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Abstract

We develop a small open economy model with nominal rigidities and fragmented labor markets to study the response of monetary policy to a migration shock. The migrants in our model are characterized by relatively low productivity, lack of access to financial markets, and wage flexibility. Our findings indicate that the response of monetary policy depends on the characteristics of both migrants and the local labor market. An inflow of low (high)-productivity workers reduces (increases) marginal costs and reduces (increases) inflation expectations, prompting the central bank to reduce (increase) the interest rate. We calibrated the model to match certain characteristics of the Colombian economy and analyzed the effects of an inflow of financially constrained workers to a sector with flexible and low wages. The model proposed captures the main features of the migration episode that occurred between 2014 and 2019. During this period, approximately 1.9 million Venezuelans migrated to Colombia.

JEL classification: E13, J31, J46, J61, E50.

Keywords: Neoclassical model, wage differentials, informal labor markets, migration, monetary policy, heterogeneous agents.

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Migración y política monetaria: Un análisis para una economía pequeña y abierta

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Resumen

En este artículo desarrollamos un modelo de pequeña economía abierta con rigideces nominales y mercados de trabajo fragmentados para estudiar la respuesta de la política monetaria a un choque migratorio. Los inmigrantes de nuestro modelo se caracterizan por una productividad relativamente baja, falta de acceso a los mercados financieros y flexibilidad salarial. Nuestros resultados indican que la respuesta de la política monetaria depende de las características tanto de los inmigrantes como del mercado laboral local. Una llegada de trabajadores de baja (alta) productividad reduce (aumenta) los costos marginales y reduce (aumenta) las expectativas de inflación, lo que lleva al banco central a reducir (aumentar) la tasa de interés. Calibramos el modelo para ajustarlo a ciertas características de la economía colombiana y analizamos los efectos de la llegada de trabajadores con restricciones financieras a un sector con salarios flexibles y bajos. El modelo propuesto captura las principales características del episodio migratorio ocurrido entre 2014 y 2019. Durante este periodo, aproximadamente 1,9 millones de venezolanos migraron a Colombia.

Clasificación JEL: E13, J31, J46, J61, E50

Palabras clave: modelo neoclásico, diferenciales salariales, mercados informales de trabajo, migración, política monetaria

1 Introduction

From 2014 to 2019, Venezuela experienced a significant exodus of approximately five million people due to severe socioeconomic decline. This event, characterized by the World Bank (2018a) as the largest migration in Latin America and one of the largest in the world, occurred in a remarkably short period of time. Colombia, due to its geographical proximity, became the main destination for these migrants.[1] During this period, Colombia's working-age population increased by 1.9 million migrants. In particular, 1.3 million of these migrants found employment mainly in low-capital-intensity industries characterized by a high incidence of informal employment contracts and low wages.[2]

Economic studies have examined the impact of migration shocks on local labor markets, finding increases in output and mixed effects on wages and employment (Becker and Ferrara 2019; George J Borjas et al. 1997; George J. Borjas 2003; Card and DiNardo 2000; Card 2001; S. P. Kerr and W. R. Kerr 2011; Latif 2015). Battisti et al. (2018), Moreno-Galbis and Tritah (2016), and Iftikhar and Zaharieva (2019) suggest that the willingness of immigrants to work for lower wages than native workers increases firm profits and stimulates employment growth for both native and immigrant workers. While recent research has shifted the focus to other macroeconomic factors such as consumption and investment, the impact on inflation, the output gap, and monetary policy remains unexplored. Migration, by increasing labor supply, affects both long-run potential output and the short-run output gap, thereby affecting monetary policy.[3][4] The ultimate impact on inflation remains uncertain due to the simultaneous effect of migration on short-term demand and supply.

From the perspective of a central bank in a small open economy (SOE), migration inflows represent an additional source of economic volatility. This paper presents a quantitative model to study the macroeconomic impact of a migration shock in an SOE and its implications for monetary policy. We propose a general equilibrium model with heterogeneous agents (formal and informal) that differ in their wage rigidity, access to financial markets, and productivity levels. In particular, formal agents have higher productivity, rigid wages, and access to financial markets, while informal agents have flexible wages and live paycheck to paycheck.

Our study examines the impact of the recent influx of Venezuelan workers into Colombia using our SOE model. We first calibrate the model to reflect certain aspects of the Colombian economy, including the split between formal and informal workers. We then simulate a scenario in which there is a permanent 10% increase in informal workers and assess the macroeconomic implications.[5]

Our results indicate that while there is a positive impact on output, consumption, and investment, these increases are less than population growth, leading to a decline in per capita indicators. From an inequality perspective, hand-to-mouth consumers experience a decline in both consumption and wages, leaving them worse off.[6]

Due to wage rigidity, firms hire fewer workers than they would under a flexible price equilibrium, resulting in a negative output gap. Inflation falls slightly as marginal costs fall with the increase in the supply of informal labor. This leads to a moderately expansionary monetary policy response.

We also examine an alternative scenario involving an influx of formal workers. The overall effects on output, consumption, and investment are similar, but more pronounced because the shock comes from workers with higher productivity. In this case, despite a negative output gap, inflation rises as formal wages remain stable due to nominal rigidities. This requires a stronger monetary policy response to contain inflation.

[1] Colombia and Venezuela share a terrestrial and fluvial border with seven official border crossings and more than a hundred underground routes used for clandestine border crossings.

[2] In 2019, migrants represented 5% of Colombia's working-age population (WAP), according to Migración Colombia and the National Administrative Department of Statistics.

[3] See Coleman and Landon-Lane (2007), Smith and Thoenissen (2019), and Lozej (2019)

[4] The Central Bank of Chile recently revised its projections for potential output, taking into account the impact of migration from Venezuela. The updated projections revealed a negative output gap, which was caused by the economy's slow adjustment to absorb the increase in labor supply and other structural changes. As a result, the Central Bank lowered its interest rate by 50 basis points, in response to the fall in the neutral monetary policy rate (Central Bank of Chile 2019).

[5] After 2019, but before the COVID-19 pandemic, the official migration projections corresponded to the size of the inflow shock.

[6] Our results on real variables and the wage gap are similar to those reported in Canova and Ravn (2000).

Empirical studies by the World Bank (2018a), World Bank (2018b), and IMF (2019) have examined the impact of Venezuelan migration on several Latin American economies, finding a positive impact on GDP growth and an increase in informality.[7] VAR and general equilibrium models have been used to study the macroeconomic consequences of migration shocks. Coleman and Landon-Lane (2007), Smith and Thoenissen (2019), and Lozej (2019) report positive effects on aggregate GDP, consumption, and investment, while Boubtane, Coulibaly, and Rault (2012) and Kiguchi and Mountford (2019) suggest that the effect on GDP per capita is ambiguous.

Theoretical models by Canova and Ravn (2000), Ben-Gad (2004), Hazari and Sgro (2003), Burda (2006), and Palivos and Yip (2010) show that a migration shock involving low-skilled workers positively affects the wages and employment of high-skilled workers, but negatively impacts the wages, employment, and welfare of low-skilled workers. These studies emphasize that the degree of substitution between migrant and native workers significantly determines the impact of migration on wages, consumption, and investment. In addition, Canova and Ravn (2000) and Palivos and Yip (2010) find that in an SOE, immigration shocks increase the return to capital and exacerbate the income gap between high- and low-skilled workers. Finally, Calderón-Mejía and Ibáñez (2016) and Morales (2018) study internal migration caused by the armed conflict in Colombia and find adverse effects on unskilled wages in urban areas.

The paper is organized as follows: Section 2 presents the theoretical general equilibrium model, examining both scenarios with and without nominal rigidities. Section 3 analyzes Venezuelan migration between 2014 and 2019, using a Bayesian vector autoregression (BVAR) model that incorporates key domestic and international macroeconomic variables. In Section 4, we calibrate the model to the Colombian economy and examine the impact of migration shocks on macroeconomic indicators, followed by an examination of the subsequent monetary policy response. Section 5 presents robustness tests and counterfactual experiments. The paper concludes with final remarks in Section 6.

2 Model

We introduce an SOE model to analyze the main transmission channels of a permanent migration shock and its implications for monetary policy, focusing in particular on changes in inflation and the output gap. First, we establish a benchmark model with a fragmented labor market and flexible prices. This model provides insights into the real effects of the migration shock. We then extend this framework to include nominal rigidities and a central bank that conducts monetary policy based on a standard Taylor rule.

2.1 Small Open Economy with fragmented labor market

The model considers an economy with two groups of households: *Formal (F)* and *Informal (I)*. These groups differ in their capital and firm ownership, labor productivity, and access to financial markets. On the production side, a representative firm uses capital and labor to produce final goods, which are allocated to consumption, investment, and net exports.

