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Inflation and Labor Migration: Modelling the Venezuelan Case

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Abstract:

The Venezuelan hyperinflation process has caused serious economic and social consequences. The wave of migrants and refugees fleeing the country is one of the most obvious and important faces of the problem. The objective of this paper is to develop a model that can explain labor migration flow from changes in price level and apply it to the Venezuelan reality. We make use of a theoretical-methodological framework related to the New Economic Geography. Results from our model's simulations show that, in the short run (1-year simulation horizon), Venezuelan industrial and agricultural workers will tend to migrate to nearby countries, such as Colombia, Brazil, Ecuador and Peru. However, in the long run (10-year simulation horizon), agents seem to decide based on real wage differential. This explains why industrial workers have a propensity to migrate to Chile, Panama, Peru and Mexico, while agricultural workers have an incentive to move to Argentina, Chile, Mexico and Brazil.

Keywords: Inflation, Migration, Venezuela, New Economic Geography

JEL Codes: J61, E31, R10

Inflation and Labor Migration: Modelling the Venezuelan Case

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Abstract

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1. Introduction

High inflation rates have always been a problem in Venezuela. If one looks at consumer price index, annual CPI inflation rate averaged 22% between 2000 and 2012, in President Hugo Chavez era. Nicolás Maduro took oath of office in the beginning of 2013, and CPI inflation reached 40% in the end of that year, climbed to 254% in 2016, then 65,000% in 2018 and 200,000% in 2019. IMF's World Economic Outlook (October 2019) forecasts a 500,000% for Venezuelan CPI inflation rate in 2020.

Even though figures are not accurate between different organizations, the pattern is still the same. For instance, according to the Central Bank of Venezuela, CPI inflation marked 180% in 2015, increased to 862% in 2017 and to 130,060% in 2018. Hanke & Bushnell (2019) use the exchange rate (free black market) between the Bolivar and US Dollar to have a more accurate and up-to-date inflation rate in Venezuela. According to the authors, the country's hyperinflation is still an ongoing case, reaching 165,400% in February/2019.

Consequently, data from the Central Bank of Venezuela show that economic activity has been shrinking since 2014, year after year. Venezuela's GDP growth rate declined -3.89% in 2014, -6.22% (2015); -17% (2016), -15.7% (2017). Therefore, even though one can cast some doubt on data quality, there is no doubt the Venezuelan economic activity has been going through some troubled times in recent years, with job losses as a result.

Social and economic consequences from Venezuelan hyperinflation phenomenon has led to an increased emigration flow. According to the World Bank, Venezuela's total population was 19.63 million in 1990 and 28.87 million in 2018 (WDI Databank). However, population growth has been decreasing. In 1990, population growth rate was about 2.5% a.a., it decreased to 0.12% in 2015, and it has been negative since then: -0.78% (2016); -1.53% (2017); -1.78% (2018). As a result, according to UNHCR (2019) 4 million Venezuelans have fled the country, until June 2019. Among them there are many workers of several different professions.

The aim of this article is to analyze how hyperinflation affects labor migration flow from Venezuela to other countries. By making use of a theoretical methodology model related to the New Economic Geography (NEG), we are able to obtain results for the short and long run. In fact, in our basic short run scenario (one year's time) Venezuelan industrial and agricultural workers tend to migrate to nearby countries, such as Colombia, Brazil, Ecuador and Peru. However, our long run scenario of ten years show that the decision is based on real wage differential. Therefore, industrial labor force from Venezuela tend to migrate to Chile, Panama, Peru and Mexico, while agricultural workers have an incentive to move to Argentina, Chile, Mexico and Brazil.

In addition to this introduction, section 2 looks at the literature and links inflation, regional heterogeneity and migration. Section 3 explains the model and its empirical implementation. Section 4 reports the results and the last section concludes the article.

2. Inflation, regional heterogeneity and migration

Milton Friedman's famous quote says that "inflation is always and everywhere a monetary phenomenon." Thomas Sargent added that "persistent inflation is always and everywhere a fiscal phenomenon." There is nothing wrong in these definitions, as they pinpoint what the main causes of inflation are. However, Friedman's and Sargent's quotes did not mention the consequences of high inflation. In fact, the recent hyperinflation case in Venezuela seems to show, once more, that inflationary aspects go beyond these classic definitions, as it can become a serious social problem, in terms of economic activity, unemployment and migration flows.

As mentioned previously, even though high inflation rates have always been a problem in the Venezuelan economy, it is not even close to its present chronic hyperinflation problem, which is expected to reach 500,000% in 2020, according to the IMF. In fact, after Cagan's (1956) classic work, a 50% monthly inflation rate has been accepted as a definition of hyperinflation. Hanke & Krus (2013) have been adopting this convention in the "Hanke-Krus World Hyperinflation Table". In fact, Hanke & Bostrom (2017) show that, until 2017, there were 58 cases of hyperinflation in the world, including the classic episodes of Hungary, Germany and Zimbabwe. Venezuela's episode started in November/2016 and it has been registered as case number 23. And it is an ongoing hyperinflation episode[1].

Emigration is a direct consequence of hyperinflation. John (2019) argues that the Venezuelan economic crisis has resulted in increased poverty and crime rates, as well as hyperinflation. Migration to neighboring Caribbean and Latin American countries is a direct consequence of the crisis. Four

[1]It is not our aim to go on with a long explanation on how Venezuela collapsed, and issues related to a petro-economy and the so-called "natural resource curse". Hausmann & Rodríguez (2014) can be an excellent source for that matter.

million Venezuelans have emigrated recently. The major hosts are Colombia (1.4 million), Peru (870,000), Ecuador (385,000), Chile (371,000), Brazil (224,000), Argentina (145,000) (UNHCR, 2019).

We have already given figures related to recent Venezuelan migration outflow, but there are other interesting experiences. For instance, Burgdorfer (1931) analyzed migration in Germany and reported that German emigration increased considerably in the hyperinflation years. For instance, 37,000 Germans emigrated in 1922. In 1923, when inflation reached its maximum, emigration increased to 115,000 and, then, dropped to 60,000 in 1924.

Theories related to international migration are vast, but fragmented. Massey et al. (1993) consider that the oldest and best-known migration theory is related to neoclassical micro and macroeconomics, which explains migration by causes related to geographic differences in the supply of and demand for labor. The Harris–Todaro human capital model, developed in Todaro (1969) and Harris & Todaro (1970) original theoretical work on rural-urban migration, can also be extended to international migration. According to this theory, a search for higher earnings would be the reason why people, using a cost-benefit calculation, migrate from less developed to more developed countries.

Other important theories are: i) New economics theory, which argues that movements are made by families or households, in order to maximize expected income and minimize risks; ii) Dual labor market theory, which claims that international migration is connected to intrinsic labor demands present in modern rich economies; iii) World system theory, which says that capitalism itself penetrates underdeveloped countries and creates a mobile population eager to migrate (Massey et al., 1993).

