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A practitioners' guide to gravity models of international migration

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Abstract

The use of bilateral data for the analysis of international migration is at the same time a blessing and a curse. It is a blessing since the dyadic dimension of the data allows researchers to analyze many previously unaddressed questions in the literature. This paper reviews some of the recent studies using this type of data in a gravity framework in order to identify important factors affecting international migration flows. Our review demonstrates that considerable efforts have been conducted by many scholars and that overall we have a much better knowledge of the relevant determinants. Still, the use of bilateral data is also a curse. The methodological challenges that are implied by the use of this type of data are numerous and our paper covers some of the most significant ones. These include sound theoretical foundations, accounting for multilateral resistance to migration as well the choice of appropriate estimation techniques dealing with the nature of the migration data and with endogeneity concerns.

Keywords: gravity equation; discrete choice models; international migration.

JEL classification codes: F22; C23.

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1 Introduction

The review of the gravity model by Anderson (2011) credits Ravenstein (1885, 1889) for pioneering the use of gravity to model migration patterns,[1] long before the seminal contribution of Tinbergen (1962) who estimated a gravity equation of international trade flows. Trade economists have explored since then, albeit in a discontinuous way (Head and Mayer, 2013), the theoretical foundations of gravity models of trade, while the interest towards gravity models of migration has only recently regained momentum because of an enhanced availability of migration data.

This paper is meant to represent a practitioners' guide to gravity models of migration, with three distinct but closely interconnected objectives. First, to analyze where the literature stands with respect to the effort to lay out the theoretical basis for the reliance on gravity models of migration, and which are the implications of the different micro-foundations for the specification of the equation that is brought to the data. Second, to review the evidence that has been produced by the estimation of gravity equations with respect to the determinants of international migration flows. Third, to provide an overview of the main challenges connected to the estimation of gravity equations and to the interpretations of the results.

Sections 2 to 4 represent our attempt to reach each of the three objectives that we have just described, while Section 5 draws the main conclusions of our paper.

2 Micro-foundations

2.1 Bilateral migration gross flows

Let s_{jt} represent the stock of the population residing in country j at time t; we can write the scale m_{jkt} of the migration flow from country j to country k at time t as:

$$m_{jkt} = p_{jkt} s_{jt} \tag{1}$$

where $p_{jkt} \in [0, 1]$ represents the *actual* share of individuals residing in j who move to k at time t. The migration literature has relied on random utility maximization models that

[1] Niedercorn and Bechdolt (1969) quote Carey (1858) as an even earlier source.

describe the location decision problem that individuals face to derive the *expected* value of p_{jkt}.

2.2 A RUM model of migration

The canonical RUM model of migration describes the utility that that individual i who was located in country j at time $t-1$ derives from opting for country k belonging to the choice set D at time t as:

$$U_{ijkt} = w_{jkt} - c_{jkt} + \epsilon_{ijkt} \tag{2}$$

where w_{jkt} represents a deterministic component of utility that can be modeled as a function of variables that are observed by the econometrician, c_{jkt} represents the time-specific cost of moving from j to k, and ϵ_{ijkt} is an individual-specific stochastic component of utility. The distributional assumptions on the stochastic term in (2) determine the expected probability that opting for country k represents the utility-maximizing choice of individual i. If we assume that ϵ_{ijkt} follows an independent and identically distributed Extreme Value Type-1 distribution (McFadden, 1974), then we have that:

$$E(p_{jkt}) = \frac{e^{w_{jkt}-c_{jkt}}}{\sum_{l\in D} e^{w_{jlt}-c_{jlt}}} \tag{3}$$

This allows us to rewrite the *expected* gross migration flow from country j to country k as follows:

$$E(m_{jkt}) = \frac{e^{w_{jkt}-c_{jkt}}}{\sum_{l\in D} e^{w_{jlt}-c_{jlt}}} s_{jt} \tag{4}$$

If we assume that the deterministic component of utility does not vary with the origin j, then we can rewrite (4) in a way that makes evident why this closely resembles a gravity equation:

$$E(m_{jkt}) = \phi_{jkt}\frac{y_{kt}}{\Omega_{jt}} s_{jt} \tag{5}$$

where $y_{kt} = e^{w_{kt}}$, $\phi_{jkt} = e^{-c_{jkt}}$ and $\Omega_{jt} = \sum_{l\in D} \phi_{jlt} y_{lt}$. The expected migration flow in (5) depends in a multiplicative way on (i) the ability s_{jt} of the origin j to send out migrants, (ii) the attractiveness y_{kt} of destination k, (iii) on the accessibility $\phi_{jkt} \leq 1$ of destination

k for potential migrants from j, and it is inversely related to (iv) Ω_{jt}, which represents the exponentiated value of the expected utility of prospective migrants from the choice situation (Small and Rosen, 1981).[2]

We can immediately observe that $\partial\Omega_{jt}/\partial\phi_{jlt} = y_{lt} > 0$, so that a reduction in the accessibility of an alternative destination l invariably leads to an increase in the expected bilateral migration flow from j to k in (5). This, in turn, implies that we can extend to migration flows the thought experiment about trade flows proposed by Krugman (1995): if we imagine to move two European countries to Mars while keeping their attractiveness and bilateral accessibility unchanged, then the migration flows between the two countries would definitely increase.