Formal agents own capital (k_F), make investment decisions (i_F), provide formal labor hours (h_F), consume (c_F), access international financial markets, and receive profits from firms (Π_t). These agents are characterized by an exogenous mass of individuals N_F. The optimization problem for a representative formal agent is given by:

$$\max_{c_F, i_F, h_F, k_F, d_F} \quad \sum_{t=0}^{\infty} \beta^t \left(\frac{c_{F,t}^{1-\sigma}}{1-\sigma} - \frac{\eta_F}{\eta_F - 1} h_{F,t}^{\frac{\eta_F - 1}{\eta_F}} \right), \tag{1}$$

subject to the budget constraint, the law of motion of capital, and the debt-elastic foreign interest rate (equations

[7] Valencia et al. (2020) analyze the same migration process focusing on the effect on Colombian fiscal variables.

2 and 3),[8]

$$P_t(c_{F,t} + i_{F,t}) + R_t^* d_{F,t+1} = W_{F,t}h_{F,t} + R_t k_{F,t} + d_{F,t} + \frac{\Pi_t}{N_{F,t}}, \tag{2}$$

$$k_{F,t+1} = (1-\delta)k_{F,t} + i_{F,t} - \frac{\phi}{2}\left(\frac{i_{F,t}}{i_{F,t-1}} - 1\right)^2, \text{ where} \tag{3}$$

$$R_t^* = (R^*\mu)^{\phi_d exp\left(\frac{D_t}{Y_t} - \overline{D}_Y\right)} \tag{4}$$

is the debt-elastic interest rate. From the first order conditions (F.O.C.) we obtain standard relationships for the marginal rate of substitution between leisure and consumption (equation 5), along with the Euler equations of capital and foreign bonds (equations 6 and 7),

$$\frac{h_{F,t}^{-1/\eta_F}}{c_{F,t}^{-\sigma}} = \frac{W_{F,t}}{P_t}, \tag{5}$$

$$c_{F,t}^{-\sigma} = Q_t\left(1 - \frac{\phi}{2}\left(\frac{i_{F,t}}{i_{F,t-1}} - 1\right)^2 - \phi\left(\frac{i_{F,t}}{i_{F,t-1}} - 1\right)\frac{i_{F,t}}{i_{F,t-1}}\right) + \beta E_t Q_{t+1}\phi\left(\frac{i_{F,t+1}}{i_{F,t}} - 1\right)\frac{i_{F,t+1}}{i_{F,t}}, \tag{6}$$

$$c_{F,t}^{-\sigma} = \beta E_t c_{F,t+1}^{-\sigma} R_{t+1}^*, \text{ where} \tag{7}$$

$$Q_t = \beta E_t\left(c_{F,t+1}^{-\sigma} R_{t+1} + Q_{t+1}(1-\delta)\right), \tag{8}$$

$d_{F,t}$ is the foreign bond, $W_{F,t}$ is the wage of formal workers, and R_t and P_t are the prices of capital and final goods (consumption and investment). Additionally, Y_t represents the level of GDP while the aggregate bond level is defined by $D_t = N_{F,t}d_{F,t}$. Table 1 lists the model parameters.

[Table 1 about here.]

In contrast, the exogenous mass of informal agents, N_I, consists of *hand-to-mouth* individuals who consume (c_I), provide informal labor hours (h_I), and receive labor income $(W_I h_I)$, where (W_I) is the informal wage. Informal agents have no access to foreign financial markets or capital ownership. The static optimization problem of a representative informal agent is given by:

$$max_{c_I, h_I} \quad \left(\frac{c_{I,t}^{1-\sigma}}{1-\sigma} - \chi_I \frac{\eta_I}{\eta_I - 1} h_{I,t}^{\frac{\eta_I - 1}{\eta_I}}\right), \tag{9}$$

subject to

$$P_t c_{I,t} = W_{I,t} h_{I,t}. \tag{10}$$

From the F.O.C and the budget constraint (Equation 10), we can express the informal labor supply as a function of the real wage. The sign of

$$\sigma_I = \frac{(1-\sigma)\eta_I}{\eta_I\sigma - 1}$$

determines the labor-wage elasticity. A negative σ_I implies an inverse relationship between wages and hours,

$$h_{I,t} = \left(\frac{1}{\chi_I}\right)^{\frac{\eta_I}{\eta_I\sigma - 1}} \left(\frac{W_{I,t}}{P_t}\right)^{\frac{(1-\sigma)\eta_I}{\eta_I\sigma - 1}}. \tag{11}$$

[8] The debt-elastic interest rate follows Schmitt-Grohé and Uribe (2003).

We assume that firms are perfectly competitive and hire capital (K_t), formal $(L_{F,t})$ and informal $(L_{I,t})$ labor, to produce an homogeneous final good for consumption and investment. We use a constant elasticity of substitution (CES) production function to aggregate formal and informal labor inputs (Lewis and Peri 2015). Following Fallon and Layard (1975), Krusell et al. (2000), and Canova and Ravn (2000), we define the production technology of the representative firm as:

$$Y_t = AK_t^{\alpha}\left(\left(\nu^{\frac{1}{\xi}}\left(L_{F,t}\right)^{\frac{\xi-1}{\xi}} + (1-\nu)^{\frac{1}{\xi}}\left(L_{I,t}\right)^{\frac{\xi-1}{\xi}}\right)^{\frac{\xi}{\xi-1}}\right)^{1-\alpha}, \tag{12}$$

where A is total factor productivity, and the aggregate levels of capital and formal and informal labor are $K_t = N_{F,t}k_{F,t}, L_{F,t} = N_{F,t}h_{F,t}, L_{I,t} = N_{I,t}h_{I,t}$. Firms optimally allocate production factors according to:

$$W_{F,t} = (1-\alpha)\nu^{\frac{1}{\xi}}Y_t L_t^{\frac{1-\xi}{\xi}} L_{F,t}^{\frac{1}{\xi}}, \tag{13}$$

$$W_{I,t} = (1-\alpha)(1-\nu)^{\frac{1}{\xi}}Y_t L_t^{\frac{1-\xi}{\xi}} L_{I,t}^{\frac{1}{\xi}}, \tag{14}$$

$$R_t = \alpha\frac{Y_t}{K_t}, \text{ where} \tag{15}$$

$$L_t = \left(\nu^{\frac{1}{\xi}}\left(L_{F,t}\right)^{\frac{\xi-1}{\xi}} + (1-\nu)^{\frac{1}{\xi}}\left(L_{I,t}\right)^{\frac{\xi-1}{\xi}}\right)^{\frac{\xi}{\xi-1}}. \tag{16}$$

The aggregate equilibrium implies that total production is used for consumption by formal and informal agents, investment, and net exports $Y_t = C_{F,t} + C_{I,t} + I_t + NX_t$, where the aggregate levels of consumption, investment, and net exports are defined by $C_{F,t} = N_{F,t}c_{F,t}, C_{I,t} = N_{I,t}c_{i,t}, I_t = N_{F,t}i_{F,t}$, and $NX_t = d_{F,t+1}N_{F,t} - R_t^* d_{F,t}N_{F,t-1}$, respectively. The population masses of each agent type follow exogenous processes: $N_{F,t} = \overline{N}_F + \epsilon_{F,t}$ and $N_{I,t} = \overline{N}_I + \epsilon_{I,t}$ where $\epsilon_{i\in\{F,I\},t}$ is a shock.

2.2 Small Open Economy with Nominal Rigidities

We build on the model in Subsection 2.1 by adding three features: *i)* formal wages result from a bargaining process between an intermediary and firms, creating wage rigidity; *ii)* prices are rigid due to heterogeneous firms that follow a Calvo pricing rule, and *iii)* a central bank that reacts to both inflation and the output gap. Wage rigidity in formal labor reflects the institutional constraints (e.g. minimum wage) that hinder immediate wage adjustments. The rest of the model is identical to the one described in Subsection 2.1. Table 2 defines the additional parameters.

[Table 2 about here.]