Other important characteristics are important when discussing international migration. For instance, Ruiz & Vargas-Silva (2013, 2015) and Dadush & Niebuhr (2016) the economic impact of forced migration. Patarra (2006) points to issues related to human rights and economical-productive restructuring in a global scale.

Family structure, cultural aspects and language can also be an important factor in the decision to migrate (Massey et al., 1993; McEwan, 2001; Teo, 2003; Halfacree, 2004; Bushin, 2009; Benson, 2012; Ryan & Sales, 2013; Bal & Willems, 2014; Thompson, 2017). In addition, other institutional aspects might be very important, such as permanent resident process, social security and labor guarantees (Bertocchi & Strozzi, 2008; Ryo, 2013; Nifo & Vecchione, 2014).

Thisse (2011) argues that labor migration flows also mean movements of production and consumption skills. As a result, product markets and labor are affected in sending and host countries. These externalities of particular importance in imperfectly competitive markets, where prices do not reflect the true social value of individual decisions. To be better studied, the effects of migration need a general equilibrium framework, through which it will be possible to capture not only the interactions between spatially separate markets (product and labor), but also the dual role of individual-worker and individual-consumer. Krugman (1991) was able to integrate all of these effects into a single framework, proving Myrdal's definition[2] (Thisse, 2011).

[2]The New Economic Geography (NEG), commonly represented by the works of Krugman (1991) and Fujita et al. (2001), incorporates increasing economies of scale to produc-

Krugman thus demonstrated the importance of transport costs in the process of spatial concentration or deconcentration. If transportation costs are low enough, then firms will focus on a single central region, while the peripheral region will offer only the standardized product. In this way, these firms will be able to obtain increasing returns by selling more products in the larger market without losing many customers in the smaller market. It is important to highlight here that the Core-Periphery structure is the unintended consequence of decisions taken by a large number of economic agents in favor of their own interests. However, if transportation costs are high enough, then interregional freight will be costly and discouraged. Hence, the economy exhibits a symmetrical regional production pattern focused on local markets. The Core-Periphery model thus allows for either convergence or divergence between regions, whereas the neoclassical model, based on constant returns and perfect competition, allows for convergence only (Thisse, 2011).

Finally, it is important to emphasize that our research aims at using a Core-Periphery model to examine the migration process driven by price level increases. Most studies on the economic and geographic impacts of migration tend to disregard such relationship (Westerlund, 1997; Dustmann, 2003; Lehmer & Ludsteck, 2011; Niedomysl, 2011; Rabe & Taylor, 2012; Coulter & Scott, 2015; Kondo & Okubo, 2015; Coulter, Ham & Findlay, 2016).

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tion functions, that together with non-linear transport costs in a quantitative model of interregional growth are able to explain spatial heterogeneity and promote greater understanding in relation to the agglomeration of economic activities. The additional value of this approach resides in modeling the interaction between transport costs and economies of scale in production, endogenizing a center-periphery dynamic, based on the Myrdal-Kaldor model (i.e., increasing returns and circular and cumulative process).

3. Method

3.1. Model

The structure of the Core-Periphery model will consist of six blocks of equations, namely: (i) price index; (ii) nominal wage; (iii) real wage; (v) migratory flow of workers and (vi) regional product. These blocks of equations, which will be described throughout this section, follows Rocha & Perobelli (2020).

Price index

Price index for industrial goods (G_r^M) follows expression (1), which depends: i) on the regional participation of industrial workers (λ_s) and industrial nominal wage (w_s^M); ii) on the cost of transportation type iceberg between regions (T_{sr}^M), which is constant; iii) and on the substitution elasticity for industrial goods (σ), which is also constant.

$$G_{r(t)}^M = [\sum_s \lambda_{s(t-1)} (w_{s(t-1)}^M T_{sr}^M)^{1-\sigma}]^{1/(1-\sigma)} \tag{1}$$

Price level for agricultural goods (G_r^A) is given by expression (2) and it is based upon the idea introduced in the previous paragraph. Parameter ϕ_s represents the participation of farmers and w_s^A is the average nominal yield in the other regions s. Assume an iceberg transport cost for agricultural goods (T_{sr}^A) and constant substitution elasticity given by η.

$$G_{r(t)}^A = [\sum_s \phi_{s(t-1)} (w_{s(t-1)}^A T_{sr}^A)^{1-\eta}]^{1/(1-\eta)} \tag{2}$$

Constants T_{sr}^M and T_{sr}^A represent the ratio between the quantity of product being shipped and the product delivered. Then $T_{sr}^M, T_{sr}^A \geq 1$, and the closer to 1, the less the waste. Empirically, because of data unavailability, it is difficult to establish an adequate value for these constants. So, we assume that:

$$T_{sr}^{M} = \begin{cases} 1, & \text{if } r = s \\ 1.2, & \text{if } r \neq s \end{cases}$$

$$T_{sr}^{A} = \begin{cases} 1, & \text{if } r = s \\ 1.4, & \text{if } r \neq s \end{cases}$$

This hypothesis seems reasonable, when dealing with interregional transportation of industrial or agricultural goods, i.e. when $r \neq s$ necessarily implies some kind of loss. In this case, for each 1 unit of industrial goods shipped, about 0.85 is delivered to the final destination. This coefficient is about 0.70 for agricultural goods. Note that there is no loss in intra-regional transport.

Nominal wage

Nominal wages for industrial sector (w_r^M) and for agricultural sector (w_r^A) can be deduced following Dixit & Stiglitz (1977) model:

$$w_{r(t)}^{M} = [\sum_{s} Y_{s(t-1)} (T_{sr}^{M})^{1-\sigma} (G_{s(t-1)}^{M})^{\sigma-1}]^{1/\sigma} \tag{3}$$

$$w_{r(t)}^{A} = [\sum_{s} Y_{s(t-1)} (T_{sr}^{A})^{1-\eta} (G_{s(t-1)}^{A})^{\eta-1}]^{1/\eta} \tag{4}$$

Components of equations (3) and (4) have already been defined in the previous blocks.

