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Omar O. Chisari
Sebastián Miller

Inter-American Development Bank
Department of Research and Chief Economist

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Omar O. Chisari*
Sebastián Miller**

* Instituto de Economía, Universidad Argentina de la Empresa (UADE) and Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina
** Inter-American Development Bank

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Abstract[1]

Migration is one of the strategies used by populations to adapt to natural shocks and also to respond to economic policies. Climate change will probably have an impact on the productivity of factors and on the health of the population of the Latin America and Caribbean region, triggering migrations. In addition, policies aimed at reducing emissions (like carbon taxes) will change relative prices and the remuneration of factors and, in turn, will alter the allocation of labor between urban and rural areas. This paper explores the potential quantitative relevance of those population movements using a CGE version of the Harris-Todaro model. Two paradigmatic cases are considered: i) domestic or internal migrations, focusing on the case of Sao Paulo (Brazil) and ii) international migrations, analyzing the displacement of population from Bolivia and Paraguay to Argentina.

JEL classifications: C68, J61, R13, R23
Keywords: Migration, Climate change, CGE, Argentina, Sao Paulo

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1. Introduction

The accumulated knowledge on climate change (CC) for the Latin American and Caribbean region (LAC) indicates it will have impacts on productivity and health of our population. The 2-3^0 increase expected in the average temperature of the world will probably be surpassed in the next 50 years, and the consequences for the environment and infrastructure are still uncertain.[2]

Climate change will also have consequences for internal and international migration, as people will move to less affected areas. Urban areas will very likely become more populated, since those areas have better infrastructure and formal and informal safety systems.

In turn, this movement will put infrastructure under stress and could also increase unemployment. An additional consequence could be an increase of emissions that would reinforce climate change, because urban activities and household habits are more intensive in energy use. A recent study of the case of Nepal confirms that “migrants prefer areas that are nearer to paved roads and have better access to electricity” (see Shilpi, Sangraula and Li, 2014). However, the migration of rural population could save some emissions stemming from less productive agriculture methods.

Latin America is a highly urbanized sub-region, home to some of the largest metropolitan areas in the world such as Buenos Aires, Sao Paulo and Mexico City. Some of these cities receive internal migrants, like Sao Paulo, but others, like Buenos Aires, receive immigrants from neighbor countries (Paraguay and Bolivia). Taking into account this urban concentration feature of LAC and the new conditions imposed by CC consequences together, the knowledge on causes and consequences of migrations should be reconsidered. Consistently with this line of reasoning, this study is aimed at exploring the adaptation and modification of models used more frequently to address labor market phenomena and problems of development in a migration framework, like the Harris-Todaro model.

In fact, this paper presents a Computable General Equilibrium (CGE) analysis of migrations based on a Harris-Todaro model applied to two paradigmatic cases. One involves the case of an open economy to migration (Argentina) that receives migrants from Bolivia and Paraguay. The second discusses the case of domestic migration from the rest of Brazil to Sao Paulo.

[2] Estimates have suggested that between 25 million and one billion people could be displaced by climate change over the next 40 years (Lackzo and Aghazarm, 2009).

The second section provides the general scenario of LAC migration to explain the nature and importance of this phenomenon. That section concludes with the selection of two paradigmatic cases to be evaluated with the CGE approach. The third section presents the general scheme of the Computable General Equilibrium model constructed to encompass simultaneously climate change and migrations, with reference to particular modeling strategies for the cases of internal and international migrations. The fourth section presents the results of the simulations, and the last section summarizes lessons and main findings.

2. Migrations in Latin America and the Caribbean

2.1 Nature and Importance

Potential migrants in Latin America and the Caribbean responding to the negative effects of climate change in their regions will add to the ongoing migration flows of individual countries. Historically, immigrants from overseas between the mid-nineteenth and mid-twentieth centuries populated the region, and in several countries (most notably Argentina, Brazil, Colombia and Chile) they accounted for a major share of the total population. Those immigrants, mostly from Europe, came to model the consumption pattern of large Latin American cities on that of European culture.

More recently, especially after World War II, the increase in rural-urban migration consolidated Latin America's condition of LA as a highly urbanized sub-continent (urban population amounts to 80 percent of total population).While this process has been considered as being almost completed by the 1970s, however there are still some important countries in terms of total population that exhibit higher shares of rural population where the actual flow of rural-urban migration might be particularly affected by climate change effects. Prospects for 2015-2050 anticipate flows of 10 to 15 percent of total population migrating from rural areas to the cities in Bolivia, Peru, Mexico, Brazil and most Central American countries.[3]

Intra-regional migration, a phenomenon related to rural-urban flows, has been growing over the last two decades. Historical cross-border migration for temporary work in agriculture has turned into intra-regional migration for working long-term in the largest cities of relatively more developed countries in the region. Cepal (2006) indicates that this trend has been favored

[3] Rural-urban migration and the growth of cities are key social change processes of our times. All too often this means that people leaving the land end up in urban slums (Davis, 2006).

by socio-economic developments and structural factors, particularly during the period 1970-90, which saw the highest rates of migration within Latin America.

Official statistics from the 2000 round of censuses (the latest available region-wide) show that approximately 13 percent of migration in Latin America and the Caribbean is intraregional, involving approximately three million migrants (Mazza and Sonhen, 2011).

Brazil and Argentina show a diminishing trend in the stock of migrants mainly due to the death of early European immigrants. In the case of Argentina, this trend reverses in the last intercensal period considered because of a major inflow of immigrants from other countries in the region. In fact, in net terms, foreign population in Argentina increases by 288,053 inhabitants over the 2001-2010 period, while the gross inflow from Latin America amounts to approximately 429,100 immigrants.

In the cases of Chile and Mexico, total migrants living in the country have been increasing steadily at least since the 1970s for Mexico and since the 1980s for Chile. In the Chilean case, Latin American immigrants account for most of this increase. In the Mexican case, Latin American immigrants, including those from Central America, account for only a small part of the immigrant flow, which is dominated by U.S. migrants.[4]

A brief look at the region's net migration flow shows that Central America, the Caribbean and several countries in South America have also been sending population out of the region; i.e., their net migration rate has been negative over 2005-10. This is explained by so called South-North migration, mainly consisting of skilled workers from LAC and the Caribbean taking their chances in the United States or Europe.[5] This flow also led to a surge in networks of immigrant communities in host countries and to a flow of remittances sent by migrants to their countries of origin.

In the Bolivian case, for instance, migrant social networks which connect communities of origin and destination also facilitate the emigration of Bolivians. Such networks provide important information on employment opportunities in other countries, including admission

[4] U.S. immigrants to Mexico totaled around 400,000 in the decade of 2000-2010. The flow of Mexicans to the United States in the previous decade, 1990-2000, exceeded 4 million people.

[5] Since the economic downturn of 2008-09, OECD countries like the United States, Spain, Italy, the United Kingdom and Belgium have experienced a long-lasting decline in reception of migrants. A recent rebound has begun in 2013 in Germany, mainly due to free movement of labor within the EU. In OECD countries on average, low-educated immigrants are more likely to be employed than their native-born peers. (Some 10 percent of OECD countries' populations, 115 million people, are immigrants).

issues, and contribute to successful integration of newly arriving workers by providing support and information in areas such as housing options. In this case, remittances constitute around 5 per cent of the GNP (OIM, 2011a).[6] In the case of Paraguay, it is estimated that at the beginning of 2010 there were about 777,000 Paraguayan emigrants, representing almost 12 per cent of the total estimated population in that year (OIM, 2011b).

Net migration figures hide a more complex situation within and across countries.[7] Considering the brief panorama of rural-urban and regional flows previously described, several South American countries classified as negative net migration countries are better depicted as both important host countries for other migrants from elsewhere in the region and countries where rural-urban migration is still taking place. At the same time, these countries are losing part of their skilled labor force, which travels to OECD destinations. As we will see below, Argentina and Chile are good examples of this trend. Brazil shares part of this complexity, in which internal migrations feature prominently. In the Mexican case, the importance of emigration to the United States combines with the relevance of rural-urban flows. In the cases of Peru, Bolivia and Paraguay, rural-urban flows take place along with emigration to regional destinations. In many Central American countries net negative migration is due to migrants going to the United States while rural-urban migration is still taking place.

Finally, analysts coincide in characterizing regional migrant flows in LAC as explained mostly by labor opportunities in neighboring countries (Maguid and Ulloa, 2010).

The evidence described above allows us to characterize Latin American migration patterns broadly as follows. In the southern part of the region, migration remains a rural-urban flow where the largest megacities in migrants' own countries or neighboring countries attract unskilled or semiskilled workers. In the Argentine case, Paraguayans, Uruguayans and Chileans accounted for the majority of intra-regional flows until the mid-1980s. More recently, immigrants from Paraguay and Bolivia account for the bulk of the inflow, while Chileans and Uruguayans have been returning to their home countries. Inflows from Peru and Bolivia are the

[6] Emigrants represented around 7 percent of total Bolivian population in 2010.
[7] Some special features such as violence and crime have also to be taken into account. According to CEPAL (2006), for instance, "Beginning in the mid-1970s and lasting well into the 1990s, two intertwined and overlapping processes also began to feature in the traditional migration flows of workers between countries in the region and especially between their border areas: first, the forced migration of large sections of the population as a result of violent conflicts and political conditions that put people's lives at risk and second, a marked increase in migration to countries outside the region, mainly the United States. This trend continued until peace processes took effect in the region (Nicaragua in 1990, El Salvador in 1992 and Guatemala in 1996)."

most important ones for Chile, while only a small portion of Paraguayans opt for Brazil as a host country. In Brazil, internal rural-urban migration is still the dominant feature, and this type of internal flow has remained important in Argentina as well. Finally, Mexico is characterized as a special case due to the massive migration of Mexican nationals to the United States, which has lasted for over a century. At the same time, Mexico continues to display an interesting pattern of internal rural-urban migration.

Around the 2000s, Argentina was the host country with the largest Iberoamerican migrant community among Iberian and Iberoamerican countries (26.7 percent of total Iberoamerican migrants, followed by Spain with 20.5 percent).

According to the 2010 Census, the share of immigrants in total population amounted to 4 percent (in the early 1900s that share exceeded 30 percent due to European massive immigration). Currently, the main international immigration flows are from regional sources: Paraguay, Bolivia and Peru. These flows have been growing steadily in the 2000s, with a slight feminization bias. As already stated, emigration has also been very important.