Following Erceg, Henderson, and Levin (2000), we model formal workers as wage-setters who supply differentiated labor under monopolistic competition. Each period, a random signal allows a fraction $\left(1-\epsilon^{W_F}\right)$ of these workers to adjust their wages, while the rest keep them constant. An employment agency aggregates the differentiated labor into a homogeneous factor (h_F) and supplies it to firms under perfect competition. The demand for each type of labor $(h_{F,t}(j))$ and the aggregate formal wage $(w_{F,t})$ are given by

$$h_{F,t}(j) = \left(\frac{w_{F,t}(j)}{w_{F,t}}\right)^{-\theta^{W_F}} h_{F,t}, \text{ and}$$

$$w_{F,t} \equiv \left[\int_0^1 w_{F,t}(j)^{1-\theta^{W_F}}\,dj\right]^{\frac{1}{1-\theta^{W_F}}}.$$

Formal agents face an optimization problem that depends on whether they can adjust their wages based on an exogenous signal. In each period, a fraction $\left(1-\epsilon^{W_F}\right)$ of them chooses their optimal wage $\left(w_{F,t}^*\right)$, while

the rest updates their wage according to past inflation. In contrast to the benchmark model, agents can trade domestic bonds $b_{F,t}$ that have zero net supply, which changes the budget constraint in Equation 2 as follows:

$$P_t(c_{F,t} + i_{F,t}) + R_t^* d_{F,t+1} + R_t^b b_{F,t+1} = W_{F,t} h_{F,t} + R_t k_{F,t} + d_{F,t} + b_{F,t} + \frac{\Pi_t}{N_{F,t}}. \tag{17}$$

The Euler equation $c_{F,t}^{-\sigma} = \beta E_t c_{F,t+1}^{-\sigma} R_{t+1}^b$ shows the household equilibrium condition for domestic bonds, where R_{t+1}^b is the expected real return of domestic bonds. The Fisher equation

$$R_t^b = \frac{1 + i_t}{1 + E_t \pi_{t+1}}$$

defines R_t^b as a function of the nominal interest rate (i_t) set by the central bank and the expected inflation $(E_t \pi_{t+1})$. The rest of the optimal conditions are unchanged. The real wage for agents who cannot adjust their wages follows the rule

$$w_{F,t}^{rule}(j) = w_{F,t-1}(j) \frac{1 + \pi_{t-1}}{1 + \pi_t}.$$

The aggregate formal wage is the composite of the wages of the agents who follow the rule and the agents who can adjust their wages optimally, as given by

$$w_{F,t} = \left[\epsilon^{W_F} \left(w_{F,t}^{rule} \right)^{1-\theta^{W_F}} + \left(1 - \epsilon^{W_F}\right) \left(w_{F,t}^* \right)^{1-\theta^{W_F}} \right]^{\frac{1}{1-\theta^{W_F}}}$$

The informal agents have flexible wages and their optimization problem is the same as in equations 9 to 11.

We assume that a continuum of differentiated firms, indexed by $m \in (0, 1)$, produce goods in a monopolistic competitive market. This gives them market power to set prices à la Calvo (1983). Each firm uses capital (K_t), formal $(L_{F,t})$, and informal $(L_{I,t})$ labor to produce a differentiated good $(y\,(m))$. Each period, a random fraction of firms, $\left(1 - \epsilon^Y\right)$, receive a random and exogenous signal and optimally set prices $(p_t\,(m))$. The optimal factor demands are given by equations 13 to 15. Due to their market power, firms set prices based on the demand curve

$$y_t^s(m) = \left(\frac{p_t(m)}{p_t} \right)^{-\theta^Y} y_t^d \text{ where}$$

$$y_t^d = \left[\int_0^1 y_t^s(m)^{\frac{\theta^Y}{\theta^Y - 1}} dm \right]^{\frac{\theta^Y - 1}{\theta^Y}}$$

is the gross output demand, and

$$p_t = \left[\int_0^1 p_t(m)^{1-\theta^Y} dm \right]^{\frac{1}{1-\theta^Y}}$$

is the aggregate price. Firms that adjust prices operate under identical constraints and have identical technology; therefore, they set the same optimal price, (p_t^*). The rest of the firms adjust their prices according to $p_t^{rule}(m) = p_{t-1}(m)(1 + \pi_{t-1})$. These assumptions imply the following expression for the inflation rate,

$$(1 + \pi_t) = \left[\left(1 - \epsilon^Y\right) \left(\frac{p_t^*}{p_t} \right)^{1-\theta^Y} (1 + \pi_t)^{1-\theta^Y} + \epsilon^Y \left(1 + \pi_{t-1}\right)^{1-\theta^Y} \right]^{\frac{1}{1-\theta^Y}}. \tag{18}$$

Finally, the central bank sets the short-term nominal interest rate according to a simple standard Taylor (1993) rule that responds to inflation and the output gap,

$$i_t = \rho^i i_{t-1} + \left(1 - \rho^i\right) \left(\bar{i} + \varphi^\pi \left(\pi_{t+3}^4 - \bar{\pi} \right) + \varphi^Y \left(Y_t - Y_t^{flex} \right) \right), \tag{19}$$

where ρ^i represents the smoothing parameter of the short-term nominal interest rate, while $\bar{i}$ denotes its long-run steady-state value, wherein both inflation and output attain their long-run values. The parameters φ^π and φ^Y determine the degree to which the central bank responds to deviations of inflation expectations from the inflation target $\left(\pi^4_{t+3} - \bar{\pi}\right)$, and to deviations of output from its flexible price level $\left(Y_t - Y_t^{flex}\right)$. Monetary policy affects the economy through investment and savings decisions.

3 Migration from Venezuela to Colombia (2014-2019): Characterization & Effects

Recent migration from Venezuela to Colombia started in 2014 and resulted in 2.4 million people migrating as of the end of 2019.[9] Migration accelerated in 2017 following a significant decline in international oil prices of 46% in 2015 and 16% in 2016, which led to a reduction in Venezuelan government income and contributed to the worsening of the economic crisis in Venezuela.

Immigrants from Venezuela differ from native Colombians in terms of labor market characteristics. They have a higher labor force participation rate (84% compared to 80%), are younger (27 years old on average compared to 32) and have higher employment rates (72% compared to 59%). In general, immigrants tend to gravitate towards traditionally low-capital, informal sectors such as restaurants and hotels, communal and private services, retail trade and construction. In the latter two sectors, immigrant employment rates exceed those of native workers. However, this participation comes at a cost, with nearly 90% of immigrants not contributing to social security and over 60% earning below the minimum wage.

The low and uncertain income of migrants, along with their consumption needs, severely limits their opportunities to save and access formal financial markets. It is not surprising that this presents a challenge as only 42% of migrants in Colombia have legal status, effectively preventing most of them from opening bank accounts or accessing public assistance programs.

To analyze the effect of migration on the Colombian economy, we divided the population into two groups: formal and informal. The latter group is similar in characteristics to migrants. We defined the informal group as workers with earnings below 1.1 times the minimum wage, and the formal group as workers with earnings above this threshold.[10] Between 2014 and 2019, 56.7% of Colombian workers were informal, with earnings corresponding to 21.3% of the total labor income. The ratio of hourly wages between formal and informal workers was 3.7 .

To quantify the impact of the recent migration shock on Colombia's main macroeconomic variables, we estimated a Bayesian vector autoregressive (BVAR) model for the period 2010q1-2019q3.[11] We selected the variables and identification strategy based on the premise that Colombia is an SOE, which mainly exports commodities. We included both domestic and foreign variables, such as real GDP, core inflation, unemployment rate, real remittances, the ratio between formal and informal wages, the real GDP of Colombia's main trading partners, and the real price of oil. The latter two were considered exogenous due to the SOE assumption. Our choice of variables aimed to model the interrelationships between the main macroeconomic variables and two notable events that occurred between 2014 and 2018. The first event was the synchronization between the fall in oil prices, the economic slowdown of trading partners, the increase in migration from Venezuela,

[9] We consider migrants to be all GEIH respondents who reported living in Venezuela five years ago.

[10] Thresholds around the minimum wage can be understood as a measure of its compliance, given that in household surveys wages are directly reported by workers. However, they may report different values for the same question. For instance, their answer may reflect the actual amount of money they receive, that is, their wage minus the social security contributions paid by the employee, which in Colombia is approximately 90% of the wage. Another possible answer might be the wage stated in their verbal or written contract, and a third option might be their monthly wage plus transport subsidy, which is a compulsory cost for minimum wage workers and is approximately 10% of the minimum wage. We compute hourly wage dividing the monthly wage computed previously by the hours worked last week.

[11] Examples of the use of structural VAR models to study the effects of migration are found in Boubtane, Coulibaly, and Rault (2012), Coleman and Landon-Lane (2007), D'Albis, Boubtane, and Coulibaly (2017), Furlanetto and Robstadb (2019), Kiguchi and Mountford (2019), Partridge and Rickman (2006), and Smith and Thoenissen (2019).

and the growth in international remittances to Colombia. The second event was the break in early 2018 of the downward trend in the ratio between formal and informal wages, which coincided with the increase in the rate of migration to Colombia (Figure 9 in the Appendix).

Given the relatively small number of observations and the large number of parameters to be estimated, we chose to use Bayesian techniques.[12] Specifically, we employed normal diffuse priors to allow the likelihood of the data to dominate the estimation process. The time series were seasonally adjusted and specified in levels.[13] Additionally, the unemployment rate and annual core inflation were expressed in percentage points (pp), while the other variables were expressed in logarithms. The shocks were identified through the Cholesky decomposition, with the most exogenous variables ordered first: GDP of trading partners, real oil price, migrant population, real remittances, real GDP, unemployment rate, wage gap, core inflation.[14] Under the assumption of Colombia as a SOE, we imposed exogeneity for migration, real GDP of the main trading partners, and the real price of oil by means of block exogeneity.[15]

Figure 1 shows the response of variables to a 10% increase in the immigrant population, equivalent to the arrival of 200,000 people, for two model versions, with and without sign restrictions for unemployment (unconditioned and conditioned models). The annual core inflation and unemployment rate responses are expressed in basis points (bp), while the rest of the variables are expressed as pp. The results suggest the migration shock is highly persistent as its effects on the immigrant population disappear only about five years after the shock.