Real wage

Real wages for industrial (equation 5) and for agricultural (equation 6) sectors come from nominal wage equations 3 and 4, deflated by the price index (cost of living).

$$\omega^M_{r(t)} = w^M_{r(t)}(G^M_{r(t-1)})^{-\mu}(G^A_{r(t-1)})^{\mu-1} \tag{5}$$

$$\omega^A_{r(t)} = w^A_{r(t)}(G^A_{r(t-1)})^{-\mu}(G^A_{r(t-1)})^{\mu-1} \tag{6}$$

Migration

By using equations 7 and 8, we are able to add dynamics to the model, which closely follows Fujita et al. (2001). Spatial change of workers and farmers (i.e., migration process) is influenced by real wage differentials, and this process changes the values of variables λ_r and ϕ_r over time.

$$\lambda_{r(t)} - \lambda_{r(t-1)} = \chi^M(\omega^M_{r(t)} - \overline{\omega}^M_{(t-1)}) \tag{7}$$

$$\phi_{r(t)} - \phi_{r(t-1)} = \chi^A(\omega^A_{r(t)} - \overline{\omega}^A_{(t-1)}) \tag{8}$$

where $\overline{\omega}^M_{(t-1)} = \sum_r \lambda_{r(t-1)}\omega^M_{r(t-1)}$ and $\overline{\omega}^A_{(t-1)} = \sum_r \phi_{r(t-1)}\omega^A_{r(t-1)}$

Regional product

Finally, expression (9) depicts the regional product (Y_r), which is the sum of nominal yields from the industry $[\mu\lambda_r w^M_r]$ and agriculture $[(1-\mu)\phi_{r(t)}w^A_{r(t)}]$

sectors.

$$Y_{r(t)} = \mu\lambda_{r(t)} w^M_{r(t)} + (1-\mu)\phi_{r(t)} w^A_{r(t)} \tag{9}$$

3.2. Empirical implementation

The model is calibrated using data released by national statistical agencies and international institutions, such as the World Bank. Tables 3 and 4-7 (Appendix A) provide a complete description of all endogenous and exogenous variables, respectively, as well the model's parameters. Choices regarding simulation time length and contemplated regions allow us to find interesting results with low computational effort. The model is simulated over a 10-year period, from 2018 on. Short-run results are those obtained within the first year of simulation, whereas long-run results are achieved in the tenth year. In our analysis, potential Venezuelan migrant workers are able to choose between Argentina (ARG), Brazil (BRA), Chile (CHI), Colombia (COL), Dominican Republic (DOM), Ecuador (ECU), Mexico (MEX), Panama (PAN) and Peru (PER). These destination countries were chosen intentionally, once 85% of Venezuelans who decide to leave their country go to one of those nations, according to information released by UNHRC for 2019 (see Table 1). Besides, our analysis considers the idea of perfect mobility, that is, destination countries do not impose barriers to the entry of migrants.

The six-block equations are log-linearized, as depicted in Appendix B. Given the condition imposed by the log-linearization process, all endogenous variables in the model have an initial value equal to zero, and projection results are given in log-deviation.

[Insert Table 1, here]

The purpose of our simulations is to observe the potential of selected destination countries to attract Venezuelan immigrants. In our case, they can be separated by workers in industrial and agricultural sectors, according to movements in real wage growth, directly affected by accelerating inflation. In other words, we assess the potential of selected Latin American countries to attract industrial and agricultural migrant workers from Venezuela, due to increases in cost of living. We use projection results related to variables λ (industrial sector employment share) and ϕ (agricultural sector employment share). Table 2 summarizes all scenarios considered in our computational simulations. The key parameters are: i) substitution elasticity for industrial (σ) and agricultural goods (η); ii) locational sensitivity of agricultural and industrial labor to real wage deviations (χ^M and χ^A, respectively). In order assess the robustness of our results, we run some sensitivity tests, adjusting the values up (Table 2, column A) and down (Table 2, column B).

[Insert Table 2, here]

4. Results

Figures 1 and 2 show the baseline scenario results in the short run, that is, a 1-year horizon (something close to 2020). In this case, industrial workers tend to migrate to neighboring countries, such as Colombia, Brazil and Ecuador (Figure 1), and agricultural workers tend to move to Colombia, Brazil and Panama (Figure 2). This evidence shows that geographic distance, and not wage-related factors, might be more important in the decision-making process to migrate in the short run. Such information is extremely relevant during a time of extreme humanitarian crisis, calling for emergency measures, from neighboring countries and international organizations (e.g. United Nations), to accommodate and protect these migrants and to provide necessary social assistance, especially in border regions.

[Insert Figure 1, here]

[Insert Figure 2, here]

Figures 3 and 4 show the long-run results, that is, a 10-year horizon (something close to 2030). In this case, Venezuelan migrant workers choose their destination country based on wage differentials. Chile, Panama, Peru and Mexico have great potential for attracting Venezuelan's industrial labor (Figure 3). The industrial value added per worker in these countries is about US$ 33,651/year, while in Venezuela it is about US$ 28,990/year (World Bank, 2018). On the other hand, Argentina, Chile, Mexico and Brazil are the countries with the greatest potential for attraction of agricultural Venezuelan workers (Figure 4). For instance, in Argentina the agricultural value added per worker is about US$ 2,513,118/year, while in Venezuela it is about US$ 21,322/year (World Bank, 2018). Therefore, in the long run, destination countries must design policies to provide employment conditions that include social security and help migrants to adapt to a new environment.

[Insert Figure 3, here]

[Insert Figure 4, here]

Results can be sensitive to key parameter values, which are substitution elasticities for industrial goods (σ) agricultural goods (η) and locational sensitivity of industrial labor (χ^M) and agricultural labor (χ^A) to deviations from real wages. In order to see this, we performed sensitivity tests related to industrial and agricultural labor migration from Venezuela to other countries. They are described in Table 2 as, respectively, tests (A) and (B). Results for both tests are shown in Figures 5 and 6, respectively. They are very similar to those obtained in the baseline scenario mentioned previously. Industrial and agricultural Venezuelan workers will tend to migrate to nearby countries, in the short run. On the other hand, in the long run, they will go to regions with greater wage differentials.

[Insert Figure 5, here]

[Insert Figure 6, here]

5. Conclusion

This article aimed at developing a model to explain Venezuelan labor migration flow in times of hyperinflation. By making use of a theoretical methodology based on New Economic Geography (NEG), we were able to take into account important variables that can influence the migrant's decision-making process, such as cost of living, geographical distance and earnings differential. Such methodology also enabled us to find similarities and differences related to short and long run simulations. Results show that, in the short run, industrial and agricultural Venezuelan migrant workers move to nearby countries, such as Colombia, Brazil, Ecuador and Peru. However, when a long run scenario is accounted for, migrants from Venezuela seem to consider matters related real wage differentials. In this case, industrial workers tend to migrate to Chile, Panama, Peru and Mexico, whereas agricultural workers move to Argentina, Chile, Mexico and Brazil.

Therefore, this research article innovates by making the connection between the Venezuelan hyperinflation process and its impact on immigration. We believe that by highlighting which countries have the greatest potential for attraction of that population, they can provide more efficient responses in terms of policies aimed at migrant's well-being.

Two points must be highlighted in our analysis. Firstly, the connection between migration and inflation is examined via a Core-Periphery model and, as mentioned in section 2, such strategy is not usual in studies related to migration and its economic and geographic effects. Secondly, our simulations show that it is important to have a clear distinction between short and long run results of migration on the labor force.

There are some limitations of our model and, consequently, of our results. For instance, we don't consider factors such as family structure, cultural aspects and language, as Massey et al. (1993) and other researchers do. We don't consider other institutional aspects either (legalization, social security, etc), as Bertocchi & Strozzi (2008) and others do. We are also fully aware that, with the process of increasing information, Venezuelans could migrate to other countries, in the long run. However, our results are spatially limited, due to computational restrictions. Furthermore, we do not assess the adjustment in Venezuela's labor market and recipient countries, which means that our analysis does not account for changes in productivity.