Notice that this choice model, as observed by Head and Mayer (2013) with respect to trade, is fully consistent with the presence of zeros in observed bilateral migration flows; for instance, if $E(p_{jkt}) = 1/s_{jt}$ so that $E(m_{jkt}) = 1$, then the probability that m_{jkt} is equal to zero is given by 36.6 percent, i.e., $(1 - 1/s_{jt})^{s_{jt}} = 0.366$.

If we take the ratio between $E(m_{jkt})$ and the corresponding expression for the expected number of stayers, normalizing ϕ_{jjt} to one, we have that:

$$\frac{E(m_{jkt})}{E(m_{jjt})} = \phi_{jkt}\frac{y_{kt}}{y_{jt}} \tag{6}$$

This ratio depends only on the attractiveness of destination k and of the origin j, and on the accessibility ϕ_{jkt}, while both Ω_{jt} and s_{jt} cancel out. This represents a manifestation of the well-known property of the independence from irrelevant alternatives that follows from the distributional assumptions *á la* McFadden (1974) on the stochastic component of utility in (2): a variation in the attractiveness or in the accessibility of an alternative destination induces an identical proportional change in both $E(m_{jkt})$ and $E(m_{jjt})$, thus leaving their ratio in (6) unchanged.

Bringing (5) to the data requires adding a well-behaved error term η_{jkt}, with $E(\eta_{jkt}) = 1$, to it, so that:

$$m_{jkt} = \phi_{jkt}\frac{y_{kt}}{\Omega_{jt}}s_{jt}\eta_{jkt} \tag{7}$$

The elegance and tractability of this model has made it the canonical reference in the migration literature, but it might be exposed to problems related to (i) the adequacy of the

[2] Ω_{jt} also captures the deterministic component of utility of not migrating, i.e., opting for the origin j.

distributional assumption on the stochastic term, and (*ii*) the specification of the deterministic component of utility. We are going to explore each of these two points in turn.

2.2.1 Distributional assumptions on the stochastic component

The derivation of (5) is based on the assumptions that the attractiveness of destination k varies neither across origin countries nor across individuals *and* that the stochastic component of utility is i.i.d. EVT-1. The hypotheses on the stochastic component can be regarded as "the natural outcome of a well-specified model that captures all sources of correlation over alternatives into representative utility, so that only white noise remains." (Train, 2003, p. 76), but the restrictive assumptions on the deterministic component of utility jeopardize the chances that the model is well-specified.

Imagine, for instance, that destination countries differ with respect to the gender gap in wages: the assumption that the deterministic component of utility does *not* vary with gender is going to introduce a positive correlation in the stochastic component of utility for a woman across countries characterized by a similar gender gap in wages. Individuals could be also heterogeneous with respect to the psychic costs of migration to any destination (Sjaastad, 1962), and this would introduce a positive correlation in the stochastic component of utility across all countries but the origin (Ortega and Peri, 2013).

What happens if we introduce more general distributional assumptions, allowing for a correlation in the stochastic component of utility in (2) across different alternatives in the choice set? We can draw on Bertoli and Fernández-Huertas Moraga (2013) to generalize (5):

$$E(m_{jkt}) = \phi_{jkt}^{1/\tau} \frac{y_{kt}^{1/\tau}}{\Omega_{jkt}} s_{jt} \tag{8}$$

where the parameter τ in (8) is inversely related to the correlation in the stochastic component of utility across alternatives. The key difference between (5) and (8) is that the resistance term Ω_{jkt} in the latter equation varies with the destination k, with the functional form of Ω_{jkt} depending on the different distributional assumptions that are adopted (Ortega and Peri, 2013; Bertoli and Fernández-Huertas Moraga, 2012, 2013). This, in turn, implies that the resistance term no longer cancels out when we take the ratio between two different expected migration flows:[3]