The unconditioned model shows that real GDP increases by almost 0.1% on impact and remains significant for four years. The migration shock reduces the unemployment rate by 5.3 bp on impact, but this effectdisappears after two quarters. This is consistent with the findings of Furlanetto and Robstadb (2019), Peri (2012), Armstrong and McDonald (2016), and D'Albis, Boubtane, and Coulibaly (2018). The wage gap between formal and informal workers increases by 0.6% and remains positive for almost two years. Immigrants increase the supply of informal labor, which puts downward pressure on informal wages and increases the wage gap, as mentioned in Section 3. Finally, the migration shock causes a decrease in annual core inflation of almost seven bp, which is significant for almost three years. This decrease in inflation is associated with a reduction in labor costs through lower informal wages.[16]

[Figure 1 about here.]

The influx of working-age migrants raises the number of individuals searching for employment. If the economy cannot accommodate this influx of workers, an increase in the unemployment rate is expected, contrary to what is observed in the unconditioned model. To assess the robustness of our results to the direction of the unemployment response, we re-estimate the BVAR by imposing sign restrictions à la Arias, Rubio-Ramírez, and Waggoner (2018). This conditioning forces the unemployment rate to increase on impact in response to the migration shock. The conditioned model (red lines in Figure 1) shows a smaller and more persistent response of the unemployment rate. The effects on GDP, inflation, and the wage gap do not change significantly with respect to the unconditioned model; however, the wage gap only reacts after three quarters. In summary, an increase in the working-age immigrant population leads to an increase in real GDP and the wage gap between formal and informal labor, a reduction in core inflation, and a negligible effect on the unemployment rate for both the conditioned and unconditioned models.

[12] As usual, the BVAR includes constants in all its equations. Appendices A and B show a detailed description of the variables included as well as their behavior over time. The AIC criterion suggested including two lags.

[13] The results of the Bayesian approach are valid regardless of non-stationarity (Sims 1988; Sims and Uhlig 1991).

[14] Figure 9 in Appendix B shows the variables.

[15] We use the standard priors in the literature, namely: autoregressive coefficient, 0.8; overall tightness 0.1; cross-variable weighting, 0.5; lag decay, 2; exogenous variable tightness, 100 and block exogeneity shrinkage, 0.001. For the estimations we used 4000 iterations with 2000 burn-it iterations.

[16] In annualized terms, the increases in real GDP and the wage gap are 0.38% and 2.2%, respectively.

4 Application: The Colombian case

The model introduce in Section 2 captures key characteristics of the recent migration from Venezuela to Colombia. In particular, we consider the low wages earned by migrants and their limited opportunities for saving and investing.[17] To examine the macroeconomic effects of the inflow of informal workers, we calibrate a quarterly version of the model to replicate some stylized facts of the Colombian economy.

We adopt most of the parameter values from González et al. (2011), Whalen and Reichling (2017), and Krusell et al. (2000). We then choose the remaining values to normalize the variables in the steady state or match specific ratios in the data (Table 3). Specifically, we choose the productivity level ($\overline{A}$) to normalize GDP to one, establish the mass of formal agents as one ($\overline{N}_F = 1$), and the debt-to-GDP ratio at 50% ($\overline{D}_Y = -50\%$).[18] Finally, we calibrate the mass of informal agents $\overline{N}_I$, the factor bias for formal labor in final goods production ν, and the scale parameter in informal agents' labor preferences χ_I to replicate the following ratios: *i)* the relative mass of formal workers

$$\frac{N_F}{N_F + N_I} = 0.43,$$

ii) the wage premium of formal agents

$$\frac{W_F}{W_I} = 3.71 \text{ and}$$

iii) the labor income share of formal agents

$$\frac{W_F L_F}{W_F L_F + W_I L_I} = 0.78.$$

[Table 3 about here.]

Three important implications of the parameter values are worth mentioning. First, formal and informal labor are imperfect complements in the production of final goods ($\xi = 0.8$). Second, firms use formal workers more intensively than informal workers ($v = 0.73$). Finally, due to its lower Frisch elasticity ($\eta_I = 2.5$), informal labor supply responds less to changes in wages.

4.1 Macroeconomic effects of an exogenous increase in the mass of informal workers

We analyze the effects of a permanent increase in the mass of informal agents, motivated by the facts described in Section 3. Specifically, we consider an initial unexpected increase of 5%, which continues to grow following a known linear trend to reach a total growth of 10% after two years, as shown in the first panel of Figure 2. In this figure, we also plot the effect on the total population and the dynamics of the main macroeconomic aggregates during the transition to the new equilibrium.

[Figure 2 about here.]

An increase in the mass of the informal population raises its labor supply and lowers its wage. This, in turn, allows firms to produce more and increase their demand for formal labor (imperfect complementarity), which increases their wages. In addition, higher informal employment reduces the capital-labor ratio and increases the marginal productivity of capital (price of capital).

Formal consumers benefit from higher wages and higher returns of capital, thus increasing consumption and investment (on impact and in the long run) and slightly reducing their labor supply (in the short run). In addition, they smooth their consumption by borrowing abroad, which increases the debt-to-GDP ratio and the trade deficit

[17] Most immigrants lack access to formal banking due to their undocumented status, unstable income and lack of credit history or credible collateral.

[18] We normalize the price of final goods to one, indicating that all prices are expressed in terms of final goods.

in the short term. On the other hand, informal agents are worse off due to lower wages, which implies lower individual consumption, thereby increasing their labor supply and further decreasing their wages. However, the total consumption of informal agents $N_I c_I$ increases because of the larger mass of informal consumers.

In summary, a permanent increase in the size of the informal population has a positive effect on consumption and investment, leading to an increase in GDP. However, this increase in GDP comes at the cost of greater inequality, as the dispersion of wages and individual consumption also increases, leaving informal agents worse off after the shock.

Despite the positive impact of migration shock on aggregate outcomes, GDP per capita declines in both the short and long run. The initial decrease in per capita output results from four factors: *i)* fixed capital in the short run, *ii)* low productivity of informal workers, *iii)* diminishing returns to scale, and iv) limited response of the formal labor force. Meanwhile, the long term decline in GDP per capita is determined by *i)* the Cobb-Douglas technology, *ii)* invariant capital-labor ratio (due to the constant marginal productivity of capital), and *iii)* the parameters associated with CES aggregation between formal and informal workers.

Changes in output are determined by changes in labor (L), because the Cobb-Douglas technology, together with the constant capital-labor ratio, implies that

$$Y = A\left(\frac{K}{L}\right)^{\alpha} L.$$

According to the CES aggregation between the two types of workers, we have:

$$\frac{\Delta Y}{Y_0} = \frac{\Delta L}{L_0} \approx \left(\left(\frac{\nu}{1-\nu}\right)^{1/\xi}\left(\frac{N_{F,0}h_{F,0}}{N_{I,0}h_{I,0}}\right)^{\frac{\xi-1}{\xi}} + 1\right)^{-1} \frac{\Delta N_I}{N_{I,0}} \approx 2.2\%.$$

We find that the fall in GDP per capita is approximately 3.6% by subtracting population growth,

$$\frac{\Delta N}{N_0} \approx \frac{N_{I,0}}{N_0}\frac{\Delta N_I}{N_{I,0}} \approx 5.8\%.$$

This effect depends on the comparison between

$$\left(\left(\frac{\nu}{1-\nu}\right)^{1/\xi}\left(\frac{N_{F,0}h_{F,0}}{N_{I,0}h_{I,0}}\right)^{\frac{\xi-1}{\xi}} + 1\right)^{-1} \text{ and } \frac{N_{I,0}}{N_0}.$$

Our calibration implies that the value on the left-hand side mainly depends on the factor bias for formal labor, (ν), and the elasticity of substitution between the two types of workers (ξ). The effect of factor bias is amplified because the elasticity of substitution is less than one. The economy is currently increasing the type of labor it uses less intensively, which leads to a fall in GDP per capita.

4.2 Macroeconomic effects of an exogenous increase in the mass of informal workers with nominal rigidities

We expand on the analysis in the previous section by incorporating nominal rigidities into the firms' pricing problem and formal wage setting, and a central bank that responds according to a standard Taylor rule.[19] This extension requires setting values for additional parameters, as shown in Table 4. We assume that formal wages adjust on average once every four quarters, reflecting institutional constraints in Colombia that do not allow for immediate adjustments.[20] To avoid taking an arbitrary stance on the relative degree of rigidity between wages and prices, we assume that firms adjust prices with the same frequency, that is, $1-\epsilon^Y = 0.25$. We calibrate the

[19] To account for price rigidities, we introduce monopolistic competition at the firm level. This addition does not affect the qualitative results of the previous section.

[20] Representatives from firms, the government, and unions negotiate the minimum wage in Colombia at the end of each year, and it becomes effective in January.

elasticity of substitution between product varieties, θ^Y, so that in the long run, the profit-to-GDP ratio equals 11.7%. Finally, the parameters of the Taylor rule imply that the Central Bank reacts more strongly to deviations in inflation expectations than to fluctuations in the output gap, ensuring adherence to the Taylor's principle.