One very interesting feature of this intra-regional flow is the concentration of immigrants in the Metropolitan Region of Buenos Aires, which contains 35 percent of the country's total population. According to the register of the National Migration Authority, the inflow of migrants from neighboring countries has been increasing in recent years.[8] One of the main reasons is the differential wage level between Argentina and countries such as Bolivia and Paraguay, even during the downturn of the economic cycle (Maurizio, 2006). Adding to this incentive, migration policy has evolved to grant immigrants full social benefits.[9]

As a consequence of favorable economic as well as regulatory factors, immigrants accelerated their arrival during the upper phase of the last economic cycle (2004-2008), when jobs in the building industry and in domestic service were easily available.[10] Feminization of migration flows has also been a salient feature, with female immigrants representing 54 percent

[8] Between the 1950s and 1960s, immigrants from neighboring countries entered for seasonal activities in the rural sector, responding to the opportunities opened up by the internal migration of Argentina's rural population to the cities due to the industrialization process.

[9] In 2004 Law 25871 was passed, which reaffirmed the granting of social rights to immigrants as stated in the National Constitution. Migrants are admitted under temporary or permanent categories, but transition between categories does not face significant obstacles under reasonable conditions. Decree 836/04 ordered the regularization of immigrants from neighboring countries (the Patria Grande Program).

[10] These two sectors explained two-thirds of the increase in total employment of the country during that period.

of the non-native population.[11] Finally, the labor activity rate is higher for immigrants in comparison to nationals, and during economic downturns migrations partly reverse, coinciding with a reduction in informal wages (Moya, 2009).

As of 2010, 220,000 immigrants living in the country had regularized their status through permanent and temporary permits. Out of that total, 52 percent lived in the suburbs of Buenos Aires City and 32 percent in the city itself. Immigrants from Paraguay and Bolivia represented 82 percent of the total, and they were predominantly of working age and single (82 percent). Half had primary studies, 30 percent had secondary studies and 8 percent had not attended school.

Like most Latin American countries, Brazil is highly urbanized, with 81 percent of the population living in cities. This fact does not preclude the persistence of internal migration that, according to the latest census data, involved almost 3 percent of total population in five years, i.e., 5.7 million people in 2005-2010. While some cities in the Atlantic coast have become new attractors to migrants, the largest share goes to the Metropolitan Region of Sao Paulo, which captures around 20 percent of the total.

External immigration is low, representing 0.14 percent of total population in 2010-2005, and of intra-regional origin (Paraguay, Bolivia and Peru).

2.2 Migration, Habits and Climate Change in Latin America and the Caribbean

Although climate change migrations seem to share similarities with forced migrations, population displacement due to desertification or climate catastrophe is more likely to be irreversible and urgent.[12] Yet not all analysts share this view. Castles (2011) points out that, while environmentalists see global warming-induced climate change as a powerful new force in population displacement, migration scholars regard environmental factors as just one part of a wider constellation of economic, social and political relationships that motivate people to move. This author also asserts that there is still little evidence that climate change has so far caused large increases in migration. However, the forecast acceleration of climate change will certainly have an important effect on migration decisions, increasing the scale of population displacement.

[11] Among Peruvian immigrants 60 percent are female, and 59 percent in the case of Paraguayan immigrants.

[12] Castles (2011) indicates that "it is customary in the climate change-induced migration field to distinguish between slow-onset processes and rapid-onset events. For example, trends to higher or lower rainfall in certain areas take place over quite long periods, giving affected groups time to adapt in various ways. Rapid-onset events include cyclones, floods and similar catastrophes that require sudden flight in order for people to survive."

One interesting aspect of migration that has not often been discussed relates to migrants' change of habits. In their country or region of origin, in general, their consumption pattern will be that of rural areas or lower urban income levels. When urban-urban migration takes place, the cities of origin are smaller and less developed compared to destination cities. Thus, it is very likely that migrants will increase their demand for goods that are more intensive in electricity and other sources of energy. In addition, they will intensively use the transport system, leading to congestion, increased emissions and losses of welfare. Even when municipal authorities try to cope with cities' needs, the increasing flow of migrants can overwhelm their efforts. Moreover, the presence of economies of agglomeration could lead to undesirable urban growth, accompanied by increased emissions. Notice that even though transport demand could be reduced in per capita terms, changing habits could increase demand for electricity, with an uncertain net result in terms of emissions.

Thus, on the one hand climate change shocks to rural areas will increase the flow of migrants, and adaptation in agriculture and rural activities could help to reduce the magnitude of the problem. On the other hand, it is necessary to anticipate the impact of increasing energy and transportation demand on total emissions. In short, what will be the net result in terms of greenhouse gas emissions? It is also important to consider whether carbon taxes on emissions will have a relevant impact on living conditions of poor migrants, as well as whether those taxes could modify the equilibrium rate of unemployment and the congestion of cities.

In the cases reviewed in this study, there is indirect evidence of this change in consumption patterns. In regard to intra-regional migration, for instance, structural factors contributing to low levels of human development in large part explain emigration from Bolivia, together with recruitment systems operating within the country designed to attract the young and relatively inexpensive workforce to destination countries, particularly for employment in the textile industry (OIM, 2011a). At present, rural-urban migration continuous to be a key feature of the Bolivian case. However, this phenomenon coincides with an outflow of population towards other Latin American countries. This outflow involves an urban population with manufacturing skills. At the same time, information on the destination of remittances indicates that 72 percent of expenditures financed by remittances are devoted to buying food and basic goods, while 12 percent goes to health and education expenses. Only 0.5 percent goes to transport costs, and only 0.7 percent to basic services.

Recent emigration flows from Paraguay to Argentina consist mostly of young adults under 35 years, and more than 60 percent are women, with both rural and urban origins. In fact, according to the National Housing Survey, 54 percent came from urban areas and 46 percent from rural areas. (Some 30 percent and 9 percent had emigrated from Central and Alto Parana, respectively, and 13 percent from Itapua, three departments with a relatively high level of urbanization). Moreover, remittances have increased steadily in recent years, representing 2.6 percent of GNP in 2009. As in the Bolivian case, most of expenditures financed by remittances are used for food and basic needs. In this case, a broad range of households receive remittances, indicating emigrants' diverse social status. The poorest households, belonging to the first and second income quintiles, received remittances equivalent to 5-6 percent of their income, while households in the richest 20 percent received remittances equivalent to 2.8 percent (OIM, 2011b).

In the case of rural-urban migration, the difference in consumption patterns is even more pronounced. In the case of Brazil, Northeast Brazil (NEB, consisting of Bahia, Pernambuco, Alagoas and Paraiba) is known for its temporal and spatial variability of precipitation and historically has been the main origin of internal migrations. At the other end, the Metropolitan Region of Sao Paulo has been the largest immigrant attractor. More recently, internal mobility has increased, and some new urban centers (in Matto Grosso and Goias, for instance) have been receiving internal migrants at the same time that a portion of migrants have returned to their place of birth.

Mexico likewise experiences rural-urban migration. In addition, Mexico is heavily exposed to climate change and has suffered in the past from climate variability. According to Sánchez Cohen et al. (2013), the arid, semi-arid and sub-humid condition of 49.2 per cent of the territory of Mexico is seriously affected by climate change. In addition, poverty and the lack of jobs have created complex livelihood situations in which young people leave rural areas, partly due to socio-economic pull factors. This includes forced migration due to climate change into the slums of megacities (or illegal immigration to the United States).

Finally, the analysis of migration data shows a relationship between migration and larger cities in the region (e.g., Buenos Aires, Sao Paulo, Mexico City and Santiago, Chile). Even though urban areas in Latin America are not major greenhouse gas emitters in comparison to those elsewhere, their emissions are growing sources of greenhouse gases, and they are hotspots of vulnerability to floods, heat waves, and other hazards that climate change is expected to aggravate (Hardoy and Romero Lankao, 2011).[13] Moreover, migrants are very likely to populate urban slums, which are particularly likely to be affected by those hazards.

To conclude, based on the discussion above, two paradigmatic cases were chosen for analysis using the CGE model: i) international migrations, from Bolivia and Paraguay to Argentina; and ii) domestic migrations, to Sao Paulo from the rest of Brazil.

3. General Scheme of the CGE Model

The interface between climate change and labor conditions has been discussed only briefly in the literature (for example, see Olsen, 2009). However, there are several interesting and meaningful links. Is it possible to address the objectives of emissions reduction under full employment and social development? Does climate change have a more intense on some regions and activities, like agriculture?

Though the effects of climate shocks on migration can be more transparent and are considered in the literature (see, for example, Wibbenmayer, 2014) there has not been an exploration of migration as a rational response to the reduction of emissions via taxes (for example, changes in the flows of entrants of workers to urban zones). Taxes have been considered in a Harris-Todaro framework (see Raghbendra and Lächler, 1981) but they have not linked to emissions.

The Harris-Todaro (1970) model is the basic model used in development economics to represent conditions of persistent unemployment in urban areas due to migration of rural workers. In that model, urban wages are given, determined for example by unions (Calvo, 1978) or efficiency needs of firms (Zenou and Smith, 1995), and rural wages are equalized to the marginal product of labor. Migration occurs until the expected wage rate in urban areas (the real wage corrected by the probability of finding a job) is equal to the rural wage.

[13] Romero Lankao (2008) points out that Buenos Aires, Santiago and Mexico City, for instance, experienced during the last two decades a region-based or polycentric urban expansion of first and second-order urban localities sprawling along major motorways and functionally linked to the main city. This pathway of urbanization is associated with relevant consequences for greenhouse gases as well as other atmospheric emissions. As illustrated by Mexico City, passengers' commuting distance and travel times increased from 3.5 km/h and 16.8 km/h by bus in 1987 to 5.6 km and 16.7 km/h in 2000. The same may be the case with freight transport. More sprawling patterns of urban growth are related to variations in car use, petrol consumption, and by this, to more emissions.

More recently, that model was enriched by introducing the market for land and transportation (see Brueckner and Zenou, 1999, and Zenou (2009) in the context of the new economic geography. In addition, Grazi and Waisman (2009) construct a CGE model applied to the United States that takes into account how urban growth and transportation can modify emissions.

Government action can influence the workings of economies in a substantial way as well, even though the inclusion of its activity is less common in the Harris-Todaro literature. The government could establish minimum formal wages, or it could hire urban labor to compensate for unemployment—which could increase rather reduce the equilibrium rate of unemployment when the Harris-Todaro paradox applies.

In a recent paper Biller, Andres and Cuberes (2014) present a model of allocation of agents between two regions, the urban and rural sector. This paper, unlike many others, highlights the role of government expenses and investments in migratory movements. This point is also mentioned by Duflot (2012) who discusses the case of Singapore and emphasizes that the result of urbanization was not related to a wage differential but to a deliberate process of reallocation led by the government, which increased urban infrastructure and subsidized housing.