[3]This expression is derived under the assumption, which is maintained in the literature (Ortega and Peri, 2013; Bertoli and Fernández-Huertas Moraga, 2012, 2013; Beine, Bourgeon, and Bricongne, 2013), that the

$$\frac{E(m_{jkt})}{E(m_{jjt})} = \phi_{jkt}^{1/\tau} \frac{y_{kt}^{1/\tau}}{y_{jt}} \frac{\Omega_{jjt}}{\Omega_{jkt}} \tag{9}$$

More general distributional assumptions, which are more consistent with the constraints imposed on the specification of the deterministic component of utility, are no longer consistent with the independence from irrelevant alternatives property: specifically, an increase in the attractiveness of a destination that is perceived as a close substitute to k, will reduce $E(m_{jkt})$ more than $E(m_{jjt})$ (Bertoli, Fernández-Huertas Moraga, and Ortega, 2013), thus inducing a decline in (9). This, in turn, questions the long-standing tradition in the migration literature of estimating the determinants of bilateral migration rates as a function of the attractiveness of j and k only (Hanson, 2010).

2.2.2 The specification of the deterministic component of utility

The canonical RUM model of migration is surprisingly silent about the time dimension of the location-decision problem that potential migrants face. The inclusion of a time subscript t in (2) suggests that individuals make repeated location choices during the course of their lifetimes. For instance, an individual who decided to migrate at time t might decide in a following period to return to her origin country or to move on to another destination. Similarly, an individual who found optimal not to change her location at time t could still consider moving at a later point in time.

These simple observations call for rewriting location-specific utility in a way that explicitly reflects the sequential nature of the location-decision problem that would-be migrants face, following the literature on dynamic discrete choice models (Artuç, Chaudhuri, and McLaren, 2010; Arcidiacono and Miller, 2011; Kennan and Walker, 2011):

$$U_{ijkt} = w_{kt} + \beta V_{t+1}(k) - c_{jkt} + \epsilon_{ijkt} \tag{10}$$

where $\beta \leq 1$ represents a discount factor, and $V_{t+1}(k)$ is the expected value of the optimal sequence of moves from time $t+1$ onwards, conditional upon being located in country k at time t. The specification of utility in (10) reveals that the deterministic component of the attractiveness of country k at time t is $w_{kt} + \beta V_{t+1}(k)$, and it thus depends also on (i) the

origin country has no close substitute in the choice set.

future attractiveness of all locations in the choice set, and (*ii*) on the future values of the whole matrix of bilateral accessibility parameters.

We can observe, following Bertoli, Brücker, and Fernández-Huertas Moraga (2013), that (10) reduces to (2) only if we assume either that individuals take myopic decisions, i.e., $\beta = 0$, or that we live in a frictionless world with no migration costs,[4] so that $V_{t+1}(k)$ does *not* vary with k and there is no path-dependence in migration decisions.[5]

If we derive the expression for the expected bilateral migration rate from (10) while maintaining the assumption that ϵ_{ijkt} is i.i.d. EVT-1, then we have (Bertoli, Brücker, and Fernández-Huertas Moraga, 2013):

$$E(m_{jkt}) = \phi_{jkt} \frac{y_{kt}}{\Omega^V_{jt}} e^{\beta V_{t+1}(k)} s_{jt} \tag{11}$$

where the resistance term Ω^V_{jt} is given by $\sum_{l \in D} \phi_{jlt} y_{lt} e^{\beta V_{t+1}(l)}$, and it does not vary with k. If we take the ratio between the expected number of migrants to k and the expected number of stayers at time t, we obtain:

$$\frac{E(m_{jkt})}{E(m_{jjt})} = \phi_{jkt} \frac{y_{kt}}{y_{jt}} e^{\beta [V_{t+1}(k) - V_{t+1}(j)]} \tag{12}$$

The expression in (12) reveals that even the traditional distributional assumptions *á la* McFadden (1974) do *not* allow to express this ratio just as a function of the *current* utility of j and k and of the accessibility ϕ_{jkt}, as (12) is sensitive to variations in the future attractiveness of alternative destinations (Bertoli, Brücker, and Fernández-Huertas Moraga, 2013).

3 Review of the empirical evidence

The attractiveness w_{jkt} of a country for potential migrants from j and the bilateral migration costs c_{jkt} are usually modeled as linear functions of two (possibly overlapping) vectors of variables, which can vary over all combinations of the origin (j), destination (k) and time

[4]This represents a theoretically interesting limiting case, as in Anderson (2011), but not certainly a good approximation of the real world.

[5]If $V_{t+1}(k)$ is invariant across all alternatives in the choice set, then it represents a constant in (2) with no influence on current location choices.

(t) dimension. We provide a review of the existing empirical evidence on the determinants of international migration flows derived from the estimation of gravity models.