[Table 4 about here.]

We used this setup to analyze the shock described in Subsection 4.1. We focused on the behavior of real and nominal variables for two versions of the model, with and without nominal rigidities (flexible prices, Figure 3). As in the benchmark case, the migration shock increases the supply of informal labor and reduces its wages; it also increases the demand for formal labor and capital. Due to nominal rigidities, formal wages increase less than in the flexible price model (2% vs. 2.4%), resulting in a relatively higher demand for factors of production, a slightly higher price of capital, and a positive output gap. The fall in informal wages and the slow adjustment of formal wagess leads to a lower present value of marginal costs and a reduction in inflation and inflation expectations.[21] As the central bank responds more strongly to inflation, it reduces the interest rate. Finally, the behavior of the per capita variables is similar to that observed in the benchmark model (Figure 4).

[Figure 3 about here.]

[Figure 4 about here.]

5 Robustness Checks & Counterfactual Experiments

5.1 Elasticity of substitution between formal and informal workers

In this section we examine how the elasticity of substitution between formal and informal workers affects our results. We consider two extreme values of ξ (0.5 and 2.0).[22] Figure 5 shows that the results are similar across scenarios. In particular, a permanent migration shock of the informal population increases GDP, consumption, and investment; decreases informal wages, inflation, inflation expectations, and the policy rate; and generates a positive output gap.

When the two types of labor are less complementary, firms demand relatively fewer formal workers because they can hire informal workers instead. This reduces the fall in informal wages caused by higher labor supply and reduces the incentives for informal households to increase their supplied hours. This scenario generates a smaller wage gap: formal wages rise less and informal wages fall less. A smaller decline in informal wages and an increase in the mass of informal households generate an increase in total informal consumption that is not observed in the other two scenarios (benchmark and more complementary). However, as wages fall, the per capita consumption of informal workers falls.

As firms hire relatively fewer formal and informal workers, output rises less in the short run and the output gap is less positive. In terms of prices, a smaller decline in informal wages has a near-zero effect on marginal costs and thus on inflation and inflation expectations. Given the small response of inflation and the output gap, the central bank hardly changes its interest rate. However, when the two types of labor are more complementary, the policy response is more active leading to a larger reduction in inflation and inflation expectations.

[Figure 5 about here.]

5.2 Implied series from migration flows

We analyzed our model's ability to forecast key macroeconomic variables in this section. To do so, we conducted three forecasting exercises using migration trajectories observed in three periods: *i)* first quarter of 2013,

[21] When nominal rigidities are absent, agents adjust prices optimally in each period, as the assumption of constant returns to scale implies that the present value of marginal cost is always zero.

[22] These values are taken from the maximum and minimum elasticities reported by Krusell et al. (2000)

ii) first quarter of 2017, and *iii)* first quarter of 2018. These periods have been characterized by different waves of migration from Venezuela in recent years. As shown in Figure 6, the forecasted series starting in 2013 (red dotted line) fails to replicate the observed series (black line). However, we can argue that between 2013 and 2019, migration contributed positively to the behavior of GDP, consumption and investment. Other shocks, such as the fall in international oil prices in 2015, could explain the difference between the forecasted and observed data. If we focus on more recent periods, such as 2017 (black dotted line) or 2018 (green dotted line), we see that the forecasted series of GDP, consumption, and investment more closely follow the observed data, especially the GDP series.

[Figure 6 about here.]

5.3 Macroeconomic effects of an exogenous increase in the mass of formal workers with nominal rigidities

As a counterfactual, we analyze the macroeconomic effects of an increase in the mass of formal households (Figure 7). For ease of comparison, we assume that this group of households experiences a shock equivalent to that experienced by informal households in the reference case.

A larger number of formal agents increases the supply of this type of labor and reduces its wage. This induces firms to demand more formal and informal labor (imperfect complements) and increase informal wages. Greater demand for labor reduces the capital-labor ratio, making existing capital more productive and increasing its price, as well as investment. The latter is reinforced by the fact that formal agents own capital. Inflation and inflation expectations depend on the current value of marginal cost, which in turn depends on factor prices. Because of nominal rigidities, formal wages fall less than in the flexible price equilibrium. This, combined with higher informal wages and capital prices, implies a positive present value of marginal costs, leading to higher inflation and inflation expectations. Nominal rigidities also generate a smaller increase in formal labor demand than in the flexible price equilibrium. As a result, aggregate output increases less and generates a negative output gap. As the central bank is more responsive to inflation, the nominal interest rate increases by 90 basis points.

[Figure 7 about here.]

Finally, migration has a greater long-term effect on GDP when migrants are formal. In this scenario, the economy has more of the type of labor that is used more intensively. Additionally, GDP increases more than the total population, thereby increasing GDP per capita. In terms of inequality, the differences in consumption and wages between formal and informal workers shrink (Figure 8).

[Figure 8 about here.]

6 Conclusions

In recent decades, migration flows around the world have intensified due to internal conflicts and poor economic conditions. Latin America is no exception, and in recent years, several countries have received a massive influx of migrants from Venezuela. Colombia, in particular, has received approximately two million people from its neighboring country since 2015, which represents more than 4% of Colombia's total population. The economic literature highlights that migration inflows can have negative effects on the wages of domestic workers with similar characteristics to migrants, but positive effects on other types of workers due to complementary linkages and general equilibrium effects through demand channels.

While the labor market effects of a migration inflow have been extensively studied in the literature, the short-run response of monetary policy in a developing economy has been largely ignored. In the presence of nominal frictions, a massive inflow of workers can affect inflation and the output gap in the short run, which are key determinants of monetary policy decisions. In this paper, we extend an otherwise standard small open

economy model with nominal rigidities and endogenous monetary policy to include heterogeneous agents in terms of productivity, capital ownership, and wage flexibility. The model captures the main characteristics of the recent migration episode from Venezuela to Colombia.

The model predicts that an inflow of migrants leads to an increase in aggregate output, consumption and investment, while the wages of local workers with similar characteristics to those of the migrants fall. The novelty of the model lies in the monetary policy response. In the case of a massive inflow of low-productivity workers with flexible wages, the model shows a moderate response of the nominal interest rate. Due to lower wages, inflation and inflation expectations fall, while the output gap turns positive because the wage rigidities of high-productivity workers allow firms to hire more. The central bank lowers the interest rate. Conversely, if there is an inflow of high-productivity workers, inflation rises due to wage rigidities and the output gap turns negative. In response, the nominal interest rate rises. These results show that the response of monetary policy is sensitive to the type of worker migrating and the characteristics of the economy. This model highlights the importance of characterizing migration episodes and host economies in terms of *i)* workers productivity, *ii)* interaction with existing workers, and *iii)* nominal rigidities. It also shows that monetary policy is not independent of migration shocks.

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Appendix

A BVAR Data sources

This appendix describes the transformations and data sources used in the Bayesian Vector Autoregression (BVAR) model. The BVAR is specified quarterly, so we take a simple average of the monthly series. The annual core inflation and unemployment rate are entered into the BVAR as percentage points, while the other series are entered as the natural logarithm of their levels. We seasonally adjust remittances and the unemployment rate using TRAMO-SEATS.

- *Colombian real GDP*: Seasonally adjusted and adjusted for calendar effects. Base year 2015. Source: National Administrative Department of Statistics (DANE, for its Spanish acronym).

- *Annual core inflation*: Constructed on the basis of the total CPI excluding the subclasses corresponding

to food, out-of-home meals and regulated prices. Base December 2018. Source: Banco de la República based on DANE data.

- *Unemployment rate:* Corresponds to the measurement that takes into account the whole country. Source: DANE with data from the Continuous Household Survey and the Great Integrated Household Survey.
- *Remittances:* Current transfers made by migrants to their country of origin, either in cash and/or in kind. We convert them to Colombian pesos using the representative market exchange rate (TRM, for its Spanish acronym) peso/dollar. We deflate remittances in pesos using total CPI. Source: Balance of Payments, Banco de la República.
- *Formal/informal wage ratio*: This variable is constructed as mentioned in Section 3.
- *GDP index for trading partners*: This variable is calculated as a weighted average of the GDP of Colombia's main trading partners. It was deflated using the World Bank's price index.
- *Real oil price index*: This variable is calculated as the price of oil relevant to Colombia, deflated using U.S. inflation.
- *Migrant population*: This variable is constructed as mentioned in Section 3.

B Series included in the BVAR

Figure 9 shows the variables included in the BVAR and their order of exogeneity for Cholesky's decomposition. The index of GDP for trading partners is the most exogenous variable, while annual core inflation is the most endogenous variable.

[Figure 9 about here.]