Biller, Andres and Cuberes (2014) develop a model that could help to explain the process of urbanization, with particular reference to the cases of Latin America and East Asia. They assume full employment and only one good produced in both regions (or at least there is not a problem of relative prices in their model).[14] They also consider that there are positive externalities due to gains of agglomeration, and that there are also negative externalities due to congestion that can be compensated with public expenditure in cities. The model examines two cases: i) the competitive case with anonymous agents, and ii) the (normative) centralized optimal solution of a benevolent planner. The benevolent planner has a utility function that depends on the utility of agents of both regions, weighted by the subjective evaluation of the planner of their relative value to welfare. It could also impose carbon taxes on the regions' economies.

[14] They consider this assumption the key element permitting the inclusion of investments in their analysis; however, that assumption does not seem necessary since it would be possible to construct an aggregate of goods to be used for investments. With reference again to capital formation, the authors assume that investments are irreversible and that it is also desirable to understand processes of urbanization that do not exhibit jumps or sudden movements of migrations from one region to other. Implicitly, when agents move they do not take the rights of receiving rents from capital left in the other regions. There is not an explicit equation for the evolution of employment in time (though the paper is dynamic), but the model implicitly assumes that labor is reallocated until the utility level in both regions is the same.

Could those taxes increase (urban) unemployment and decrease welfare? In fact, excessively stringent environmental measure could lead to a positive answer to that question; see Chisari and Miller (2015) and Wang, Wang and Zhao (2012). The model is also suitable for the inclusion of agglomeration economies. As noted by Glaeser (2010: 1) "agglomeration economies are the benefits that come when firms and people locate one another together in cities and industrial clusters." In our case that could be interpreted as additional benefits for location of migrants in the urban area due, for example, to learning from urban workers, new opportunities for finding jobs, help of relatives that have already moved or even reduced time of search. All those phenomena can be included in the model as internal (non-market or shadow) self-subsidies of families to the localization that are proportional to size or scale of activity of urban areas.

The objective of this paper is to analyze whether those effects are quantitatively relevant and to explore compensatory policy measures.

3.1 The One-Country Model: Basic Harris-Todaro Case with Emissions

In our analysis there are elements of economic geography. We pay attention to the allocation of labor between regions of the same country, or between countries; we also consider trade in goods and different degrees of mobility of capital. We additionally have to emphasize the economic incentives to migration.

Thus a benchmark model to encompass the economic motivations for migration is the Harris-Todaro model, which in spite of its age remains a milestone in development economics and a basic reference for new geography economics (see Zenou, 2009).

In that model, agents migrate as a response to differential between the expected remunerations for factors. We shall keep that basic property as a fundamental equation of our models. However, we shall take into account net remunerations after migration costs and residence expenses.

We shall further include change of patterns of consumption or habits via the introduction of representation of migration as a process of production. One agent in economy B can be transformed into labor supply in economy A if the necessary "inputs" are used. The specification of the list of inputs is coincident with the estimated average expenses of migrants in host countries.

3.1.1 The Simplest Case

Let us first follow Zenou (2009) in his Appendix C to introduce a basic Harris-Todaro model. Let us assume that there are two regions, the urban *T* and the rural *R*, and that both regions produce the same good and this good is the numeraire. The assumption of only one good produced in both regions will be relaxed soon, since relative prices have a meaningful role to play in CGE.

Wages are given and $w^T > w^R$.

The total number of agents in the urban area is N^T, while total population in the rural region is N^R. Total urban population includes employed L^T and unemployed U^T:

$$N^T = L^T + U^T$$

In addition, there is no unemployment in the rural area, i.e.,

$$N^R = L^R.$$

The rate of unemployment in the urban area is $u^T = U^T/ (L^T + U^T)$, and workers allocate labor between both regions until the expected wage rate in the urban region is equal to the rural wage rate:

$$w^T L^T/(L^T + U^T) = w^T L^T/(N - L^R) = w^R.$$

N is total population $N^T + N^R$ and taking derivatives:

$$dL^T = -(w^R/w^T)\, dL^R.$$

Thus since $(w^R/w^T) < 1$, when one position is lost in *R*, less than one is created in T.

Accordingly, the so-called Todaro paradox always exists in this model because, after an increase in the number of positions in the urban area, there is always an increase in urban unemployment. Even this simple model shows that it is useful is to take into account the incentives to migrate given by wages, corrected with the probability of employment, to understand urban unemployment.

This model has many limitations, however, since there are no relative prices and both regions produce the same good, wages are exogenously determined, and there are no costs of migration or of residence in the urban area. Furthermore, it is not a general equilibrium presentation with an explicit treatment of budget conditions and market equilibria.

This simple model additionally fails to tell us what will happen to total emissions of GHG following additional migrations to urban areas when $dL^R < 0$. The result will depend on the emission coefficients of both regions and on the consumption habits of workers in different regions; even though the numbers of jobs created in the urban zone are smaller than jobs lost in the rural area, the net result in terms of emissions will depend on their absolute differences.

3.1.2 The Analytical Model

In this section we develop a simple general equilibrium framework that makes the model more complex. Though it is not strictly necessary, we still follow the original Harris-Todaro hypothesis in the sense that they consider the migration decision to urban regions of low-productivity rural workers, who are risk-neutral and therefore, the optimal allocation of labor implies the equalization of rural wages with expected urban wages.

The presence of unemployment in urban areas is the basic source of risk and, given that risk neutrality, agents take into account expected income without risk premium to make their labor supply decision. Both regions, urban and rural, are in the same country. In more general terms, the initial drivers of migration in this model are income differences.[15] However, we enrich the analysis by including the costs of residence (a wide set that includes energy use and transportation as well as consumption of needs and goods that are habits in the new place of residence).

In the following sections we will address the problem of migration between different countries.

Let us then consider the following model in the spirit of Harris-Todaro. In the urban area, profits of producers are given by:

$$\Pi_T = p_T F(L_T^{\ d}) - wL_T^{\ d} \quad (1)$$

In that expression Π_T are profits, p_T is the price of the urban good, $F(L_T^{\ d})$ is the (standard neoclassical) production function that uses labor $L_T^{\ d}$ with remuneration w.

The optimal condition for maximization of profits is:

$$p_T F_L'(L_T^d) = w \quad (2)$$

Urban agents receive profits and wages on effective employment and spend their budget on urban, c_T, or rural goods c_B (with price p_B). Their budget constraint is given by:

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[15] Those are the basic drivers identified by Borjas (1994). He points out the relative reduction of skills of migrants that reduces the benefits and increases costs for host countries. Lucas (2004) emphasizes the bright side of migration to cities, arguing that it is there where they can accumulate skills; thus he addresses growth more than a static condition.

$p_T\, c_T + p_B c_B^T = wL^0\,(1\text{-}TD) + \Pi_T$ (3)

Notice that labor income assumes that households have an endowment of labor that is supplied inelastically to the market, but that is affected by unemployment (the rate of unemployment is indicated as TD).

The first order condition for maximization of utility $U(c_T, c_B)$ is the familiar expression:

$U_T/U_B = p_T/p_B$ (4)

In the rural area, firms maximize profits Π_B:

$\Pi_B = p_B\, H(L_B^d) - w_B\, L_B^{\ d}$ (5)

given the production function $H(L_B^d)$ and pay wages w_B. The first order condition in this case becomes:

$p_B\, H_L'(L_B^d) = w_B$ (6)

The budget condition for rural agents is given by:

$p_B\, c_B = w_B\, L_B^d + wL_A\,(1 - TD) - p_T\, c_T^m + \Pi_B$ (7)

Here we assume that rural households can supply labor to both areas, and that there is no unemployment in the rural region. Moreover, there are no housing or transport expenses for rural agents. Instead, the supply of labor to urban areas L_A is subject to potential unemployment, and there is an additional expense in urban goods since it is assumed that to supply one unit of labor to the urban area, the rural household has to purchase η_T units of urban goods. This implies that the reallocation of labor requires urban goods; and therefore, there is an implicit transformation curve that permits changing rural labor into urban labor, but an additional cost. This cost reflects the change of habits since the consumption basket of urbanized rural workers could be similar to that of urban agents (for example, it may include more energy, more transportation, different food habits, and so on).

In this simplified version, it is assumed that there is only one type of urban goods that do not change their relative prices and can be treated as a Hicks-composite good. In the computational model, this assumption can be relaxed and substitution between different urban goods can be easily admitted.

Equation (8) represents the total allocation of the endowment of labor of rural agents N^0 between urban and rural regions:

$$L_A + L_B^d = N^0 \quad (8)$$

Thus the total demand of urban goods due to urbanization of labor supply is:

$$c_T^m = \eta_T L_A \quad (9)$$

Under this specification the transformation of one unit of rural labor into one unit of urban labor is costly and adds demand to urban goods (which could include energy and transport).

Taking into account those equations, the maximization of labor income requires:

$$w_B - w(1 - TD) + p_T \eta_T = 0 \quad (10)$$

Notice that net urban wages have to be corrected because there is unemployment and because living in the city requires additional or different expenses.

Again, workers are neutral to risk, and they allocate their "asset" to equalize the expected return between regions; Gugler (1968) sees that wage differential as potentially being so large that it compensates the risk, even when workers are risk averse.

Then we have the equations that correspond to market clearing conditions, for urban goods, rural goods and labor:

$$c_T + c_T^m = F(L_T^d) \quad (11)$$
$$c_B + c_B^T = H(L_B^d) \quad (12)$$
$$L_T^d = (L^0 + L_A)(1 - TD) \quad (13)$$

Finally, following the Harris-Todaro model, we have the exogenous determination of urban wages:

$$w \geq w^* \quad (14)$$

Taking this into account, the model includes 14 unknowns: Π_T p_T L_T^d w p_B c_B w_B L_A c_T^m Π_B L_B^d c_T c_B^T TD.

3.1.3 Determination of Wages

There is no general agreement on how urban wages are determined. For example, Calvo (1978) considers that urban wages are set by unions. In other models, urban wages are determined to meet some efficiency standards; following the ideas of Shapiro and Stiglitz (1984) the model of

Zenou (2009) includes incentive compatibility constraints (non-shirking conditions) for a given level of effort. An alternative is the model of insiders-outsiders where unionized workers determine wages without considering the rate of unemployment of the non-unionized (see Lindbeck and Snower, 1988); in that case, the wage curve would not include the rate of unemployment of migrants to the urban area if they were not unionized.

One interesting question is how to index wages, or in other terms, to which basket of goods are urban wages indexed. In the original Harris-Todaro model, wages are fully indexed to manufactures, which are presumed to be located in the urban areas, in this model that would amount to assuming that $w \geq p_T$. It is difficult to defend the assumption that the adjustment of wages will not take into account the price of agricultural goods, mainly produced in rural areas. So in modern economies, a wider set of prices should probably be taken into account for simulations.