3.1 Origin or destination-specific factors

3.1.1 Income

A key determinant of the attractiveness w_{kt} of each location is represented by the level of income per capita that characterizes each potential destination. A RUM-based model of migration does *not* impose any constraint on the functional form of the relationship between income per capita and the deterministic component of location-specific utility in (2). Grogger and Hanson (2011) favor a specification where w_{kt} depends linearly on income per capita, while other papers in the literature opt for a logarithmic specification (Mayda, 2010; McKenzie, Theoharides, and Yang, 2013; Bertoli, Fernández-Huertas Moraga, and Ortega, 2013; Bertoli and Fernández-Huertas Moraga, 2013; Ortega and Peri, 2013). The literature generally assumes that the income prospects of potential migrants from *all* origins can be measured through GDP per capita at destination,[6] thus mostly imposing the assumption of a common trend in migrants' earnings at destination, with Bertoli and Fernández-Huertas Moraga (2013) representing an exception in this respect, and also minimizing the concerns about reverse causality. Refinements have been proposed by Grogger and Hanson (2011), which apply country-specific income tax schedules to obtain measures of post-tax earnings, Grogger and Hanson (2011) and Belot and Hatton (2012), which recover education-specific earnings, and by Beine, Bourgeon, and Bricongne (2013), which focus on wages rather than on earnings. The empirical evidence points to a robust positive relationship between income per capita and location-specific utility, with variations in earnings at destination that exert a stronger influence on the bilateral migration rate than identical proportional variations at origin in estimates that are consistent with departures from the standard distributional assumptions (Bertoli, Fernández-Huertas Moraga, and Ortega, 2013).

3.1.2 Credit constraints

The canonical RUM model of migration with distributional assumptions *à la* McFadden (1974) implies that a simultaneous variation in the (logarithm of) income per capita at

[6] We have relied on this common practice for the derivation of (5).

origin and at destination that leaves the differential between the two countries unchanged does not influence the bilateral migration rate. Such a perfect symmetry can disappear if we consider that potential migrants might face credit constraints that hinder their location choices. Credit constraints can be accommodated into the model by assuming that bilateral migration costs c_{jkt} are *negatively* correlated with income at origin, and hence with w_{jjt}. If the dependency of bilateral migration costs on economic conditions at origin is not properly controlled for, then an increase in incomes at origin would reduce the bilateral migration rate less than an identical decrease at destination, and it might even expand the scale of bilateral migration flows. The role of credit constraints has thus been captured either through the inclusion higher-order terms of income at origin (Vogler and Rotte, 2000; Clark, Hatton, and Williamson, 2007; Mayda, 2010), controlling for the incidence of poverty at origin (Belot and Hatton, 2012) or splitting the sample as a function of income at origin (Ortega and Peri, 2013). The econometric evidence provided by Vogler and Rotte (2000), Clark, Hatton, and Williamson (2007) and Belot and Hatton (2012) suggests that credit constraints do hinder observed international migration flows, blurring the effect of income if not properly controlled for (Belot and Hatton, 2012).

3.1.3 Expectations

The sequential model of migration that we summarized in Section 2.2.2 implies that the current bilateral migration rate depends on the expectations about the evolution of economic conditions in all countries belonging to the choice set. Bertoli, Brücker, and Fernández-Huertas Moraga (2013) have recently provided econometric evidence on the role of expectations in driving bilateral migration flows. Specifically, they have shown that the fluctuations in the yields on 10-year government bonds in European countries are significantly associated with the country-specific share of respondents that are concerned about the evolution of personal job prospects in the Eurobarometer surveys. The analysis of the bilateral migration flows to Germany between 2006 and 2012 conducted by Bertoli, Brücker, and Fernández-Huertas Moraga (2013) reveals that the elasticity of the migration rate with respect to the yields of 10-year bonds at origin stands at 0.14, so that changes in expectations can influence current migration decisions even after controlling for traditional determinants of the attractiveness of a country. Furthermore, when changes in the future attractiveness of alternative destinations are not controlled for, the estimates of the effect of current labor market conditions at origin are significantly biased.