Tables

Table 1: List of Parameters

Parameter	Definition	Parameter	Definition
σ	Intertemporal elasticity of substitution	$\overline{D}_Y$	Debt over GDP
β	Discount factor	χ_I	Preference for labor (I)
η_F	Inverse of Frisch elasticity (F)	α	Capital share in production
η_I	Inverse of Frisch elasticity (I)	ν	Factor bias (F) labor
δ	Depreciation of capital	ξ	Elasticity of substitution (labor)
ϕ	Investment adjustment costs	$\overline{A}$	Long run productivity
R^*	Long run foreign interest rate	$\overline{N}_F$	Initial mass of (F) agents
μ	Foreign interest rate premium	$\overline{N}_I$	Initial mass of (I) agents
ϕ_d	Elasticity of foreign interest rate		

Table 2: Parameters. Small Open Economy with nominal rigidities.

Parameter	Definition
$\bar{\pi}$	Inflation target
θ^{W_F}	Elasticity of substitution between formal labor varieties
$1-\epsilon^{W_F}$	Wages adjustment probability
θ^{Y}	Elasticity of substitution between product varieties
$1-\epsilon^{Y}$	Prices adjustment probability
ρ^i	Smoothing parameter in Taylor rule
φ^π	Taylor rule elasticity to deviations of inflation from target
φ^Y	Taylor rule elasticity to output gap fluctuations

Table 3: Parameters for the Small Open Economy Model.

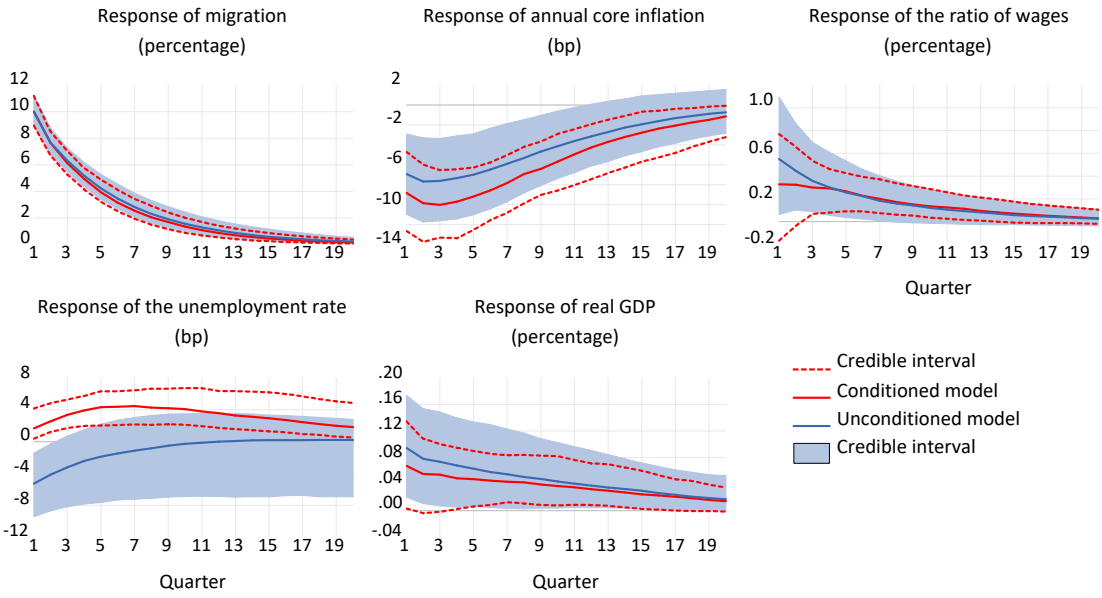
Parameter	Value	Source	Parameter	Value	Source
σ	1.1	González et al. (2011)	η_F	3.7	Whalen and Reichling (2017)
β	0.9878	González et al. (2011)	η_I	2.5	Whalen and Reichling (2017)
α	0.32	González et al. (2011)	$\overline{D}_Y$	50%	Calibrated
δ	2.5%	González et al. (2011)	χ_I	3.13	Calibrated
ϕ	3.25	González et al. (2011)	ν	0.73	Calibrated
R^*	1.0086	González et al. (2011)	$\overline{A}$	0.32	Calibrated
μ	1.0037	González et al. (2011)	$\overline{N}_F$	1.0	Calibrated
ϕ_d	0.01	González et al. (2011)	$\overline{N}_I$	1.33	Calibrated
ξ	0.8	Krusell et al. (2000)			

Table 4: Parameters. Small Open Economy with nominal rigidities.

Parameter	Value	Source
$\bar{\pi}$	0.03	González et al. (2011)
θ^{W_F}	2.00	González et al. (2011)
$1-\epsilon^{W_F}$	0.25	Calibrated
θ^{Y}	12.1	Calibrated
$1-\epsilon^{Y}$	0.25	Calibrated
ρ^{i}	0.70	Calibrated
φ^{π}	4.50	Calibrated
φ^{Y}	2.25	Calibrated

Figures

Figure 1: Responses to a 10% migration shock. Unconditioned and conditioned models



Note: The results correspond to the responses to a migration shock of 10% in a quarter in a BVAR(2) model, using the Cholesky identification and imposing block exogeneity. The blue lines represent responses in the unconditioned model. The red lines represent the responses in the conditioned model imposing a positive sign restriction on the unemployment response. Credible intervals at 65%.

Figure 2: Aggregate effects of a permanent shock on the informal population. Percentage changes from the initial steady state.

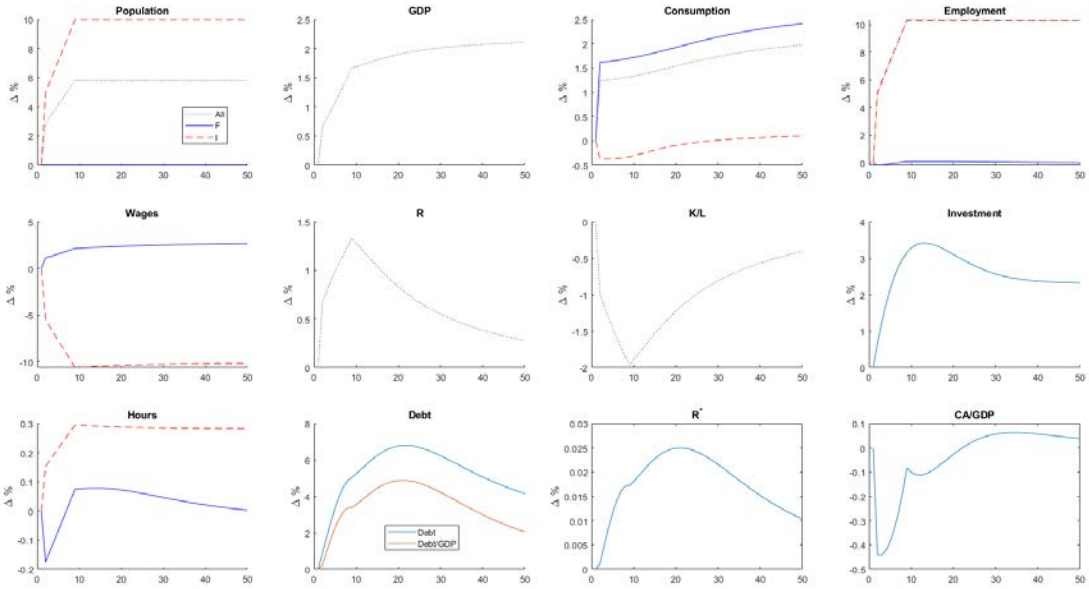


Figure 3: Aggregate effects of a permanent shock to the informal population in the presence of nominal rigidities. Percentage changes from the initial steady state.

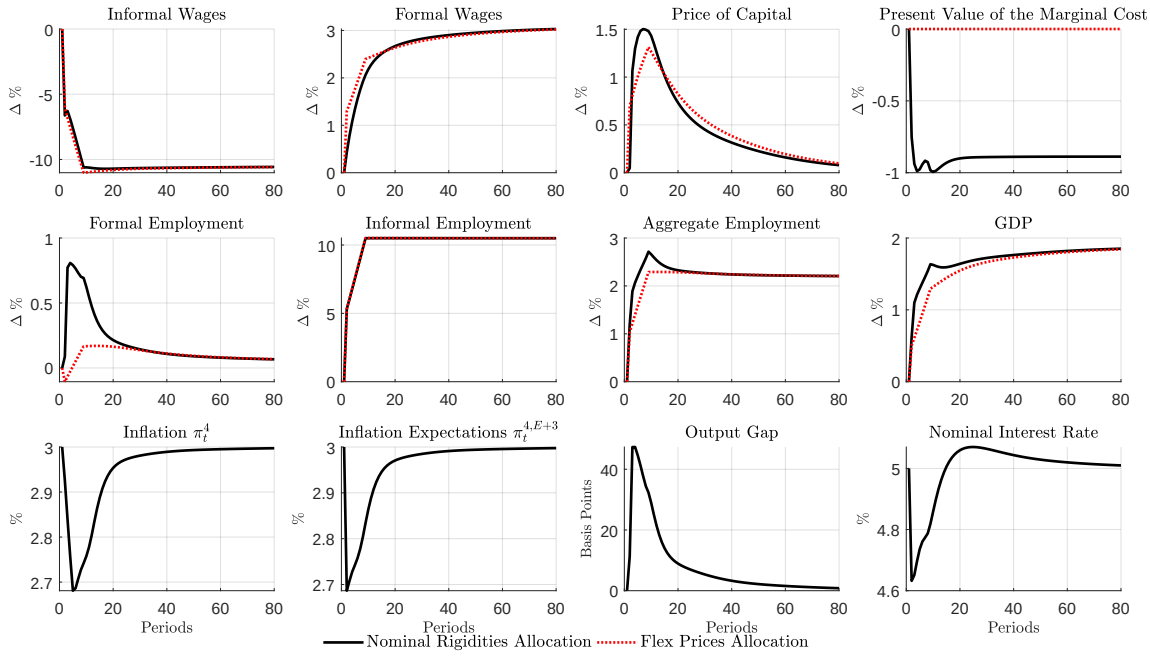


Figure 4: Per capita effects of a permanent shock in the informal population in presence of nominal rigidities. Percentage changes from the initial steady state.

