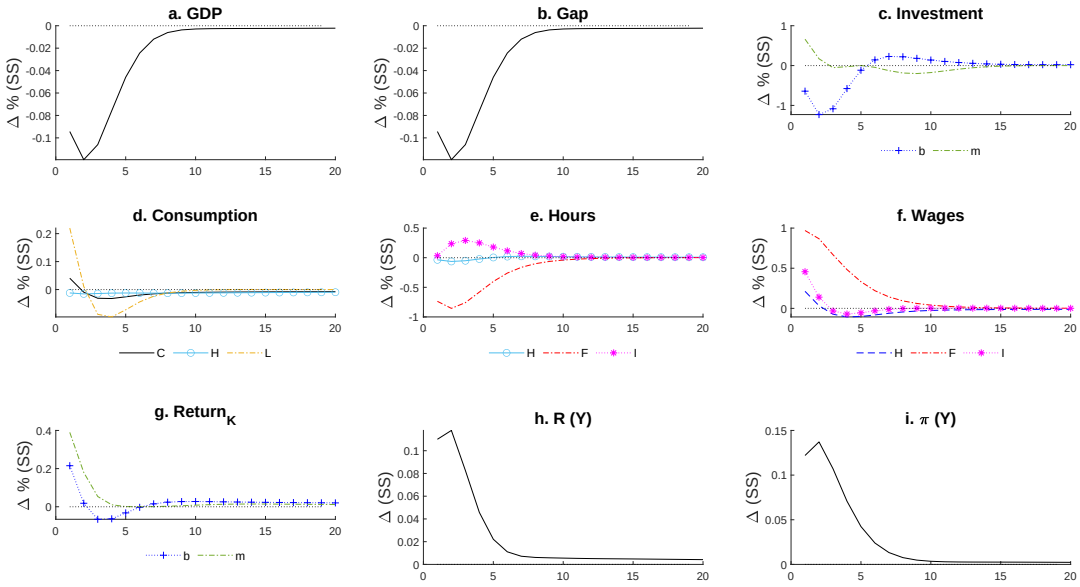

Figure B.1: Impulse Response of Main Macroeconomic Aggregates to a 100 bp transitory increase in the minimum wage.

Note: The vertical axis shows the percentage difference with respect to the initial steady state except for the interest rate, R, and inflation, π (annualized absolute difference). H stands for High-skilled, F for formal low-skilled, I for informal, and L for low-skilled.