But the presence of unemployment could hamper or moderate the adjustment of wages. In that case, a wage curve, more similar to a Phillips relation could be $w \geq p_T(1 - TD)$. This version of the Harris-Todaro model includes a correction given by the rate of unemployment and helps to represent the fundamental equilibrium condition on wages (equation (10)) in several models; see Rutherford and Light (2001) and Markusen and Rutherford (2004). However, it is necessary to be cautious in this aspect, because the inclusion of a wage curve could lead to duplicate the impact of rationing of the labor market on individual agents. In fact, rationing (unemployment) means that labor income should include only the effective employment, but in that case modeling wages as adjusted for unemployment could amplify the effect on workers' income.

For the simulations, it is assumed that wages are adjusted to the Retail Price Index.

3.1.4 Habits

Even though there are two markets for labor, labor mobility has a cost. In fact, η_T encompasses a habit change; if, for any reason, a worker migrates from *B* to the urban area, his expenses must include a basket of urban goods (probably more intensive in energy than those of rural zones). It is a "habit" not necessarily linked to preferences, because migrants in the city need to buy transportation and housing, and implicitly energy. Even though there has been a wide exploration of migration due to climate change (see for, example, Brown, 2008, and Piguet, Pécoud and de

Guchteneire, 2010), the dimension of emissions and the implicit change of habits of migrant population have not been explored deeply, especially for the Latin American and Caribbean case.

Of course, it is not necessary to use a linear relation as in (9); the transformation function could have a different shape, and its purpose is just to illustrate the procedure to be translated into the programming code.

A different perspective addresses the importance of habits for climate change in terms of inertia in the use of energy. However, from the perspective of evolutionary economics, Maréchal (2008 and 2010) emphasizes the role of history and points out the possibility of taking advantage of the fact that migrants have not been exposed to the history of the host country, and that habits of new consumers (in our case migrants) could be changed before it is too late. Thus new migrants could be "educated" to reduce emissions, something more difficult for indigenous populations.

One point that could be argued instead is that when migrants arrive in a city, the supply of goods (their type and quality) already contains the "habits" of its citizens in an implicit model of agreement, and therefore the adoption of habits is embedded in the goods. Moreover, it is possible that goods that reproduce the habits and norms of the city are less expensive because they are already available and for reasons of economics of scale and relative resources abundance. The adoption of the new habits will be a matter of availability (scarcity or abundance) of goods (or implicit high transport costs of alternatives) and relative prices, not a matter of habits (in terms of a different structure of preferences). This point could be illustrated by the quick adoption of food habits of the host populations by migrants, as traditional foods of their homeland may not be available in the host country or may be very expensive; Sweeny et al. (2013) discuss how choices can be limited by a great variety of factors.

New food habits can in turn increase emissions. If we take the example of countries like Argentina, Southern Brazil and Uruguay, the migration of European population increased the demand for beef (an abundant food already), and one of the main sources of emissions is cattle.

One interesting point is that in from a comparative static perspective the adoption of new habits by migrants is associated with their response to expected higher wages, and to net higher income. Any exogenous shock that makes it convenient for them to transform more rural work into urban work must increase higher expected net income, and this transformation will entail the adoption of habits of the host country represented by the transformation function. Thus, to some extent it can be seen that habits are intrinsically woven into the process of migration. Of course, migrants would also be changing their income status (though that would be applicable to any agent of a lower income bracket).

To some extent, the differential of habits helps to solve the problem of non-existence of equilibrium in economic geography posed by Starrett (1978), that homogeneity of regions across the board makes the solution indeterminate. According to his analysis, a model with homogenous regions does not have a competitive equilibrium; see Thysse (2011) for a summary of the evolution of economic geography.

3.1.5 Labor Market Conditions

A full employment case would also be of great interest. In fact, some modern evidence shows that unemployment might affect more domestic workers than migrants, particularly when they are unskilled: migrants could accept lower wages, work in informal activities or go back home when the labor market conditions are not favorable. Some surveys show that migrants could suffer from overemployment more than unemployment, which in any case affects migrants with higher levels of education.

But one of our concerns is the change in patterns of emissions due to migration and the interaction of labor markets with those of energy, housing and transportation. A paper that deals with this issue is Brueckner and Zenou (1999), though Lucas and Prescott (1974) first called attention to the spatial issue in their seminal paper. See also Gutiérrez (2011) for a study on employment variables of the substitution between housing and transportation in the case of Bogota and an econometric estimate.

Total emissions in urban and rural areas, E and $E_{B,}$ respectively, can be computed as:

$$E = \gamma_T (c_T + c_T^m) \quad (15)$$
$$E_B = \gamma_B (c_B + c_B^T) \quad (16)$$

In this case the intensity of emissions is given by the coefficients γ_T and γ_B and emissions are associated with consumption, though here the conditions of equilibrium imply that the result will be the same.

A report on Sao Paulo (Brazil) shows that, as of 2003, 76 percent of total emissions were associated with energy use and almost 24 percent with final disposal of solid waste (see Prefeitura, 2005). This indicates that emissions include transportation, electricity use and packaging, the use of which is more limited in rural areas. In the case of Buenos Aires (Gobierno, 2009) available information as of 2008 indicates that energy use accounts for 56 percent of emissions and transportation for 38 percent, while waste disposal accounts for the remaining 6 percent.

3.1.6 Interaction with Land and Housing Markets

An interesting question for the highly urbanized societies of Latin America and the Caribbean is whether de-urbanization could help to reduce emissions.[16] As discussed below, however, it should also be noted the process of urbanization has not yet ended when data on certain countries such as Argentina, Bolivia and Paraguay are taken into account, as urbanization responds to international migration.

The representation of expenses of migrants determined by a transformation function is more in line with an important insight from modern urban economics and new economic geography: the need to consider the interaction of the labor market with other markets, like those for land and housing (see Zenou, 2009). Crampton (1999) summarizes empirical evidence and highlights the importance of taking into account the job search process search. Even though we are not explicitly considering job search, total emissions are associated with the number of employed persons, and therefore it is implicitly assumed that the average expenses of the employed and unemployed are the same. However, the expenses of the latter can be included separately in the model as a specific cost involving demand for transportation and housing by the unemployed, which is probably different from the coefficient of employed migrants.

In our case, since we are assuming in this simplified version only one urban good, there is one aggregated demand function for urban goods.

Those additional expenses (p_T and η_T in the model) can change the pattern of emissions associated with rural workers when they migrate, as there are additional emissions associated with energy, housing and transportation. This also poses interesting policy problems. For example, expanding land or housing availability will reduce p_T and increase net urban wages,

[16] Some recent studies show that the size of the city itself influences the total heat produced (see http://www.clarin.com/ciudades/por_que-aire-no-refresca-Ciudad-edificios-rio-jurado_0_1318668161.html). Glaeser (2011) argues in Chapter 8 that cities can reduce emissions and be green; however his case is one of comparison of concentration in centers vs. suburban locations, which require higher intensity of transportation. That issue, though, is more a matter of the organization of urban zones than one of migration between rural and urban zones, as we are discussing here.

and it will foster migration and increase emissions. Brueckner and Zenou (1999) modify the original Harris-Todaro model to study whether the growth of the formal urban sector reduces the urban rate of unemployment; they include a market for land as a new determinant for unemployment. An increase in urban employment could increase the price of land and limit migration, and therefore an increase in wages, for example, would not necessarily increase migration and unemployment. In our case, that would be shown as an increase in p_T.

Alternatively, Zenou and Smith (1995) include the idea the unemployed live in conurbations far from the city centers where jobs are created. This implies that there is some substitution between transportation and location. Elhorst and Oosterhaven (2006) analyze how reductions in transport costs influence the individual decision on location of residence; as expected, when access is faster and less costly to a zone, workers will move there.

3.1.7 Drivers of Migration and the Role of Government

As mentioned above, a recent interesting study by Shilpi, Sangraula and Li (2014) identifies access to paved roads and electricity as main drivers of migration of rural populations in Nepal. This gives additional evidence on the relevance of energy and transportation as basic components of the basket of goods that will be purchased (or used) by migrants in the host region or country. (This will require the disaggregation of our η_T above at least in those two components for the final model; in this version the differentiation of urban goods would not further clarify the workings of the model and was therefore not included). The authors also survey the literature, which is divided into two basic strands: one that emphasizes the role of income differentials, and another that considers the relevance of provision of infrastructure and public goods as attractors for migrants. Both aspects can be considered in our model, since the provision of goods by the government can be included as a determinant of the level of private expenses in η_T. More provision of public infrastructure can be modeled as a reduction of η_T or of the costs associated with it (reductions in the specific component in the aggregated price level indicated by p_T).

But the government can also influence migrations through the creation of additional jobs. Define LG as government employment and t as a tax on T goods as defined in the model. Then the equations of the model should now read:

$$\Pi_T = p_T F(L_T{}^d) - wL_T{}^d \quad (1)$$
$$p_T F_L{}^{\prime}(L_T{}^d) = w \quad (2)$$
$$(1 + t)\, p_T c_T + p_B c_B{}^T = wL^0 (1\text{-}TD) + \Pi_T \quad (3)$$
$$U_T/U_B = (1 + t)\, p_T/p_B \quad (4)$$
$$\Pi_B = p_B H(L_B{}^d) - w_B L_B{}^d \quad (5)$$
$$p_B H_L{}^{\prime}(L_B{}^d) = w_B \quad (6)$$
$$p_B c_B = w_B L_B{}^d + wL_A (1 - TD) - p_T c_T{}^m + \Pi_B \quad (7)$$
$$LG + L_A + L_B{}^d = N^0 \quad (8)$$
$$c_T{}^m = \eta_T (LG)(L_A + LG) \quad (9)$$
$$c_T + c_T{}^m = F(L_T{}^d) \quad (11)$$
$$c_B + c_B{}^T = H(L_B{}^d) \quad (12)$$
$$L_T{}^d + LG = (L^0 + L_A)(1 - TD) \quad (13)$$
$$LG = tp_T c_T \quad (13^{\prime})$$
$$w \geq w^* \quad (14)$$

Equation (13´) is the budget equilibrium condition for the government.

First of all, notice that in this new setting taxes are charged on urban goods in the model, and thus they will reduce the demand for those goods and total emissions. However, those taxes are devoted to hiring additional urban workers and thus expand the allocation of agents to the urban zones, which probably increases emissions; note that *LG* increases the urban demand for labor in equation (13).

How will additional *LG* be used? If it were used to increase urban infrastructure it would also reduce η_T (take $d\eta_T/dLG < 0$). This could reduce emissions per capita but stimulate migration (a rebound effect similar to Jevons' effect for energy). Then the net effect on migration and emissions is not determined qualitatively and requires a quantitative exploration.