3.1.4 General immigration policies

Migration costs c_{jkt} can be, at least partly, policy-induced. The immigration policies adopted by the country of destination can be either *general*, i.e., addressed to all countries of origin, or *bilateral*. We analyze here the existing evidence on general immigration policies, while bilateral policies are dealt with in Section 3.2.2. Limited progress has been made on the measurement of policy-induced migration costs compared to the existing data sources on tariff and non-tariff barriers to trade (see Anderson and van Wincoop, 2004). Early attempts have been provided by Clark, Hatton, and Williamson (2007), Mayda (2010) and Ortega and Peri (2013). In particular, Ortega and Peri (2013) analyze the role of general immigration policies in a micro-founded gravity model as in (8). The key policy measure, which represents an extension of Mayda (2010), refers to an index of entry tightness over the period 1980-2006 for 15 OECD countries. This index, which is *not* comparable across destinations, is negatively associated with the scale of incoming migration flows in estimates where between-destination variability is not used for identification. An attempt to build measures of immigration policies that are comparable both between countries and over time is represented by the on-going IMPALA project, which aims at building a database based on immigration laws in the 26 most important destination countries.[7] While progress has been made on this front, we are nevertheless very far away from a full-fledged database usable in the estimation of gravity models. In the absence of satisfying measures on immigration, one can nevertheless make use of the panel dimension and include d_{kt} fixed effects that control for the influence of general immigration policies, as in Beine, Docquier, and Ozden (2011), Bertoli and Fernández-Huertas Moraga (2012) and Beine and Parsons (2012).

3.1.5 Unemployment rate

The unemployment rate figures prominently in the seminal analysis of internal migration decisions by Harris and Todaro (1970), but little evidence on its impact on international migration flows has been, to date, gathered, with Beine, Bourgeon, and Bricongne (2013) and Bertoli, Brücker, and Fernández-Huertas Moraga (2013) representing two recent exceptions.

[7] The general presentation of the project and an analysis of preliminary data are exposed in Burgoon, Beine, Boucher, Crock, Gest, Hiscox, McGovern, Rapoport, Schaper, and Thielemann (2013).

An increase in the unemployment rate can reduce the attractiveness w_{kt} of a potential destination, and supportive evidence in this direction has been provided by Beine, Bourgeon, and Bricongne (2013) and Bertoli, Brücker, and Fernández-Huertas Moraga (2013). The effect of an increase in the unemployment rate on the decision to migrate can be mitigated by the existence of unemployment benefits: as recently arrived immigrants are not eligible for these benefits, then the bilateral migration flow m_{jkt} could be more sensitive to variations in unemployment in the destination k rather than in the origin j. This differential sensitivity could be reinforced if an increase in unemployment at origin tightens the credit constraints discussed in Section 3.1.2. Beine, Bourgeon, and Bricongne (2013) find support for a negative impact of unemployment at origin on top of its direct migration-enhancing role.[8]

3.1.6 Environmental factors

There is a very substantial empirical literature on the impact of environmental factors on international migration. Environmental factors include a large set of natural factors in which pure climatic factors represent only a subset. Environmental factors include pure climatic factors such as rainfalls and temperatures. They also include natural disasters whose climatic origin might be subject to discussion. Hurricanes or extreme floods are supposed to be related to climate since their frequencies and magnitudes have clearly increased along with climate change. The connection is much less obvious for other events such as earthquakes or insect invasion.

The channels through which climatic factors spur emigration are many-fold, with four of them mostly considered in the literature. First, negative climatic shocks decrease income at origin, which influences w_{jt}, through a decline in wages or a rise in the employment rate. Second, the shocks might increase bilateral migration costs c_{jkt} if they destroy assets, thus making credit constraints more binding. Third, detrimental climatic shocks tend to decrease attractiveness at origin independently from income (for instance, because of an increase in morbidity), which in turn leads to emigration. A fourth channel can be called the volatility channel: if climatic conditions become more volatile, then this can increase the volatility of

[8] Nevertheless, as the authors emphasized, the results should be taken with caution, since they are obtained from a specification that departs from the theory, as it does not include origin-time dummies (see Section 4.5 on this).

w_{jt}, inducing risk-averse people to opt for migration.

Most of the empirical literature linking climatic factors and migration has operated in models of monodic migration flows, as opposed to dyadic flows which is the basic unit of analysis in gravity frameworks. The main bulk of papers have also focused on South-North migration, i.e., emigration from less developed countries in the face of adverse climatic disturbances. Lilleor and Van den Broeck (2011) and Millock (2013) provide good surveys of this extensive literature. In general, the literature finds much evidence in favor of a strong labor market channel but also finds compelling evidence that in some cases the liquidity channel is at work. In contrast with this extensive literature on climatic shocks, there is much less work relying on gravity models of migration. Beine and Parsons (2012) represent a noticeable exception. Their use of a longitudinal multiple-origin multiple-destination dataset allows to include a rich combination of fixed effects for capturing unobservable factors. In particular, the inclusion of d_{kt} fixed effects allows to control for general immigration policies. This is particularly important since the main effects of climatic factors are supposed to operate in South-North (and South-South) international migration. Immigration policies in developed countries are expected to be quite restrictive for prospective migrants coming from less developed countries, the areas that are the most adversely affected by climatic shocks. Beine and Parsons (2012) find support in favour of a strong labour market channel in South-North migration, but reject the so-called amenity channel.