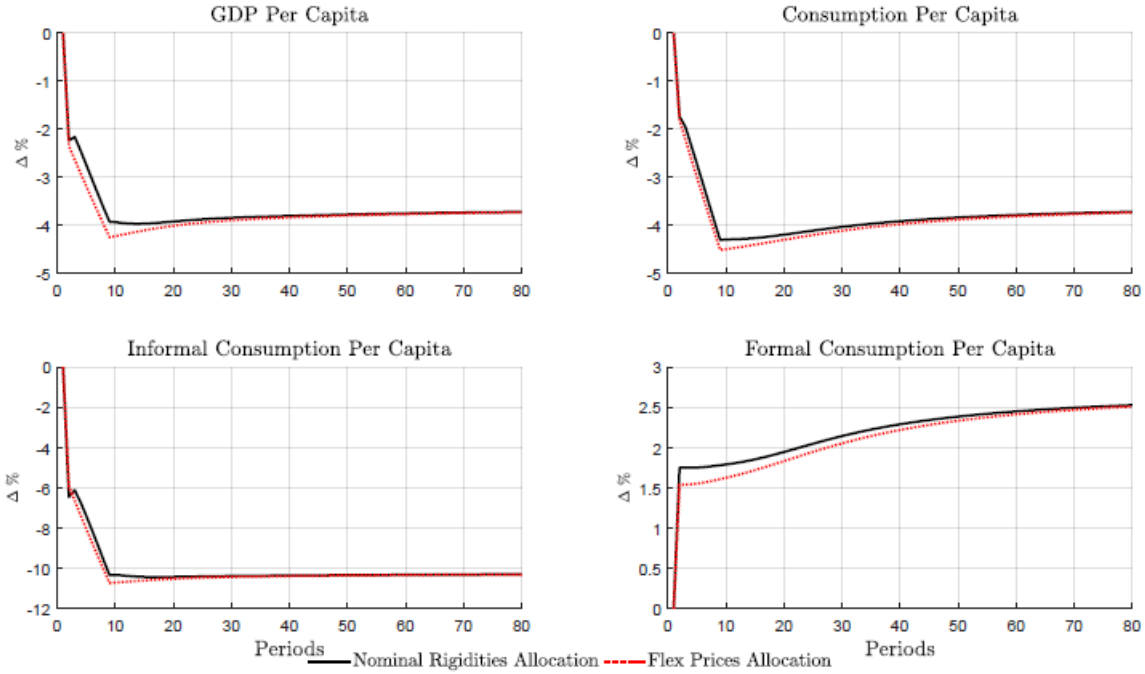


Figure 5: Robustness Analysis: Sensitivity to the elasticity substitution between labor. Permanent shock in the informal population in the presence of nominal rigidities

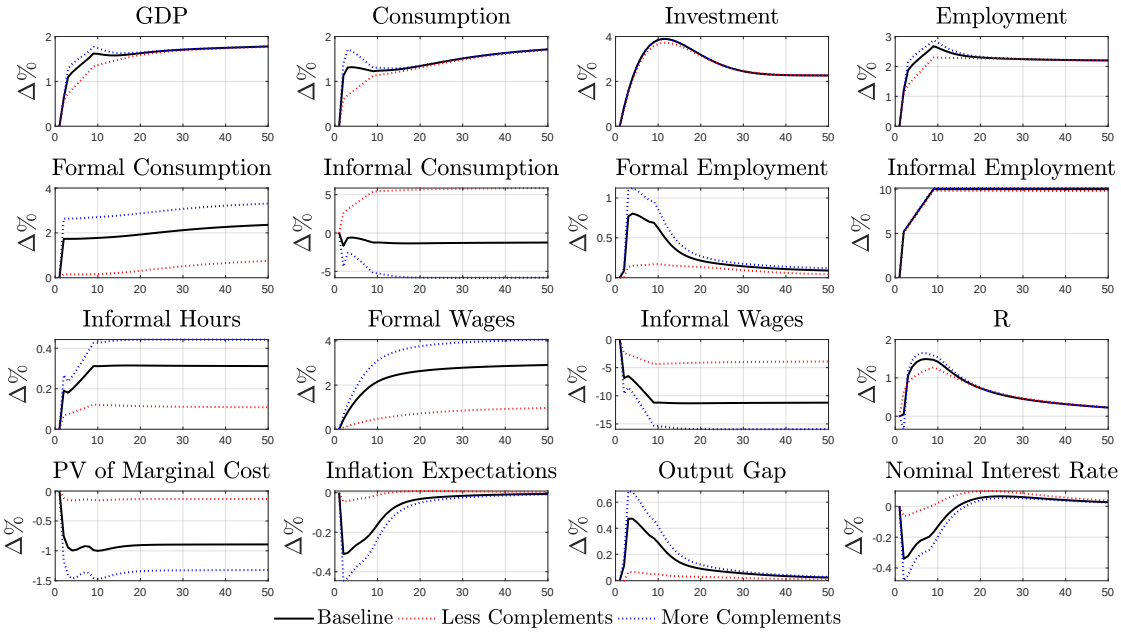


Figure 6: Implied series from migration flows. Model with nominal rigidities

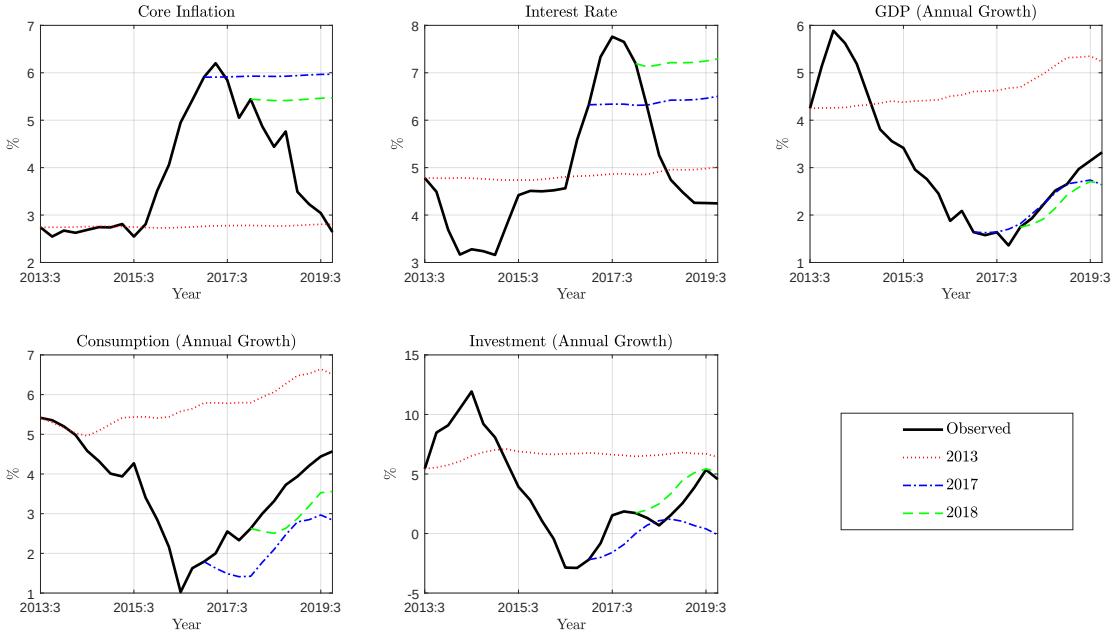


Figure 7: Aggregate effects of a permanent shock to the formal population in the presence of nominal rigidities. Percentage changes from the initial steady state.