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Tables and Figures

Table 1: Venezuelan migration - main destinations

Destinations	Venezuelan migration	
	in thousands	%
Argentina (ARG)	145.0	3.5
Brazil (BRA)	224.0	5.4
Chile (CHI)	371.0	9.0
Colombia (COL)	1400.0	33.8
Dominican Republic (DOM)	30.0	0.7
Ecuador (ECU)	385.0	9.3
Mexico (MEX)	71.0	1.7
Panama (PAN)	94.0	2.3
Peru (PER)	870.0	21.0
Total - selected countries	3590.0	86.7
Other countries	548.8	13.3
Total - all countries	4138.8	100.0

Source: UNHRC, 2019.

Table 2: Key parameter values for the baseline scenario and sensitivity tests

Parameter	Baseline scenario	Sensitivity test	
		(A)	*(B)*
σ	2.00	3.00	1.00
η	1.50	2.25	0.75
χ^M	0.10	0.15	0.05
χ^A	0.10	0.15	0.05

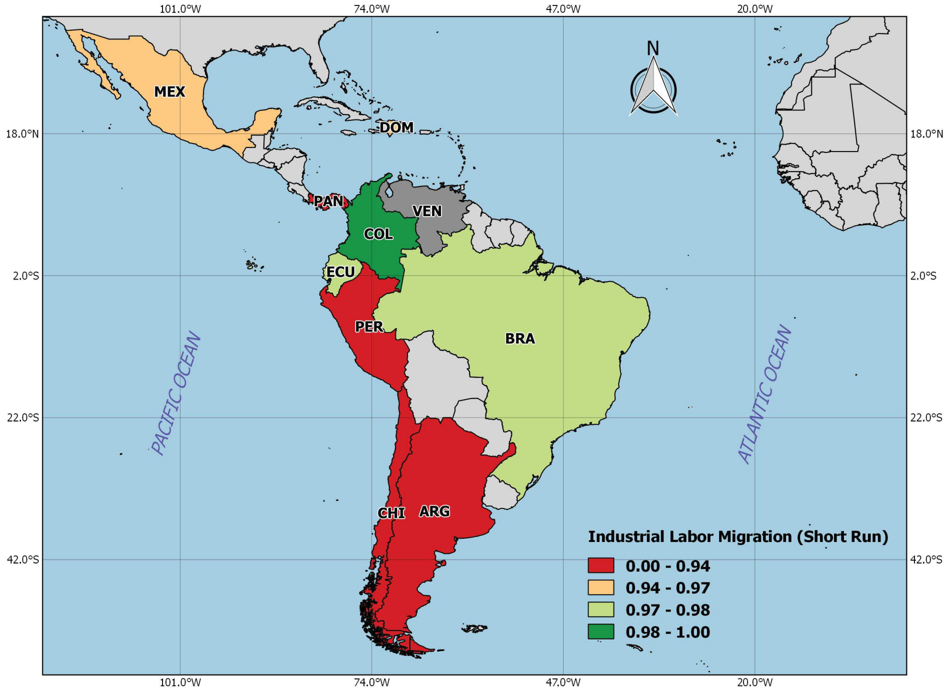

Figure 1: Industrial labor migration from Venezuela to other countries (short run)

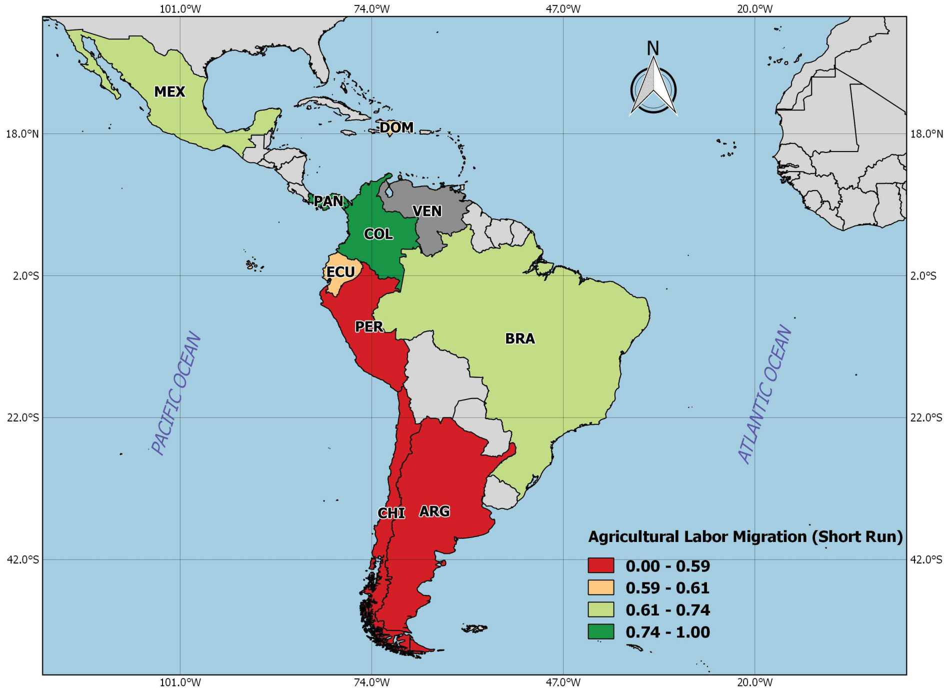

Figure 2: Agricultural labor migration from Venezuela to other countries (short run)

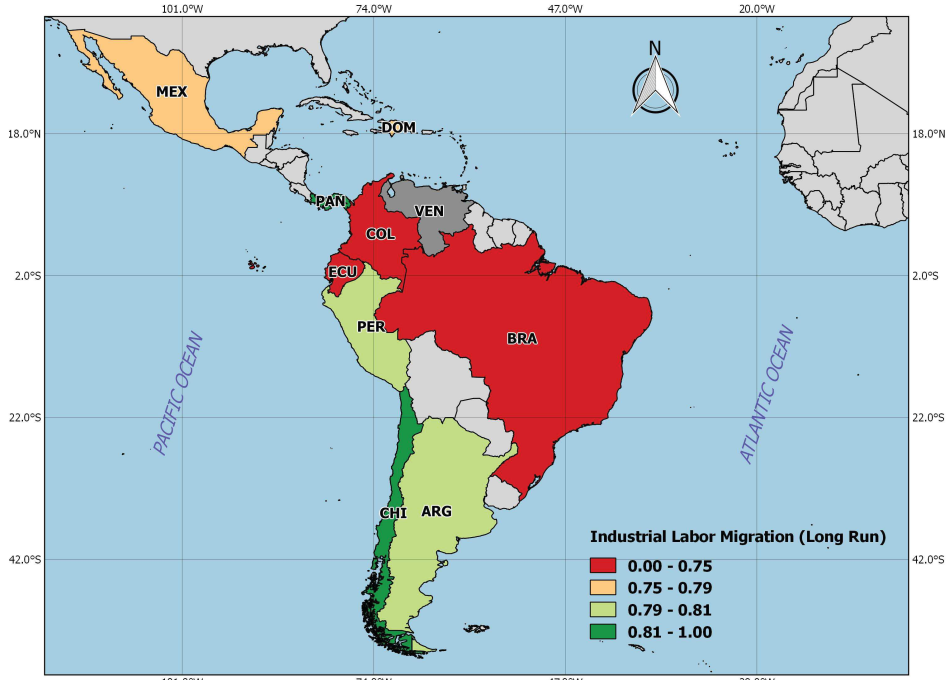

Figure 3: Industrial labor migration from Venezuela to other countries (long run)