3.2 Dyadic factors

The dyadic factors that influence migration costs c_{jkt} can be both time-invariant, such as linguistic and cultural proximity, and time-varying factors, such as bilateral migration policies and networks. We cover these factors in reverse order.

3.2.1 Networks

An extensive literature has been devoted to the role of migration networks on the magnitude and the shape of bilateral migration flows.[9] The role of networks have been analyzed in micro-founded gravity models such as (4); while there are obviously econometric challenges to be overcome in order to correctly estimate that effect, the few existing papers based on structural

[9]For classical examples of a microeconomic analyses of the role of migrants' networks, which are not covered here, see Munshi (2003) and McKenzie and Rapoport (2010).

gravity models (Beine, Docquier, and Ozden, 2011; Bertoli and Fernández-Huertas Moraga, 2012; Beine and Parsons, 2012) come up with quite consensual results: a 10 percent increase in the bilateral migration stock leads to a four percent increase in the bilateral migration flow over the next ten years. This elasticity increases to 0.7 when we restrict our attention to migration to OECD destinations, and it is higher for low-educated than for high-educated migrants, thus lowering the average level of education of the migrants.[10] We can also notice that the share of explained variability by structural gravity models of migration is in the range of 50 to 70 percent, and at least one third of that proportion can be ascribed to the network effect. Failure to account for networks can lead to some an omitted variable bias. This is well illustrated by the role of colonial links. Once accounted for the network effect, regressions based on micro-founded gravity models such as (4) fail to find any remaining role for colonial links.

3.2.2 Bilateral immigration policies

Two broad types of measures capturing bilateral policies have been used in the literature. First, one can capture the prevalence of bilateral agreements between countries: for instance, Grogger and Hanson (2011) and Beine, Bourgeon, and Bricongne (2013) find larger bilateral migration flows when both the origin and the destination country are signatories of the Schengen agreement,[11] and Beine, Bourgeon, and Bricongne (2013) provide similar evidence for the bilateral agreements between OECD countries and collected by the IOM. The second main measure relates to bilateral visa policies. Visa waivers, which do not belong *de jure* to the legal framework that regulates immigrants' admission at destination, can facilitate the legal entry of migrants, thus reducing the bilateral migration costs c_{jkt}, and also reflect a preferential treatment at the dyadic level. Bertoli and Fernández-Huertas Moraga (2013) provide evidence on the impact of visa waivers on bilateral migration flows to Spain in a specification that uses high-frequency migration data and controls for time-varying bilateral unobservables, including cultural proximity, through a rich structure of fixed effects. Similar evidence in provided by Bertoli and Fernández-Huertas Moraga (2012) and Beine and Parsons

[10] This aggregate effect can be decomposed into an assimilation channel, e.g., decrease in policy *un*related migration costs such as information and adaptation costs, and into a policy-related effect, with Beine, Ragot, and Noel (2013) proposing an identification strategy to disentangle the two channels.

[11] Ortega and Peri (2013) provide similar evidence, but the Schengen dummy is not bilateral, as it is based only on the signatory status of the destination country.

(2012), with this latter paper using longitudinal data on bilateral visa policies collected by the DEMIG project at Oxford University.

3.2.3 Linguistic and cultural proximity

As in the trade literature, the most important time-invariant dyadic components of bilateral migration costs c_{jkt} are bilateral distance, colonial links, linguistic and cultural proximity. Bilateral distance does not require much explanation. As discussed above, the influence of colonial links can be indirectly captured through the network effect. This is in contrast with linguistic proximity that exerts some additional effect beyond its influence through networks. Most of the analyzes based on gravity equations and covered here capture the role of languages either through the use of dummies for the existence of a common (official or spoken) language between j and k, or through some simple measures of linguistic proximity. More elaborated indicators of linguistic proximity have been nevertheless used in gravity equations: Belot and Ederveen (2012) and Adsera and Plytikova (2012) employ proximity indicators based on family trees established by linguists. This captures the fact that Italian prospective migrants can (more) easily become proficient in the local language in either Spain or France than in Japan, although Italy does *not* share a common language with none of these three destinations. Cultural proximity is a more elusive concept than linguistic proximity. Belot and Ederveen (2012) use particular measures capturing, at least partly, this dimension: these are variables describing bilateral religious distance and survey-based measures capturing the cultural orientation of countries, both fostering bilateral migration flows.