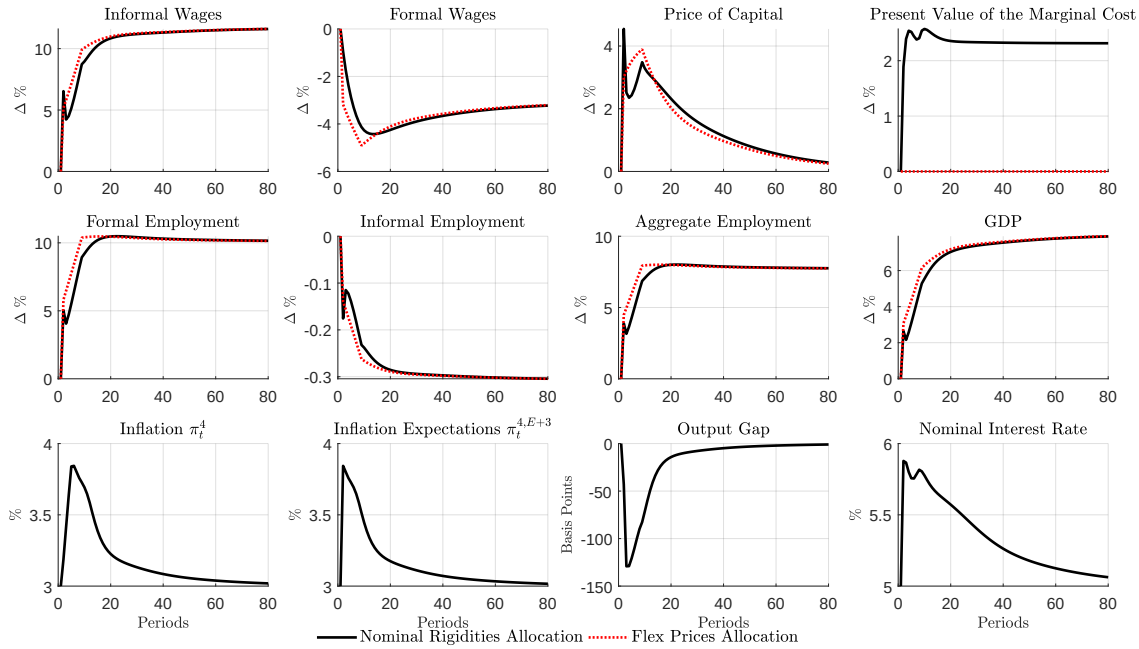


Figure 8: Per capita effects of a permanent shock to the formal population in the presence of nominal rigidities. Percentage changes from the initial steady state.

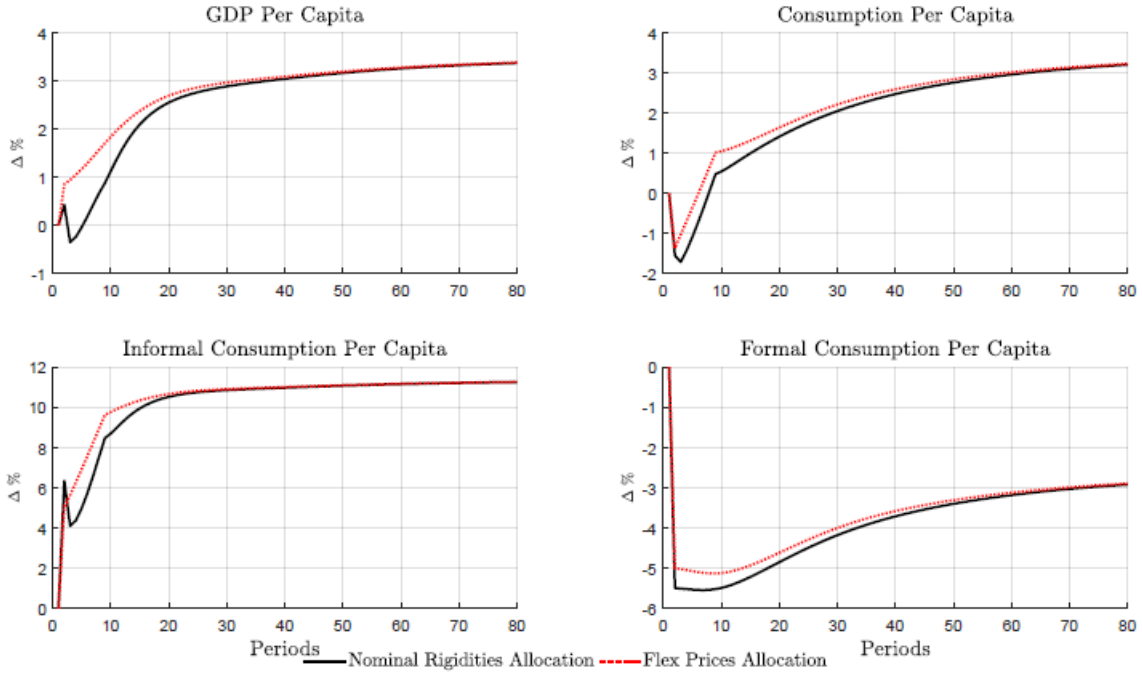
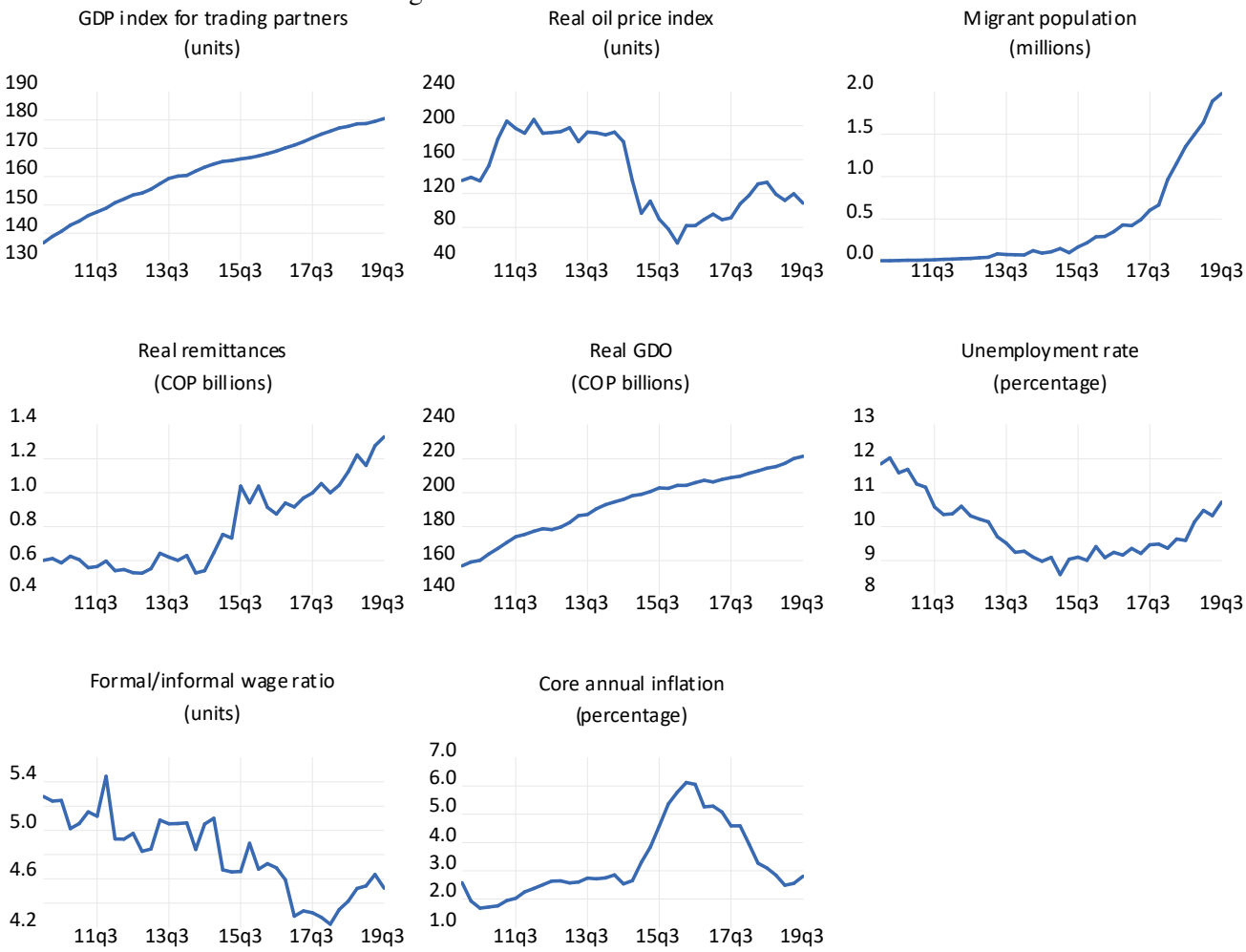


Figure 9: Variables included in the BVAR



Note: Seasonally adjusted real GDP is calculated by DANE, core inflation corresponds to non-food and non-regulated inflation, the unemployment rate corresponds to that observed in the national total published by DANE, remittances in real terms are based on information from Banco de la República. The ratio between the salaries of formal and informal workers corresponds to the ratio between the salaries of employees earning more than 1.1 legal minimum wage and those earning less than that threshold. The real GDP indices of the principal trading partners and the oil price take into account the dynamics of the external economies and the oil price that most influence the Colombian economy.
Source: DANE, Banco de la República, Gran Encuesta Integrada de Hogares (GEIH) and own calculations.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