The important dimension of government actions' impact on emissions is not fully exploited in the Harris-Todaro framework. Demand for labor by the government is mostly urban demand, which favors migration by reducing the rate of unemployment or increasing urban wages (this dimension, impact on wages, is discussed by Harris and Todaro, 1970). The provision of infrastructure adds incentives to migration to urban areas.

3.1.8 Endogenous Prices

It can be seen that, at variance with several presentations of the Harris-Todaro model, prices of goods are endogenous in this model. Again as an example, Calvo (1978) takes prices as given (in terms of foreign currency because they are commodities and tradable), and the basic model of Zenou (2009) assumes that urban and rural areas produce the same good.

This last assumption does not correspond to the original version of the model. Harris and Todaro adopted a representation that puts the model closer to a general equilibrium representation, since they assumed that relative prices were not fixed, and they presented a synthetic expression for total demand and prices determination that could be interpreted as the result of equations (4) and (7) of our model.

Notice that, though we have been emphasizing its role because it is a key element of Harris-Todaro model, a cornerstone of labor market economics in development theory, unemployment is a side effect and not indispensable for our argument.

3.1.9 Intermediate Inputs and Emissions

If we follow the last line of reasoning, a new dimension becomes apparent when we admit transactions (of inputs) between industries of the economy. It is probably more realistic to admit that firms located in urban areas will have demand for inputs produced by rural areas and, conversely, that rural zones will require urban inputs. This will have consequences on total emissions. In effect, urban firms will need rural goods (for example, grain and beef to produce food) and therefore total rural output will not be reduced in a significant way. The migration of workers of low or nil productivity will not affect total production in the rural sector, and total emissions will not be lower when some labor moves to urban zones.

3.1.10 The Mobility of Capital

Neary (1988) and Funatsu (1988) show that the presence of mobile capital and more than one type of capital can modify the conditions for the stability of the equilibrium of the Harris-Todaro model. Our model considers two different types of capital: specific for each industrial sector and freely mobile between sectors.

3.2 The Two-Country Case: International Migration

The pattern of migrations has changed in contemporary times. It has been observed that movement from rural to urban areas within countries has ended or at least declined, but that migration from rural (and sometimes urban) areas of some countries to urban areas of other countries has intensified. The recent experience of migrants of Central American countries to the United States and from Bolivia and Paraguay to Argentina are just two examples of a movement that seems to be present all over the world. Moreover, those flows of migrants are intensive between countries with very different levels of emissions. Recent evidence shows that emissions per capita in Argentina are almost four times greater than the average of those in Bolivia and Paraguay, and that urban population in Argentina is close to 92 percent, compared to almost 68 percent in Bolivia and 60 percent in Paraguay. Those figures support the hypothesis that migrants from Bolivia and Paraguay will probably be moving from rural to urban areas, thus becoming more intensive consumers of goods that produce more emissions.

To take into account this new phenomenon we will adapt the model to consider two countries. This obliges us to take into consideration the trade balance of individual economies. In the host country we shall assume that there are two industries, one of tradable and one of non-tradable goods. We shall denote those host country industries with the respective subscripts T and N, and denote with B the industry in migrants' home country. In this simplified version we assume that there is only one tradable goods industry in that country.

Therefore profits and the maximization conditions for firms at the host industries are given by equations (1) to (4):

$$\Pi_T = (p_T - \alpha_T p_m) F(L_T^{\ d}) - wL_T^{\ d} \quad (1)$$
$$(p_T - \alpha_T p_m) F_L'(L_T^d) = w \quad (2)$$
$$\Pi_N = (p_N - \alpha_N p_m) G(L_N^d) - wL_N^d \quad (3)$$
$$(p_N - \alpha_N p_m) G_L'(L_N^d) = w \quad (4)$$

In these expressions *F* and *G* are the production functions, and L_i^d (i = T, N) is the demand for labor. Since labor is homogenous, wages are the same for both industries. Notice that prices are given by p_i and also that it is assumed that both industries have requirements for imported inputs in constant proportions α_i per unit of output at price p_m.

The budget condition of domestic agents of the host country is:

$$p_T c_T + p_N c_N = wL^0 (1- TD) + \Pi_T + \Pi_N \quad (5)$$

and to complete the demand specification the familiar equalization of marginal rate of substitution with relative prices is:

$$U_T/U_N = p_T/p_N \quad (6)$$

$U(c_T, c_N)$ is the utility function of agents of the host country that depends on the consumption of both goods.

TD is the rate of unemployment in the host country. Thus, given the endowment L^0 of labor, only a fraction (1 – TD) generates income for households.

The corresponding definition of profits and maximization conditions for country *B* are given by:

$\Pi_B = (p_B - \beta_B\, p_m)\, H(L_B^{\ d}) – w_B\, L_B^{\ d}$ (7)

$(p_B - \beta_B\, p_m)\, H_L´(L_B^{\ d}) = w_B$ (8)

In this case wages are given by w_B and prices by p_B, and the coefficient of imports is β_B. The variable $L_B^{\ d}$ stands for labor employed at *B* and Π_B for profits.

Both for the case of two countries and for the individual country case with internal migration we have assumed that capital is specific and non-mobile. This assumption can be easily removed.

The following equation gives the budget constraint:

$p_B\, c_B = w_B\, L_B^{\ d} + wL_A(1- TD) – p_T\, c_T^{\ m} – p_N\, c_N^{\ m} + \Pi_B$ (9)

L_A is labor of country *B* allocated to the market of the recipient, and the total use of labor to supply to the local and the foreign country adds up to the total endowment in equation (10). The variable c_B stands for consumption of the only good produced in that country (an aggregate of all goods, assuming constant relative prices). There are two additional expenses in *T* and *N* given by $c_T^{\ m}$ and $c_N^{\ m}$, which are the requirements of tradable and non-tradable goods associated with migrants' labor supply to the host country; they are assumed to be in constant proportions η_i in equations (11) and (12).

$L_A + L_B^{\ d} = N^0$ (10)
$c_T^{\ m} = \eta_T\, L_A$ (11)
$c_N^{\ m} = \eta_N\, L_A$ (12)

In this case it is not necessary to specify the equalization of the marginal rate of substitution with relative prices, since there is only one good produced in *B*. Instead, households in *B* maximize total income, choosing L_A appropriately, and an equivalent to the Harris-Todaro equilibrium condition for labor is obtained:

$w_B - w\,(1 – TD) + p_T\, \eta_T + p_N\, \eta_N = 0$ (13)

The transformation function (13) synthesizes a probably very complicated process of decision-making which involves the whole family and its alternative strategies of diversification to cope with risk; see Carillo, Quintieri and Vinci (1999).

In the CGE model it is possible to include a utility function for agents of *B* that considers expenses in the host country as well. In that case, (11) and (12) would be change to inequalities in minimum consumption, meaning that agents are able to consume beyond the necessary to supply labor to the market.

The composition of expenses could be the result of several processes:

1. A movement along an indifference curve, given the change of relative prices of goods. When the agent migrates, he finds that relative prices are different in the host country.
2. The result of an income effect, given higher wages in the host country.
3. A modification of the order of preferences as a result of the interaction with the new social environment.
4. The inclusion of new “needs” as transportation and electricity consumption to “produce” the labor supply to the host market (a kind of Becker production function).

Our intention is not to identify which of these could be the most relevant or empirically significant. Instead we shall assume that the change in composition of the basket of goods does happen and has an impact for emissions. Moreover, the composition of the consumption basket can be also the result of a process of assimilation that includes learning of new habits by migrants and even the imitation of conspicuous consumption in the host country (see Becchetti, Castriota and Giachin Ricca, 2010, who also indicate that in the modern world habits are copied from other economies even without migration).

It could be argued that the process of acquisition of habits could take time and be related to the educational process in which children of migrants lead the change in standards of consumption.

Equation (13) states that wages in B must be equalized to expected wages in the host country, corrected by the expenses necessary to transform one unit of domestic labor into labor usable in the host, which represents a process of choice that transforms labor in one region into labor in another region. While this applies to a voluntary change of location, migration can also be forced. Schmeidl (1997) discusses the case of forced migration associated with economic crisis and social and political reasons. For us it will be interesting to observe the case of forced migration as result of productivity shocks, such as those resulting from climate change. Droughts or floods could induce people to migrate, and they can be understood as permanent or transitory productivity shocks in migrants' home country. The resulting productivity losses will reduce wages in the rural regions or country of origin, and they will create a transitory disequilibrium in labor markets until migrations restore the equilibrium between net expected wages.

This has important consequences, because the conditions of markets for tradable and non-tradable could modify labor supply from *B*. Local policies in the host country could also alter requirements (for example, infrastructure investments) and alter labor supply. This offers a way to model how reduction of congestion or better housing conditions could affect the labor market; see Biller, Andres and Cuberes (2014).

There are several potential extensions of this specification. One possibility is to consider the presence of public goods and have households of *B* allocating labor to maximize utility from public and public goods; see also Biller, Andres and Cuberes (2014). That could facilitate the modelling of how the "lights of the city" attract migrants. However, the original Harris and Todaro (1970) paper is in fact a reaction to the propensity to use those arguments in the previous literature.

We then have market-clearing conditions for *T*, *N* and *B* in equations (14) to (16) and for the labor market in the host country, given by (17):

$$c_T + c_T^m + x = F(L_T^d) \quad (14)$$
$$c_N + c_N^m = G(L_N^d) \quad (15)$$
$$c_B + x_B = H(L_B^d) \quad (16)$$
$$L_T^d + L_N^d = (L^0 + L_A)(1 - TD) \quad (17)$$

In those expressions, variables x and x_B stand for exports from the host country and for exports from *B* to the rest of the world, respectively. In both cases they are necessary to compensate for imports and for remittances v. In fact, implicit remittances can be calculated as $wL_A(1- TD) - p_T\, c_T^m - p_N\, c_N^m$. Working with equations (5) and (9) and the corresponding definitions and market-clearing conditions the trade balance for each economy is obtained.

Equation (17) implicitly assumes that migrants and domestic workers are perfect substitutes. This is not necessarily so, and complementary could be considered in both the analytical model and the computational version. The international literature has considered both cases; see Carillo, Quintieri and Vinci (1999).

Then we have the price determination for tradable goods:

$p_T = p^*$ (18)
$p_m = p_m^*$ (19)
$p_B = p_B^*$ (20).

This implies that the economies are small with respect to the rest of the world.

It is also necessary to include the determination of wages in the host country to determine unemployment:

$w = w^*$ (21)

With regard to this equation, the same observations made for the one-country case are applicable. Wages could be indexed to a basket of tradable and non-tradable goods and/or corrected by the presence of unemployment.