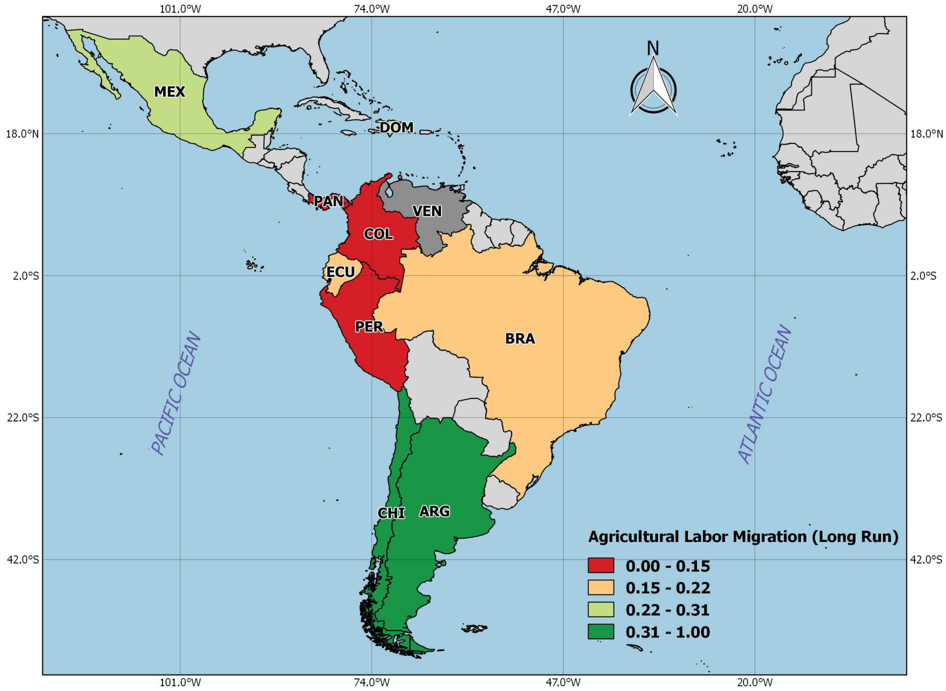

Figure 4: Agricultural labor migration from Venezuela to other countries (long run)

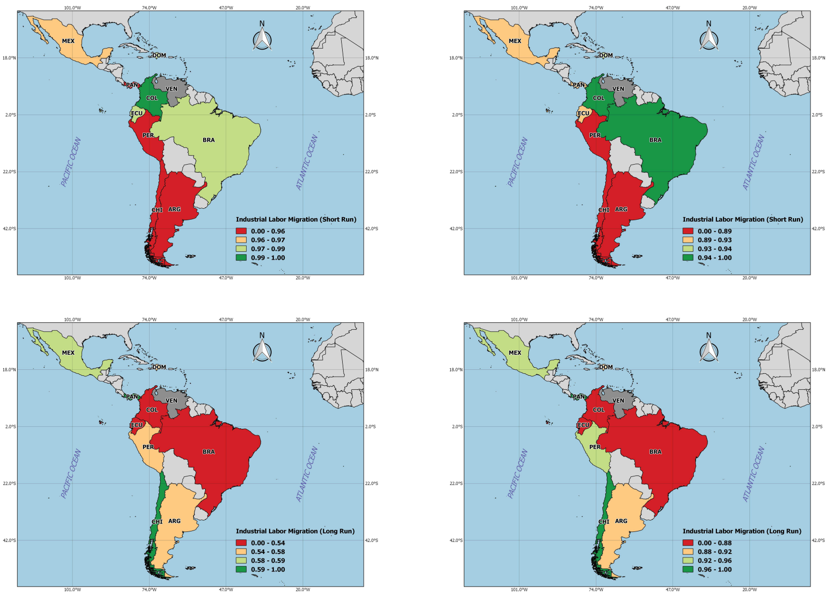

Figure 5: Sensitivity test - industrial labor migration from Venezuela to other countries

Note: (upper left corner) short run sensitivity test A; (upper right corner) short run sensitivity test B; (bottom left corner) long run sensitivity test A; (bottom right corner) long run sensitivity test B

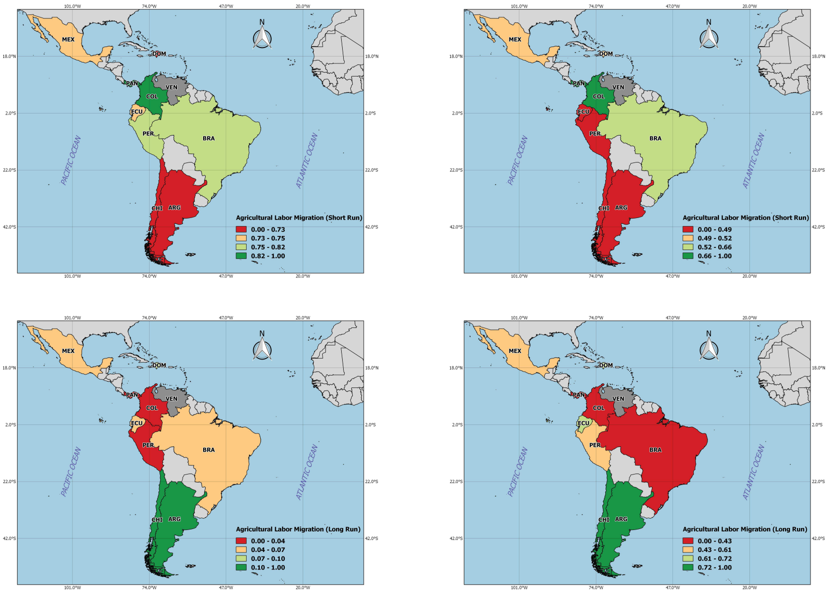

Figure 6: Sensitivity test - agricultural labor migration from Venezuela to other countries

Note: (upper left corner) short run sensitivity test A; (upper right corner) short run sensitivity test B; (bottom left corner) long run sensitivity test A; (bottom right corner) long run sensitivity test B