4 Challenges for the estimation

4.1 What is the origin of the migrant?

An international migrant can be defined as “any person who changes his or her country of usual residence” (United Nations, 1998), but the measures of the bilateral gross migration flows m_{jkt} often departs from this definition. Specifically, the origin j can be defined as (i) the country of birth, (ii) the country of citizenship, or (iii) the country of last residence of the migrant. These three criteria partly overlap, but do *not* coincide, because of naturalizations and of the possibility of repeated migration episodes. Existing data sources rarely provide information on more than one of the criteria (i)-(iii), so that, say, data on bilateral migration flows based on the country of birth j aggregate the migration decisions of individuals who are citizens and that resided in countries other than j. The adoption of one of these three criteria, which are often data-driven, presents some advantages and limitations. For instance, some dyadic determinants of migration costs, such as visa waivers, depends on citizenship, while linguistic proximity could depend more closely on the country of birth and economic conditions in the country of last residence could shape the incentives to move.

4.2 The empirical counterpart for the log odds

The RUM model analyzed in Section 2 implies that the logarithm of the odds of migrating to country k over staying in country j can be expressed as a linear function of the differential in the deterministic component of utility associated to the two countries. Ideally, the empirical counterpart of the log odds would be represented by the ratio between the gross flow of migrants from j to k observed on a certain time period[12] over the number of individuals who remained in j throughout the period.

As far as the numerator of this ratio is concerned, gross flows have been used by Mayda (2010), Ortega and Peri (2013), Bertoli and Fernández-Huertas Moraga (2013), McKenzie, Theoharides, and Yang (2013) and Bertoli, Brücker, and Fernández-Huertas Moraga (2013). Other papers have used a *proxy* for the gross flows represented by the variations in migration stocks (Beine, Docquier, and Ozden, 2011; Bertoli and Fernández-Huertas Moraga, 2012; Beine and Parsons, 2012). A limitation is that variations in stocks differ from gross flows as they are also influenced return migration, migration to third countries, deaths, and naturalizations (if the definition of immigrants is based on citizenship) and births (if the country of destination adopts the *jus sanguinis*). Furthermore, while m_{jkt} is by definition nonnegative, variations in stocks can take negative values, which have been excluded from the sample (Beine, Docquier, and Ozden, 2011), set to zero (Bertoli and Fernández-Huertas Moraga, 2012), or added to the proxy for the flow from k to j (Beine and Parsons, 2012). Grogger and Hanson (2011) and Llull (2011) have used *stocks* for the numerator, but this choice

[12]The length of the time period also represents a crucial analytical choice: longer time periods, such as a decade, create problems for the (implicit) assumption in the RUM model that the deterministic component of location-specific utility in (2) does *not* vary within the period.

creates a tension with the underlying micro-foundation of the gravity equation.

For the denominator, the size of population at origin has been used (Bertoli and Fernández-Huertas Moraga, 2012), possibly restricted to certain age cohorts (Bertoli, Brücker, and Fernández-Huertas Moraga, 2013), but this also includes immigrants, or the number of natives at origin (Beine and Parsons, 2012), which represents a superior alternative as it only includes stayers and returnees. A convenient alternative, for datasets that include multiple destinations, is represented by the inclusion of origin-time dummies d_{jt} that control for the denominator of the dependent variable, although this choice comes at a cost that is discussed in Section 4.4 below.

4.3 Multilateral resistance to migration

Bertoli and Fernández-Huertas Moraga (2013) define multilateral resistance to migration as the confounding influence that the attractiveness of alternative destinations exerts on the determinants of bilateral migration rates. Section 2 follows Bertoli, Brücker, and Fernández-Huertas Moraga (2013) and shows how multilateral resistance to migration can arise either from more general distributional assumptions on the stochastic component in (2), or from explicitly accounting for the sequential nature of migration decisions.

Ignoring the term Ω_{jkt} in (9) generates biases in the estimation of relevant coefficients of the determinants of migration. For example, both Bertoli and Fernández-Huertas Moraga (2013) and Bertoli, Brücker, and Fernández-Huertas Moraga (2013) find that the effect of economic conditions at origin on migration rates is *over*estimated when the influence of alternative destinations is ignored. The reason is that economic conditions are correlated between origins and alternative destinations, both over time and space. Thus, when alternative destinations are disregarded, the origin term w_{jt} picks up both its own effect and the effect of these alternative destinations that goes through Ω_{jkt}. If, say, migration between Ecuador and Spain increased because of worsening economic conditions in Ecuador and worsening economic conditions in Ecuador were correlated with worsening economic conditions in, say, Chile, then estimates that disregard Ω_{jkt} would attribute all of the increase in the bilateral migration rate to Spain to the worsening of economic conditions in Ecuador. The scope for large biases is even more pronounced when migration policies are considered. Given that migration policies tend to be coordinated among destination countries, e.g., the European Union, it is not surprising that studies controlling for multilateral resistance to migration tend to find much larger policy effects than studies that do not control at all (Bertoli and Fernández-Huertas Moraga, 2012, 2013). This happens even in the case of empirical strategies that only control for Ω_{jkt} under less general distributional assumptions (Ortega and Peri, 2013; Beine and Parsons, 2012).