There are 21 unknowns in this version of the model:

$\Pi_T \; p_T \; L_T{}^d \; w \; p_m \; \Pi_N \; p_N \; L_N{}^d \; p_B \; c_B \; w_B \; L_A \; c_T{}^m \; c_N{}^m \; \Pi_B \; x_B \; x \; L_B{}^d \; c_N \; c_T$ TD

Emissions can be linked to total consumption or to total production:

$E = \gamma_1 F(L_T{}^d) + \gamma_2 G(L_N{}^d)$ (22)
$E_B = \gamma_B H(L_B{}^d)$ (23)

One alternative for the specification of the equations of emissions would be to associate emissions with consumption by domestic workers and migrants. The main difference would involve the deduction of exports from total production.

4. Computational Results of the Analytical Models

The model for the simulation is written in MPSGE-GAMS. A discussion of its properties and characteristics can be found in Chisari, Maquieyra and Miller (2012). The intention of this section is to present the results of the simulations of the model applied to the two paradigmatic cases identified.

On the one hand, Argentina stands for the case of an economy open to migration. The country has been a recipient of migrants throughout is history. In particular, from the late nineteenth century to approximately 1950, extensive European migration to Argentina occurred because of a combination of the country's opportunities and low productivity and wars in Europe. Since 1950 Argentina has received migration from neighboring countries. Our model particularly takes into account migration from Paraguay and Bolivia, the most important sources (although there has been a notable flow from other countries of the region as well).

On the other hand, we focus on internal migrations in Brazil to the Sao Paulo area, which is the country's most important industrialized region. This type of migration is more volatile and responds very fast to incentives, as our model confirms.

Tables 1 and 2 show some selected indicators for Argentina and Brazil. B&P stand for Bolivia and Paraguay, and the parameters represent the weighted average for each country. It can be seen that GDP per capita is estimated to be almost five times those of migrants' home countries, while emissions per capita in Argentina are about 3.6 times those of the two countries combined. As shown below, it is estimated that migrants represent almost 3 percent of the total population of Argentina and almost 4 percent of their home countries' population.

Migrants also represent approximately 3 percent of total population of the area of Sao Paulo, and though GDP per capita is approximately 80 percent higher in San Paulo, emissions per capita are lower.

Table 1. Argentina	
Rate of Unemployment Argentina	10.2%
GDP Argentina pc/GDP B&P pc	4.8
Emissions Tnpc (ARG)/Tnpc(B&P)	3.64
LB(in Arg)/{LA(in Arg)+LB(in Arg)}	2.8%
LB(in Arg)/{LB(in B&P)+LB(in Arg)}	3.9%
Sector participation in terms of GDP (at producers prices)	
Primary sector	9.7%
Mining	3.4%
Industry	17.1%
Electricity, Gas and Water	2.8%
Transport	6.3%
Public Administration and other public sectors	7.3%
Rest of Services	53.3%

Table 2. Brazil	
Rate of Unemployment Brazil	7.78%
GDP Sao Paulo pc/GDP RBR pc	1.79
Emissions Tn pc (SP)/Tn pc (RBR)	0.81
LRBR(in SP)/{LSP+LRBR(in SP)}	3.0%
LRBR(in SP)/{LRBR (in RBR)+LRBR(in SP)}	0.8%
Sector participation in terms of GDP (at producers prices)	
Agriculture	2.8%
Forestry	0.3%
Livestock	2.5%
Mining	2.3%
Energy intensive Industry	2.5%
Rest of industry	14.0%
Oil refining	0.6%
Electricity, Gas and Water	3.6%
Construction	4.9%
Trade	12.1%
Transport	4.8%
Rest of Services	49.7%

Table 3 in the next subsection shows the results for Argentina, while Tables 4 and 5 show those for Brazil. In both cases we analyze sensitivity to structural parameters, but in this presentation we emphasize the degree of substitutability between migrant labor and domestic labor. Thus Table 4 presents a high elasticity of substitution for Brazil (HS), while Table 5 presents a low elasticity of substitution (LS) for the same country.

Those tables show the GDP of the regions or country, the fiscal result, the (regional, when applicable) rate of unemployment , changes in the intensity of migration and activity levels of industries, welfare levels of the poor and of the rich, and several indicators of greenhouse gas emissions.

For the latter, we include an estimate of total emissions of the country that takes into account structural changes in the economy as well as scale effects for the home country (or region) of the migrants. We also include a Kuznets index of intensiveness of emissions per unit of GDP for Argentina to have an indicator of the change of composition of GDP (the indicator gives an estimate of the marginal impact on emissions of changes in GDP).

4.1 The Case of an Economy Open to Migrants: Argentina

We consider several shocks due to policies as well as autonomous changes in parameters and behavior. The main results can be summarized as follows. The simulations assume that wages are downward inflexible in dollar terms (unless otherwise noticed).

Table 3. Argentina Simulation (% changes)

Indicators	ET	ETCT	ETL	PCNW	PCRW	CR	T	AM	NW	KTLS	KT
Macroeconomy											
GDP Argentina	-0.62	0.04	-0.16	-7.71	-2.09	-0.19	-0.34	0.26	-2.47	-1.42	-1.42
GDP B&P	0.04	-0.01	0.00	0.34	0.17	0.18	-0.03	-0.49	0.09	0.02	0.03
Fiscal result (welfare)	1.03	-0.25	0.24	-6.26	-0.80	-0.26	-2.61	0.50	-2.35	-0.39	-0.39
Rate of unemployment	11.55	10.53	10.47	24.80	12.52	10.30	11.20	10.38	15.73	11.51	11.51
Migratory activity	-2.49	0.33	-0.04	-22.40	-11.13	-11.76	1.71	32.36	-5.85	-1.61	-1.65
Welfare											
Poor household	-0.64	0.06	-0.15	-8.40	-3.38	-0.08	1.07	-0.24	-2.23	-1.55	-1.55
Rich Household	-1.70	-0.12	-0.42	-8.88	-3.52	0.18	0.18	-0.06	-2.39	-2.18	-2.18
Sectoral activity levels											
Agriculture	-1.99	-1.62	-2.04	-0.89	1.17	-0.04	0.07	0.05	-0.85	-1.33	-1.33
Mining	-0.86	-0.02	-0.14	-8.84	-1.71	-0.32	-0.19	0.36	-3.12	-1.48	-1.48
Manufactures	0.33	1.06	0.43	-0.31	1.24	-0.03	0.09	0.03	-0.64	-1.33	-1.33
Energy	-1.16	0.15	0.13	-9.32	-1.10	-0.30	0.14	0.05	-3.52	-1.29	-1.29
Transport	-0.81	0.22	0.06	-8.11	-1.86	-0.20	0.08	0.32	-2.73	-1.48	-1.47
Public administration	1.41	-0.41	0.77	-12.63	-1.58	-0.21	-4.13	0.31	-4.86	-0.80	-0.80
Rest of services	-0.63	-0.04	-0.03	-7.91	-1.72	-0.18	-0.32	0.38	-2.71	-1.54	-1.53
Emissions											
Total in Argentina (benchmark=100)	96.35	97.05	96.79	95.13	99.37	99.86	100.11	100.21	98.17	98.54	98.54
Kutznetz Argentina (benchmark=100)	96.95	97.00	96.95	103.08	101.49	100.05	100.45	99.95	100.65	99.96	99.96
Expected Emissions ARG	-0.02	0.02	0.01	-0.16	-0.19	-0.25	0.00	0.71	0.01	0.00	-0.25
Emissions B&P	0.04	-0.01	0.00	0.34	0.17	0.18	-0.03	-0.49	0.09	0.02	0.03

Source: Authors' estimates using CGE model.

4.1.2 Emission Taxes

The first three columns of Table 3 show the results of applying a $20 tax per ton of emissions for three cases: **ET** (not compensated), **ETCT** (compensated with an across-the-board reduction of all taxes) and **ETL** (compensated with a reduction of labor taxes, both for migrants and domestic workers). As expected, in the first case there is a reduction of GDP for Argentina, accompanied by an increase in the rate of unemployment and a reduction in welfare levels of the poor, the rich and migrants. The expected (and in fact confirmed) outcome is a reduction in the intensity of migration (in fact, there is a reduction of about 2.5 percent of the stock of migrants in the economy) and a decrease in emissions measured by the composition effect and the scale effect (the composition effect is much stronger). However, when compensated with a proportional reduction of overall taxes the net effect is an increase in migratory activity; notice that in that case the increase in the rate of unemployment is smaller and that GDP is growing, and that the composition of GDP is changing in favor of manufactures, which is an important sector for migrant workers. The compensation is not enough to cause a reversal of the sign of change in GDP when it is applied to labor taxes; this scale effect explains why migratory activity falls slightly. It is interesting to see that the reduction of the activity level reduces expected emissions in Argentina. The expected emissions take emissions per capita as constant before the policy and estimates emissions by extrapolation, taking into account total labor supply (because it is assumed that emissions are proportional to total workers and not to total workers actually employed). It can be seen that there are significant differences with total emissions in general equilibrium because expected emissions do not take into account the composition effect. Notice that we include changes in emissions per capita of the home country of migrants as well, because when they return home there is an increase of activity level and of emissions. One corollary is that we should expect changes in the intensity of migration following taxes or additional costs imposed on polluting industries, but that those changes could be smaller when a compensation of labor taxes is applied.

4.1.3 Reduction of Export Prices (PC)

There has been, and still is, growing concern regarding the impact of the reduction of commodity prices on activity levels and living standards of Latin American countries following a deceleration of China’s growth and macroeconomic imbalances in developed economies. Columns **PC** show the results of assuming a 10 percent fall of export prices of Argentina under two conditions: **PCNW**, inflexible nominal wages (in dollars) and **PCRW**, flexible nominal wages (though with inflexible real wages). It can be seen that the fall of GDP is much stronger in the case of inflexible nominal wages and this leads to a significant reduction of migrants of more than 22 percent (assuming that the export prices of Bolivia and Paraguay are constant).

Emissions are reduced following the reduction of GDP, but it is interesting to see that the Kuznets Index is increased in the second case, which means that the economy has become more emissions-intensive (there is a relative increase of polluting industries in the composition of GDP). There are clear incentives for the reduction of migration since the rate of unemployment is high and the welfare indicators fall).

4.1.4 Additional Government Transfers to Private Agents (T).

An overall increase of 10 percent in transfers from the government to private agents provides an incentive to migration from neighboring countries. Those transfers include direct assistance as well as pensions, and when migrants are included in the system, as in the case of Argentina, transfers become incentives to migration. Notably those transfers reduce GDP, probably because the increase of transfers has to be compensated by reducing other fiscal expenses, including employment (as can be seen there is an increase of the rate of unemployment). Notably, there is an increase in emissions and in the Kuznets Index (the economy becomes more intensive in emissions) which means that there is an expansion of activities that are relatively more polluting. Though there is an increase in welfare of the poor it must be taken into account that it is at the cost of reducing the provision of public goods (the indicator of welfare of the government falls, and it is an indirect measure of the provision of public goods).