Appendix

A. Endogenous variables, exogenous variables and parameters

Endogenous variables

Table 3: Description of endogenous variables*

Variable	Description
$\overline{g}_r^M$	Industrial price index in region r (log-deviation)
$\overline{g}_r^M$	Agricultural price index in region r (log-deviation)
$\overline{w}_r^M$	Industrial sector nominal wage in region r (log-deviation)
$\overline{w}_r^A$	Agricultural sector nominal wage in region r (log-deviation)
$\overline{\omega}_r^M$	Industrial sector real wage in region r (log-deviation)
$\overline{\omega}_r^A$	Agricultural sector real wage in region r (log-deviation)
$\overline{\lambda}_r^M$	Industrial sector employment share in region r (log-deviation)
$\overline{\phi}_r^A$	Agricultural sector employment share in region r (log-deviation)
$\overline{y}_r$	Social income in region r (log-deviation)

Note: (1) $r = VEN, ARG, BRA, CHI, COL, DOM, ECU, MEX, PAN, PER$.
*(2) *Given the condition imposed by the log-linearization process, all endogenous variables in the model will have an initial value equal to zero.*

Exogenous variables and parameters

Table 4: Description of exogenous variables and parameters (baseline scenario)

Variable	Description	Value	Source
G_r^{M*}	(steady-state) Industrial price index in region r*	6.037	Values calculated from the model
G_r^{A*}	(steady-state) Agricultural price index in region r*	1.324	Values calculated from the model
w_r^{M*}	(steady-state) Industrial sector nominal wage in region r (constant 2010 US$)*	28301.019	World Bank
w_r^{A*}	(steady-state) Agricultural sector nominal wage in region r (constant 2010 US$)*	259360.862	World Bank
λ_r^*	(steady-state) Industrial sector employment share in the region r (%)*	0.599	National Statistics Institutions and World Bank
ϕ_r^*	(steady-state) Agricultural sector employment share in the region r (%)*	0.401	National Statistics Institutions and World Bank
Y_r^*	(steady-state) Social income in region r (US$)*	114992 $\times 10^4$	Values calculated from the model
μ^M	Proportion of industrial workers in relation to total (%)*	0.550	World Bank
μ^A	Proportion of agricultural workers in relation to total (%)*	0.450	World Bank
σ	Substitution elasticity for industrial goods	2.000	Assumed value
η	Substitution elasticity for agricultural goods	1.500	Assumed value
χ^M	Locational sensitivity of industrial labor to deviations from real wages	0.100	Assumed value
χ^A	Locational sensitivity of agricultural labor to deviations from real wages	0.100	Assumed value

*Note: *Average values.*

Table 5: Euclidean distance matrix (in km)

Origin/Destination	VEN	ARG	BRA	CHI	COL	DOM	ECU	MEX	PAN	PER
VEN	0									
ARG	4736.31	0								
BRA	2469.61	3053.65	0							
CHI	5044.3	744.47	3640.38	0						
COL	848.79	4463.85	2762.26	4655.81	0					
DOM	1353.59	6037.72	3785.97	6288.73	1666.26	0				
ECU	1696.27	4074.6	3044.41	4141.03	868.83	2424.44	0			
MEX	4464.19	7811.6	6731.45	7711.36	3970.23	3650.61	3873.72	0		
PAN	1560	5164.66	3697.59	5255.89	936.32	1572.98	1116.82	1720.6	0	
PER	2031.84	3095.42	2378.31	3213.79	1462.83	3125.7	991.12	3689.4	2069.62	0

Table 6: Transportation loss (constant) - industrial goods (T_{sr}^{M})

Origin/Destination	VEN	ARG	BRA	CHI	COL	DOM	ECU	MEX	PAN	PER
VEN	1.0									
ARG	1.2	1.0								
BRA	1.2	1.2	1.0							
CHI	1.2	1.2	1.2	1.0						
COL	1.2	1.2	1.2	1.2	1.0					
DOM	1.2	1.2	1.2	1.2	1.2	1.0				
ECU	1.2	1.2	1.2	1.2	1.2	1.2	1.0			
MEX	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.0		
PAN	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.0	
PER	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.0

Table 7: Transportation loss (constant) - agricultural goods (T_{sr}^{A})

Origin/Destination	VEN	ARG	BRA	CHI	COL	DOM	ECU	MEX	PAN	PER
VEN	1.0									
ARG	1.4	1.0								
BRA	1.4	1.4	1.0							
CHI	1.4	1.4	1.4	1.0						
COL	1.4	1.4	1.4	1.4	1.0					
DOM	1.4	1.4	1.4	1.4	1.4	1.0				
ECU	1.4	1.4	1.4	1.4	1.4	1.4	1.0			
MEX	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.0		
PAN	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.0	
PER	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.0

B. Log linearization

The log-linearization method applied is quite simple and it is based on Uhlig (1999). The example depicted here resembles Rocha & Perobelli (2020). Assume the following equality to be log-linearized:

$$Y_t = X_t \tag{10}$$

After a trivial transformation, equation (10) can be rewritten as:

$$Y_t = X_t X^* / X^* \tag{11}$$

or

$$Y_t = X^* X_t / X^* \tag{12}$$

where X^* is the steady state value of variable X. The next step is to take the exponential of a natural logarithm on the right-hand side of equation (10). Note that this transformation doesn't change the value of the expression. Then:

$$Y_t = X^* exp(ln(X_t / X^*)) \tag{13}$$

Remember that $ln(X_t/X^*) = ln(X_t) - ln(X^*)$. Hence, we can define $x_t = ln(X_t) - ln(X^*)$ as the deviation of X around the steady state (X^*). The new expression becomes:

$$Y_t = X^* exp(x_t) \tag{14}$$

By taking a first-order Taylor series of $exp(x_t)$ around zero, we see that $exp(x_t) \approx 1 + x_t$ then (14) takes the form of (15) which represents equation (10) log-linearized.

$$Y_t \approx X^*(1 + x_t) \tag{15}$$

We are now able to log-linearize the dynamic equations and demonstrate them below. Just for simplicity and convenience, a hypothetical situation of two regions ($r = 2$) is used.