4.1.5 Increase of the Cost of Residence (CR)

This simulation assumes that there is an increase in the cost of residence of migrants. Possible explanations could be increases in housing costs or even an increase in the discount rate applicable to the flow of income of migrant workers. The latter has been discussed in the literature as the Sjaastad-Hicks case, which considers the time discount of the flows of income in the Harris-Todaro wages equalization formula (see Wibbenmayer, 2014). The 10 percent increase in those costs results in a reduction of more than 11 percent in migration activity. There are not significant changes in emissions, though there is slight decrease in GDP of the economy.

4.1.6 Autonomous Increase of Migration (AM)

This simulation considers an autonomous increase in willingness to migrate, which results in an increase of more than 32 percent in the supply of migrants. This movement could be the result of a change in preferences or of non-voluntary migration due to a productivity fall in the home country. In the first case, the supply of public goods in the host country (known in the literature as the “lights of the city” prior to the Harris-Todaro paper) attracts migrants who see more opportunities for consumption and personal development. In the second case, migrants move in response to a reduction of their wages in the home country, for example, due to a drought, a flood or some other climate shock. Thus migration is an adaptation strategy. It can be see that this movement increases the GDP as result of the additional labor force, but it results in a reduction of welfare both of the poor and of the rich in the host population; this outcome is due to the increase in the rate of unemployment and in the increase of some domestic prices following the additional demand. There is an increase of the rate of unemployment as well following the migratory flow, and an increase of emissions but a slight fall in the Kuznets Index. Though there is a reduction of emissions of migrants’ home country, the host country increase is greater.

4.1.7 Unions’ Pressure on Nominal Wages (NW).

This simulation assumes that there is a 5 percent increase in nominal wages in the host country as a consequence of unions’ pressure in the negotiation of wages. Remember that wages are fixed in nominal (dollar) terms in this model. As expected, there is a noticeable increase in the rate of unemployment, and the net result is a reduction in migrants, who return to their country of origin. The fall of GDP creates both a scale effect and a composition effect. It can be seen that total emissions are reduced because the index of effective emissions is lower, but at the same time there is a change in the composition of GDP because industries that are labor intensive decline more than the rest. As result, the Kuznets Index rises because agriculture loses relatively less activity than the rest of the economy.

4.1.8 Negative Shock of Climate Change on Domestic Capital (KT)

A 10 percent negative shock to the productivity of domestic mobile and specific capital in all sectors reduces total GDP by approximately 1.4 percent. This impact is independent of the elasticity of substitution of migrant labor with domestic labor (compare columns **KT** and **KTLS**). There are not significant differences in either the scale effect or emissions indicators (both fall); it can be seen that the scale effect (which is reduced proportionally) is more relevant than the composition effect because the Kuznets Index is almost unchanged. Migration activity is reduced, which means that migrant labor tends to behave as complementary to capital and domestic value added.

4.2 Domestic Migration: The Case of Brazil

As noted above, Table 4 shows the results of the simulations for the case of Brazil under high elasticity of substitution between GDP of Sao Paulo and the GDP of the rest of Brazil. Table 5, in contrast, shows a case of low elasticity of substitution. The model considers that both regions have the same input-output requirements, and migrants can move freely between those regions. We assume that there is specific and mobile capital. Mobile capital can also move freely between regions and industries.

Though the economy is open for trade of goods, unlike the case of Argentina it is assumed that there are no flows of migrants from abroad (and that there is no outflow of workers to the rest of the world). At variance with the basic Harris-Todaro tradition, it is assumed that there is unemployment in both the Sao Paulo region and the rest of Brazil.

Table 4. Brazil (Sao Paulo – HS) Simulations (% changes)

Indicators	ET	ETL	ETCT	NWSP	NWAm	RWAm	PCNW	PCRW	CR	AM	KSP	KRBR
Macroeconomy												
GDP	-2.54	-1.11	-1.05	-1.43	-4.87	-5.02	-12.83	-2.64	-0.03	0.32	-0.26	-0.97
GDP SP	-2.59	-1.02	0.55	-3.82	-3.68	-3.79	-10.10	-2.40	-0.03	0.32	-0.25	-0.94
GDP RBR	-4.51	-1.03	-0.30	-0.26	-5.45	-5.62	-13.93	-2.56	-0.03	0.32	-0.26	-0.96
Fiscal result (welfare)	0.04	-0.34	-1.84	-1.13	-3.34	-3.43	-7.59	-1.02	-0.09	0.94	0.32	-0.88
Rate of unemployment SP	9.53	8.64	8.93	12.62	12.22	12.44	22.27	7.61	7.17	14.06	12.08	5.82
Rate of unemployment RBR	12.54	9.47	9.74	8.64	17.48	17.75	29.41	10.60	7.95	6.06	7.16	9.30
Migratory activity	-41.41	-30.11	-3.34	-100.00	-100.00	-100.00	-100.00	-73.18	-21.47	221.01	136.50	-95.64
Welfare												
Poor Household	-3.66	-1.24	-0.57	-0.90	-5.48	-5.63	-14.07	-3.41	-0.12	1.05	0.51	-1.73
Rich Household	-1.17	-0.30	0.37	-0.63	-1.11	-1.23	-8.35	-1.07	0.56	-5.46	-4.78	2.02
Sectoral activity levels												
Agriculture	-21.14	-19.43	-18.99	-0.40	-4.76	-4.90	-8.12	2.37	-0.03	0.31	-0.22	-0.88
Mining	1.14	1.38	1.94	0.16	-1.43	-1.47	-1.65	1.37	-0.03	0.30	-0.22	-0.86
Forestry	-5.71	-4.04	-3.45	-0.39	-0.73	-0.75	-0.49	0.88	-0.03	0.31	-0.23	-0.89
Livestock	-3.87	-2.04	-1.44	-0.40	-1.86	-1.91	-2.68	1.29	-0.03	0.31	-0.23	-0.89
Energy intensive Manufactures	-5.90	-4.32	-3.80	-0.75	-3.53	-3.64	-11.58	-4.32	-0.03	0.30	-0.20	-0.84
Oil refining	-8.49	-7.15	-5.89	-0.37	-2.14	-2.20	-18.94	-10.77	-0.03	0.30	-0.22	-0.87
Rest of Manufactures	-1.16	1.20	1.87	-2.39	-6.91	-7.12	-15.50	-0.75	-0.03	0.30	-0.20	-0.84
Energy	-1.71	-0.52	0.39	-1.16	-3.79	-3.91	-9.29	-1.25	-0.03	0.32	-0.25	-0.93
Transport	-2.77	-1.21	-0.72	-1.35	-4.54	-4.68	-11.10	-1.49	-0.03	0.31	-0.25	-0.93
Construction	-2.29	-1.06	-1.08	-1.29	-4.25	-4.38	-12.01	-3.13	-0.03	0.33	-0.30	-1.06
Trade activities	-2.21	-0.60	-0.46	-1.42	-4.58	-4.72	-11.13	-1.42	-0.03	0.30	-0.24	-0.90
Rest of services	-1.48	-0.32	-0.93	-1.44	-5.08	-5.24	-12.25	-1.50	-0.03	0.33	-0.27	-0.98
Emissions												
Emissions total (benchmark=100)	93.59	95.24	95.83	99.46	98.24	98.19	96.70	100.32	99.97	100.31	99.77	99.11
Kutznetz index (benchmark =100)	96.03	96.31	96.85	100.91	103.27	103.38	110.94	103.04	100.00	99.99	100.04	100.08
Expected Emissions SP (linear pc)	-3.23	-1.90	-1.35	-8.47	-8.04	-8.28	-18.96	-2.18	-0.03	0.32	-0.26	-0.96
Expected Emissions RBR (linear pc)	-4.91	-1.63	-2.12	-0.23	-9.89	-10.19	-22.93	-2.58	-0.03	0.33	-0.27	-0.99

Source: Authors' estimations using CGE model.

Table 5. Brazil (Sao Paulo – LS) Simulation (%changes)

Indicators	ET	ETL	ETCT	NWSP	NWA	RWA	PCNW	PCRW	CR	AM	KSP	KRBR
Macroeconomy												
GDP	-2.51	-1.12	-1.05	-1.54	-4.76	-4.89	-13.64	-7.23	-0.15	0.32	-0.26	-0.97
GDP SP	-3.04	-0.66	0.56	-1.66	-4.91	-5.05	-14.17	-7.51	-0.15	0.32	-0.26	-0.95
GDP RBR	-4.26	-1.21	-0.31	-1.48	-4.68	-4.82	-13.15	-6.88	-0.15	0.32	-0.26	-0.96
Fiscal result (welfare)	0.02	-0.31	-1.84	-1.02	-3.24	-3.32	-8.01	-3.97	-0.43	0.94	0.32	-0.88
Rate of unemployment SP	9.52	8.60	8.92	12.53	13.35	13.59	28.56	15.55	4.95	14.06	12.08	5.83
Rate of unemployment RBR	12.37	9.58	9.75	9.43	16.74	16.97	28.65	18.76	8.57	6.06	7.16	9.30
Migratory activity	-55.28	-18.97	-2.87	-37.51	-100.00	-100.00	-100.00	-100.00	-100.00	221.10	136.32	-96.02
Welfare												
Poor Household	-3.52	-1.33	-0.58	-1.56	-4.88	-5.00	-13.66	-7.68	-0.54	1.05	0.51	-1.73
Rich Household	-1.15	-0.31	0.37	-0.63	-2.10	-2.24	-11.80	-5.29	2.58	-5.46	-4.78	2.02
Sectoral activity levels												
Agriculture	-21.12	-19.44	-19.00	-0.32	-4.76	-4.89	-8.33	-2.46	-0.14	0.31	-0.22	-0.88
Mining	1.12	1.39	1.94	0.25	-1.42	-1.46	-1.42	0.03	-0.14	0.30	-0.22	-0.86
Forestry	-5.35	-4.01	-3.42	-0.15	-0.59	-0.60	-0.31	0.34	-0.14	0.31	-0.23	-0.89
Livestock	-3.83	-2.05	-1.44	-0.20	-1.79	-1.84	-2.67	-0.47	-0.14	0.31	-0.23	-0.89
Energy intensive Manufactures	-5.86	-4.29	-3.77	-0.76	-3.50	-3.60	-12.06	-7.51	-0.14	0.30	-0.20	-0.84
Oil refining	-8.32	-7.03	-5.78	-0.35	-2.06	-2.12	-18.80	-14.50	-0.14	0.30	-0.22	-0.87
Rest of Manufactures	-1.13	1.18	1.85	-2.66	-6.72	-6.91	-16.99	-7.41	-0.14	0.30	-0.20	-0.84
Energy	-1.69	-0.52	0.39	-1.20	-3.71	-3.82	-9.97	-4.88	-0.15	0.32	-0.25	-0.93
Transport	-2.75	-1.20	-0.72	-1.43	-4.45	-4.57	-11.89	-5.83	-0.14	0.31	-0.25	-0.93
Construction	-2.27	-1.06	-1.08	-1.35	-4.16	-4.28	-12.75	-7.14	-0.16	0.33	-0.30	-1.06
Trade activities	-2.19	-0.60	-0.46	-1.51	-4.49	-4.62	-11.99	-5.81	-0.14	0.30	-0.24	-0.90
Rest of services	-1.45	-0.33	-0.93	-1.56	-4.95	-5.09	-13.05	-6.35	-0.15	0.33	-0.27	-0.98
Emissions												
Emissions total (benchmark=100)	93.85	95.27	95.86	99.63	98.35	98.31	96.68	98.75	99.86	100.31	99.77	99.11
Kutznetz index (benchmark =100)	96.26	96.34	96.87	101.18	103.26	103.36	111.95	106.44	100.01	99.99	100.04	100.08
Expected Emissions SP (linear pc)	-3.67	-1.50	-1.32	-6.36	-9.27	-9.53	-25.78	-11.67	-0.15	0.32	-0.27	-0.97
Expected Emissions RBR (linear pc)	-4.63	-1.83	-2.13	-1.53	-9.08	-9.33	-22.10	-11.31	-0.15	0.33	-0.27	-0.98

Source: Authors' estimations using CGE model.

The main simulations and results are reported in the following subsections.

4.2.1 Emission Taxes

Again, the first three columns of Table 4 show the results of applying a $20 per ton of emissions tax for three cases: **ET** (not compensated), **ETCT** (compensated with an across-the-board reduction of all taxes) and **ETL** (compensated with a reduction of labor taxes for both migrants and domestic workers). The shock to GDP is reduced under compensation, but there is almost no difference between compensation with general taxes and compensation with labor taxes. It can be seen that migration is significantly reduced in the non-compensated case and when labor taxes are reduced (indicating that jobs are more affected in the Sao Paulo region). This compensation is not enough, however, to reverse the sign of change of GDP. There is a reduction in total emissions as result of the scale effect and of the Kuznets Index (though the reduction is lower in this case, showing that the composition effect is less important). In comparison with the case of Argentina, it can be seen that the elasticity of migration to different parameters is much higher in this case; this seems to be supported by empirical evidence, according to which the flows of migrants easily change in response to different shocks in Brazil.

4.2.2 Reduction of Export Prices (PC)

In this case two main scenarios are considered: when wages are fixed in nominal (dollar) terms or in real terms (following the CPI) as in the case of Argentina (indicated with PC**NW** and PC**RW**). The sizes of the effects are very different, and the case of real wages has a lower impact on GDP. In both cases, however, there is a very important reduction in migration, and migrants tend to move back to the rest of the country. This may be due to the fact that manufactures and oil refining display more significant adjustments and create fewer jobs than other sectors. Notably, there is an increase in the emission index and in the Kuznets Index, indicating that the scale effect is not enough to reduce emissions in the Real Wages case, and that the composition effect has made the economy more emissions-intensive.

4.2.3 Increase of the Cost of Residence (CR)

As in the case of Argentina, this simulation assumes that there is an increase in the cost of residence of migrants. But in this case it is assumed that the increase is 1 percent, given the high elasticity of response of migrants' labor supply. It can be seen that there is a decrease in migratory activity and a reduction of GDP in both regions. Again, there are no significant changes in emissions.

4.2.4 Autonomous Increase of Migration (AM)

This simulation again considers an autonomous increase in willingness to migrate, which results in a more than 220 percent increase in the supply of migrants. Again, this autonomous change takes into account the result of a change of preferences and the attraction of the city. In contrast to the case of Argentina, the shock to productivity is considered in a separate simulation. A sudden increase can be seen in the unemployment rate in the region of Sao Paulo and a reduction in the rest of the country. There is a slight increase in total emissions without a significant change in the Kuznets Index, showing that the composition effect is not relevant (this is confirmed by almost equal proportional changes in industries' activity levels). Changes in migrants' consumption patterns do not seem to be meaningful in this case.

4.2.5 Unions' Pressure on Nominal Wage (NW)

This simulation assumes that there is a 5 percent increase in nominal wages in i) the Sao Paulo region and ii) in both the Sao Paulo region and the rest of the country as a consequence of unions' pressure in the negotiation of wages (see column NWAm). As in the previous case, wages are fixed in nominal (dollar) terms in this model. Again, there is a significant fall in the GDP in both cases, but it is particularly large in the case of Sao Paulo when the increase in wages is restricted to that area. There are also important changes in migration as result of the increase in the unemployment rate; in fact, all migrants return to their home region. This may be the result of the reduction in jobs in Sao Paulo's industries relative to the rest of the economy. Notice that there are reductions in emissions (scale effect) but increases in the Kuznets Index, showing that the economy as a whole becomes more emission-intensive (probably because forestry and agriculture fall less than the rest of the economy). Column RWAm shows the case of a 5 percent increase in real wages in both regions.

4.2.6 Negative Climate Change Shock to Domestic Capital (KT)

In this case a negative 10 percent shock to the productivity of mobile and specific capital of all sectors in both regions is assumed. The impact is higher in the rest of the country (**KRBR**) than in Sao Pauo (**KSP**) because there are differences in the relative size of regions. There are, however, very clear differences in migration. Migration increases when the reduction of productivity occurs in Sao Paulo, while it decreases when the shock is observed in the rest of the country. This indicates that migration responds as if migratory workers were substitutes for capital. In both cases the scale effect reduces total emissions, but increases potential emissions given the Kuznets Index.

5. Main Lessons and Concluding Remarks

The main results of this paper are the following:

1. Migration is a relevant challenge for Latin American and Caribbean economies, and it is significant for climate change in regard to both mitigation and adaptation. Mitigation is affected since migrants move from regions of low emissions per capita to urban areas with high intensity of emissions (due to three basic sources: energy use, transportation and treatment of solid waste). Migration relates to adaptation as well, since migrants could be "forced" to migrate at a faster pace following climate change shocks (thus making migration a means of adaptation).
2. Migration from rural to urban areas takes place internationally as well as within countries, which calls for models that take into account international environments as well as domestic conditions.
3. Several Latin American countries exhibit this pattern. Urban Argentinean and Chilean areas receive migrants from rural areas of neighboring countries, and urban areas of Brazil are used as income buffers for migrants from rural areas.
4. The main driver of migration seems to be income differentials, though an increasing amount of evidence indicates that the provision of infrastructure and public goods is also relevant.
5. Thus, some elements of the new economic geography that consider net income after costs of residence have to be taken into account.
6. Additional migrants put cities' infrastructure under stress, as well as housing markets and fiscal public goods provision and aid programs.
7. It is important to take into account government action. On the one hand, governments tend to increase the demand for urban workers and provide public services and infrastructure that stimulate migration to cities. On the

other hand, they can help to reduce emissions when providing certain goods such as public transportation. The net effect on migration is not qualitatively determined and requires a quantitative appraisal.

8. Migrants adopt new habits when they move to host countries. New habits can be motivated by different relative prices of goods (the relative abundance of goods is different), changes in preferences due to higher income, needs determined by the dynamics of living in a city, or conspicuous consumption.
9. The quantitative simulations show that migrations can respond to changes in incentives determined by carbon taxes. Changes in composition of GDP of economies at the national and regional levels can modify the pattern of migration. However, those patterns are more stable when emission taxes are compensated with reductions in labor taxes or general taxes.
10. There are significant differences between expected emissions and those estimated when we take emissions per capita constant with total emissions estimated in general equilibrium. Expected emissions do not take into account the composition effect (change of structure of the economy). One corollary is that we should expect changes in the intensity of migration following taxes or additional costs imposed on polluting industries, but that those changes could be smaller when compensation with labor taxes occurs.
11. We should expect reductions in the intensity of migration following taxes or additional costs imposed on polluting industries, but those changes will be smaller if revenue is compensated with labor taxes.
12. Those results are confirmed in the case of Sao Paulo, but the elasticity of response is much higher. Some evidence confirms that migratory flows in Brazil are sensitive to changes in parameters.
13. The case of Argentina and Brazil shows that a fall in the price of exports (mostly commodities) will negatively affect the economy and, ceteris paribus, will increase the rate of unemployment. This will lead to a significant reduction of the flow of migrants to the country/region that will be more dramatic when wages are downward inflexible in nominal (foreign currency) terms. The results indicate that the flow of migrants to the Sao Paulo region

decreases very quickly when commodity prices fall; people move back to their home regions. The composition effect (using the Kuznets Index as a proxy) indicates that there is a worsening, in the sense that the economy is becoming more emissions-intensive.

14. One interesting result is that the effects of increasing transfers from the government to private agents (pensions, direct aid to poor families) could have an ambiguous effect. In fact, additional transfers will create a diversion of public expenses including expenses in personnel. Thus, though host locations will become more attractive to migrants if they are included in those programs, on the other hand those programs will reduce the demand for labor and increase the rate of unemployment. This will have a discouraging impact on migrants, as predicted by the Harris-Todaro model.
15. The cost of residence (including housing and even the rate of interest applied to "migration projects") does reduce the incentives to migrate, confirming the intuition of the Hicks-Sjaastad effect.
16. An autonomous increase in migration increases emissions both in the host country/region and in global terms (taking into account a reduction of emissions in the home country), as shown by the case of Argentina. This is due to two effects. First, there is a change of habits because migrants move to the new country and adopt (as the model assumes) a basket of goods similar to that country's poorest deciles (the composition effect is limited in the host country, however, because there is a relative increase in activity of labor-intensive industries). Second, there is a scale effect, because the presence of migrants increases the activity level of the host economy. In the case of Sao Paulo autonomous movement, which is very intense, does not have a meaningful impact on emissions.
17. Additional pressure of unions on nominal wages creates unemployment, return of migrants to their home, and a reduction of emissions because of the scale effect.
18. When there is a reduction of productivity of capital (due for example to a climate change shock) migrants' response is different in the cases of

Argentina and Sao Paulo. In the first case, migrant labor seems to behave as complementary to capital, and there is a reduction of migration (and of emissions basically due to a scale effect). In the case of Sao Paulo, on the other hand, migrants behave as substitutes for capital, and migration increases to regions where the productivity of capital has been reduced.

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