Price index

$$G^M_{1(t)} = [\lambda_{1(t-1)}(w^M_{1(t-1)} T^M_{11})^{1-\sigma} + \lambda_{2(t-1)}(w^M_{2(t-1)} T^M_{21})^{1-\sigma}]^{1/(1-\sigma)} \tag{16}$$

$$G^M_{2(t)} = [\lambda_{1(t-1)}(w^M_{1(t-1)} T^M_{12})^{1-\sigma} + \lambda_{2(t-1)}(w^M_{2(t-1)} T^M_{22})^{1-\sigma}]^{1/(1-\sigma)} \tag{17}$$

$$\tilde{g}^M_{1(t)} = \psi_{11M}(\tilde{w}^M_{1(t)} + \frac{1}{(1-\sigma)}\tilde{\lambda}_{1(t)}) + \psi_{12M}(\tilde{w}^M_{2(t)} + \frac{1}{(1-\sigma)}\tilde{\lambda}_{2(t)}) \tag{18}$$

$$\tilde{g}^M_{2(t)} = \psi_{21M}(\tilde{w}^M_{1(t)} + \frac{1}{(1-\sigma)}\tilde{\lambda}_{1(t)}) + \psi_{22M}(\tilde{w}^M_{2(t)} + \frac{1}{(1-\sigma)}\tilde{\lambda}_{2(t)}) \tag{19}$$

$$G^A_{1(t)} = [\phi_{1(t-1)}(w^A_{1(t-1)}T^A_{11})^{1-\eta} + \phi_{2(t-1)}(w^A_{2(t-1)}T^A_{21})^{1-\eta}]^{1/(1-\eta)} \tag{20}$$

$$G^A_{2(t)} = [\phi_{1(t-1)}(w^A_{1(t-1)}T^A_{12})^{1-\eta} + \phi_{2(t-1)}(w^A_{2(t-1)}T^A_{22})^{1-\eta}]^{1/(1-\eta)} \tag{21}$$

$$\tilde{g}^A_{1(t)} = \psi_{11A}(\tilde{w}^A_{1(t)} + \frac{1}{(1-\eta)}\tilde{\phi}_{1(t)}) + \psi_{12A}(\tilde{w}^A_{2(t)} + \frac{1}{(1-\eta)}\tilde{\phi}_{2(t)}) \tag{22}$$

$$\tilde{g}^A_{2(t)} = \psi_{21A}(\tilde{w}^A_{1(t)} + \frac{1}{(1-\eta)}\tilde{\phi}_{1(t)}) + \psi_{22A}(\tilde{w}^A_{2(t)} + \frac{1}{(1-\eta)}\tilde{\phi}_{2(t)}) \tag{23}$$

where $\psi_{11M} = \frac{(T^M_{11}\lambda_1^{*1/(1-\sigma)}w_1^{M*})}{G_1^{M*}}$; $\psi_{12M} = \frac{(T^M_{21}\lambda_2^{*1/(1-\sigma)}w_2^{M*})}{G_1^{M*}}$; $\psi_{21M} = \frac{(T^M_{12}\lambda_1^{*1/(1-\sigma)}w_1^{M*})}{G_2^{M*}}$; $\psi_{22M} = \frac{(T^M_{22}\lambda_2^{*1/(1-\sigma)}w_2^{M*})}{G_2^{M*}}$; $\psi_{11A} = \frac{(T^A_{11}\phi_1^{*1/(1-\eta)}w_1^{A*})}{G_1^{A*}}$; $\psi_{12A} = \frac{(T^A_{21}\phi_2^{*1/(1-\eta)}w_2^{A*})}{G_1^{A*}}$; $\psi_{21A} = \frac{(T^A_{12}\phi_1^{*1/(1-\eta)}w_1^{A*})}{G_2^{A*}}$ and $\psi_{22A} = \frac{(T^A_{22}\phi_2^{*1/(1-\eta)}w_2^{A*})}{G_2^{A*}}$ are calculated parameters.

Nominal wage

$$w^M_{1(t)} = [Y_{1(t-1)}(T^M_{11})^{(1-\sigma)}(G^M_{1(t-1)})^{(\sigma-1)} + Y_{2(t-1)}(T^M_{12})^{(1-\sigma)}(G^M_{2(t-1)})^{(\sigma-1)}]^{1/\sigma} \tag{24}$$

$$w^M_{2(t)} = [Y_{1(t-1)}(T^M_{21})^{(1-\sigma)}(G^M_{1(t-1)})^{(\sigma-1)} + Y_{2(t-1)}(T^M_{22})^{(1-\sigma)}(G^M_{2(t-1)})^{(\sigma-1)}]^{1/\sigma} \tag{25}$$

$$\tilde{w}^M_{1(t)} = \alpha_{11M}(\frac{(\sigma-1)}{\sigma}\tilde{g}^M_{1(t-1)} + \frac{1}{\sigma}\tilde{y}_{1(t-1)}) + \alpha_{12M}(\frac{(\sigma-1)}{\sigma}\tilde{g}^M_{2(t-1)} + \frac{1}{\sigma}\tilde{y}_{2(t-1)}) \tag{26}$$

$$\tilde{w}^M_{2(t)} = \alpha_{21M}(\frac{(\sigma-1)}{\sigma}\tilde{g}^M_{1(t-1)} + \frac{1}{\sigma}\tilde{y}_{1(t-1)}) + \alpha_{22M}(\frac{(\sigma-1)}{\sigma}\tilde{g}^M_{2(t-1)} + \frac{1}{\sigma}\tilde{y}_{2(t-1)}) \tag{27}$$

$$w^A_{1(t)} = [Y_{1(t-1)}(T^A_{11})^{(1-\eta)}(G^A_{1(t-1)})^{(\eta-1)} + Y_{2(t-1)}(T^A_{12})^{(1-\eta)}(G^A_{2(t-1)})^{(\eta-1)}]^{1/\eta} \tag{28}$$

$$w^A_{2(t)} = [Y_{1(t-1)}(T^A_{21})^{(1-\eta)}(G^A_{1(t-1)})^{(\eta-1)} + Y_{2(t-1)}(T^A_{22})^{(1-\eta)}(G^A_{2(t-1)})^{(\eta-1)}]^{1/\eta} \tag{29}$$

$$\tilde{w}^A_{1(t)} = \alpha_{11A}(\frac{(\eta-1)}{\eta}\tilde{g}^A_{1(t-1)} + \frac{1}{\eta}\tilde{y}_{1(t-1)}) + \alpha_{12A}(\frac{(\eta-1)}{\eta}\tilde{g}^A_{2(t-1)} + \frac{1}{\eta}\tilde{y}_{2(t-1)}) \tag{30}$$

$$\tilde{w}^A_{2(t)} = \alpha_{21A}(\frac{(\eta-1)}{\eta}\tilde{g}^A_{1(t-1)} + \frac{1}{\eta}\tilde{y}_{1(t-1)}) + \alpha_{22A}(\frac{(\eta-1)}{\eta}\tilde{g}^A_{2(t-1)} + \frac{1}{\eta}\tilde{y}_{2(t-1)}) \tag{31}$$

where:
$\alpha_{11M} = \frac{(T^M_{21})^{(1-\sigma)/\sigma}(Y^*_1)^{1/\sigma}(G^{M*}_1)^{(\sigma-1)/\sigma}}{w^{M*}_1}$; $\alpha_{12M} = \frac{(T^M_{12})^{(1-\sigma)/\sigma}(Y^*_2)^{1/\sigma}(G^{M*}_2)^{(\sigma-1)/\sigma}}{w^{M*}_1}$; $\alpha_{21M} = \frac{(T^M_{21})^{(1-\sigma)/\sigma}(Y^*_1)^{1/\sigma}(G^{M*}_1)^{(\sigma-1)/\sigma}}{w^{M*}_2}$; $\alpha_{22M} = \frac{(T^M_{22})^{(1-\sigma)/\sigma}(Y^*_2)^{1/\sigma}(G^{M*}_2)^{(\sigma-1)/\sigma}}{w^{M*}_2}$; $\alpha_{11A} = \frac{(T^A_{21})^{(1-\eta)/\eta}(Y^*_1)^{1/\eta}(G^{A*}_1)^{(\eta-1)/\eta}}{w^{A*}_1}$; $\alpha_{12A} = \frac{(T^A_{12})^{(1-\eta)/\eta}(Y^*_2)^{1/\eta}(G^{A*}_2)^{(\eta-1)/\eta}}{w^{A*}_1}$; $\alpha_{21A} = \frac{(T^A_{21})^{(1-\eta)/\eta}(Y^*_1)^{1/\eta}(G^{A*}_1)^{(\eta-1)/\eta}}{w^{A*}_2}$; $\alpha_{22A} = \frac{(T^A_{22})^{(1-\eta)/\eta}(Y^*_2)^{1/\eta}(G^{A*}_2)^{(\eta-1)/\eta}}{w^{A*}_2}$.

Real wage

$$\omega^M_{1(t)} = w^M_{1(t)}(G^M_{1(t-1)})^{-\mu}(G^A_{1(t-1)})^{\mu-1} \tag{32}$$

$$\omega^M_{2(t)} = w^M_{2(t)}(G^M_{2(t-1)})^{-\mu}(G^A_{2(t-1)})^{\mu-1} \tag{33}$$

$$\tilde{\omega}^M_{1(t)} = w^M_{1(t)} - \mu\tilde{g}^M_{1(t-1)} + (\mu-1)\tilde{g}^A_{1(t-1)} \tag{34}$$

$$\tilde{\omega}^M_{2(t)} = w^M_{2(t)} - \mu\tilde{g}^M_{2(t-1)} + (\mu-1)\tilde{g}^A_{2(t-1)} \tag{35}$$

$$\omega_{1(t)}^{A} = w_{1(t)}^{A}(G_{1(t-1)}^{M})^{-\mu}(G_{1(t-1)}^{A})^{\mu-1} \tag{36}$$

$$\omega_{2(t)}^{A} = w_{2(t)}^{A}(G_{2(t-1)}^{M})^{-\mu}(G_{2(t-1)}^{A})^{\mu-1} \tag{37}$$

$$\tilde{\omega}_{1(t)}^{A} = w_{1(t)}^{A} - \mu\tilde{g}_{1(t-1)}^{M} + (\mu-1)\tilde{g}_{1(t-1)}^{A} \tag{38}$$

$$\tilde{\omega}_{2(t)}^{A} = w_{2(t)}^{A} - \mu\tilde{g}_{2(t-1)}^{M} + (\mu-1)\tilde{g}_{2(t-1)}^{A} \tag{39}$$

Migration

$$\lambda_{1(t)} - \lambda_{1(t-1)} = \chi^{M}(\omega_{1(t)}^{M} - \overline{\omega}_{(t-1)}^{M}) \tag{40}$$

$$\lambda_{2(t)} - \lambda_{2(t-1)} = \chi^{M}(\omega_{2(t)}^{M} - \overline{\omega}_{(t-1)}^{M}) \tag{41}$$

$$\tilde{\lambda}_{1(t)} = \frac{\chi^{M}}{\lambda_{1}^{*}}[\omega_{1}^{M*} + \omega_{1}^{M*}\tilde{\omega}_{1(t)}^{M} - \Pi] + \tilde{\lambda}_{1(t-1)} \tag{42}$$

$$\tilde{\lambda}_{2(t)} = \frac{\chi^{M}}{\lambda_{2}^{*}}[\omega_{2}^{M*} + \omega_{2}^{M*}\tilde{\omega}_{2(t)}^{M} - \Pi] + \tilde{\lambda}_{2(t-1)} \tag{43}$$

where $\Pi = \lambda_{1}^{*}\omega_{1}^{M*}(1+\tilde{\omega}_{1(t-1)}^{M}+\tilde{\lambda}_{1(t-1)})+\lambda_{2}^{*}\omega_{2}^{M*}(1+\tilde{\omega}_{2(t-1)}^{M}+\tilde{\lambda}_{2(t-1)})$ is the log-linearized representation of the general average of the lagged industrial real wage.

$$\phi_{1(t)} - \phi_{1(t-1)} = \chi^{A}(\omega_{1(t)}^{A} - \overline{\omega}_{(t-1)}^{A}) \tag{44}$$

$$\phi_{2(t)} - \phi_{2(t-1)} = \chi^{A}(\omega_{2(t)}^{A} - \overline{\omega}_{(t-1)}^{A}) \tag{45}$$

$$\tilde{\phi}_{1(t)} = \frac{\chi^{A}}{\phi_{1}^{*}}[\omega_{1}^{A*} + \omega_{1}^{A*}\tilde{\omega}_{1(t)}^{A} - \Gamma] + \tilde{\phi}_{1(t-1)} \tag{46}$$

$$\tilde{\phi}_{2(t)} = \frac{\chi^A}{\phi_2^*}[\omega_2^{A*} + \omega_2^{A*}\tilde{\omega}_{2(t)}^A - \Gamma] + \tilde{\phi}_{2(t-1)} \tag{47}$$

where $\Gamma = \phi_1^*\omega_1^{A*}(1 + \tilde{\omega}_{1(t-1)}^A + \tilde{\phi}_{1(t-1)}) + \phi_2^*\omega_2^{A*}(1 + \tilde{\omega}_{2(t-1)}^A + \tilde{\phi}_{2(t-1)})$

Regional product

$$Y_{1(t)} = \mu^M\lambda_{1(t)}w_{1(t)}^M + \mu^A\phi_{1(t)}w_{1(t)}^A \tag{48}$$

$$Y_{2(t)} = \mu^M\lambda_{2(t)}w_{2(t)}^M + \mu^A\phi_{2(t)}w_{2(t)}^A \tag{49}$$

$$\tilde{y}_{1(t)} = \zeta_{1M}(\tilde{\lambda}_{1(t)} + \tilde{w}_{1(t)}^M) + \zeta_{1A}(\tilde{\phi}_{1(t)} + \tilde{w}_{1(t)}^A) \tag{50}$$

$$\tilde{y}_{2(t)} = \zeta_{2M}(\tilde{\lambda}_{2(t)} + \tilde{w}_{2(t)}^M) + \zeta_{2A}(\tilde{\phi}_{2(t)} + \tilde{w}_{2(t)}^A) \tag{51}$$

where $\zeta_{1M} = \frac{\mu^M\lambda_1^*w_1^{M*}}{Y_1^*}$; $\zeta_{2M} = \frac{\mu^M\lambda_2^*w_2^{M*}}{Y_2^*}$; $\zeta_{1A} = \frac{\mu^A\phi_1^*w_1^{A*}}{Y_1^*}$ and $\zeta_{2A} = \frac{\mu^A\phi_2^*w_2^{A*}}{Y_2^*}$ are calculated parameters.