Different authors have proposed different strategies to control for Ω_{jkt}. When the panel and longitudinal dimension of the dataset are large enough, the resistance term nicely conforms with the structure of the CCE estimator proposed by Pesaran (2006). This is the methodology used by Bertoli and Fernández-Huertas Moraga (2013) and Bertoli, Brücker, and Fernández-Huertas Moraga (2013) and it has the additional advantage of being robust even in the presence of residual cross-sectional dependence in the data (Pesaran and Tosetti, 2011). Using less data-demanding approaches, Ortega and Peri (2013) control for the multilateral resistance to migration that is induced by an heterogeneity in the preference for migration, so that Ω_{jkt} does not vary across destinations k except the origin j itself. This empirically corresponds to estimating the gravity equation with origin-year dummies d_{jt}. Bertoli and Fernández-Huertas Moraga (2012) go one step further, and assume that potential migrants are heterogeneous in their preferences towards subsets (nests) of destination. With their cross-sectional data, this specific Ω_{jkt} can be controlled for with origin-nest dummies. Finally, Beine and Parsons (2012) use destination-year dummies d_{kt}, which allows them to partly control for the dynamic resistance terms introduced in Section 2.2.2.

Whether any of these alternative approaches or even the classical one that ignores multilateral resistance to migration altogether is enough to generate unbiased estimates is ultimately an empirical question. Following the theory, one necessary condition for the estimates to be RUM-consistent is to make sure that their residuals are cross-sectionally independent. In this sense, Bertoli and Fernández-Huertas Moraga (2012) propose adapting the CD test by Pesaran (2004) to make sure there are no remaining signs of correlation across destinations for different origins so that Ω_{jkt} is properly controlled for.

4.4 Estimates and structural parameters of the RUM model

Using a micro-founded model to estimate the determinants of aggregate migration rates can have some costs in terms of the interpretation of the coefficients. Whenever the existence of multilateral resistance to migration forces the researcher to depart from the classical framework, the parameters of the different distributions that can be used to model the dependence of bilateral decisions on unobserved factors can impede the exact identification of the relevant elasticities of migration flows with respect to their determinants.

Bertoli and Fernández-Huertas Moraga (2012) provide a very simple example. In their model, individual utility in each location depends on origin-destination factors plus an individual-specific error term that is allowed to be correlated within different nests of destinations. This correlation is the one that generates multilateral resistance to migration when individual decisions are aggregated at the origin-level for estimation purposes. In particular, Bertoli and Fernández-Huertas Moraga (2012) write the bilateral migration flow between two countries as a function of bilateral factors, origin country fixed effects and an origin-nest fixed effect, which embodies the effect of the characteristics of countries that are perceived as close substitutes to the destination by origin-country individuals. The problem is that the bilateral factors also belong to this origin-nest term and they belong to it with a particular functional form. In the simple case of a nested logit model, this means that the elasticity of migration flows with respect to bilateral factors will depend on the dissimilarity parameter τ in (8).

The type of variability that Bertoli and Fernández-Huertas Moraga (2012) exploit for identification does not allow them to separately identify τ. The only thing they can do is to take advantage from the fact that $\tau \in (0, 1]$. and that the elasticities are monotonic functions of τ. This allows them to construct upper and lower bounds for the elasticities of interest. These bounds are bilateral since the elasticities do not only depend on fixed parameters but also on the shares of the population who migrate or not between countries and on the substitutability of the destination countries with alternative destinations for each origin. Due to this dependence, the tightness of the bounds will hinge on the particular origin-destination pair. In general, bounds will be tighter whenever a given destination does not have many alternatives that are considered substitutable.

The inclusion of origin-time dummies d_{jt} among the regressors[13] implies that the estimates are consistent with a RUM model that is *not* based on distributional assumptions *à la* McFadden (1974), so that the fundamental uncertainty in the estimated elasticities should always be considered.

[13]See, for instance, Beine, Docquier, and Ozden (2011), McKenzie, Theoharides, and Yang (2013) and Ortega and Peri (2013) for different justifications for the inclusion of these dummies.

4.5 Estimation in logs or in levels

The pseudo-gravity model of migration derived from the underlying RUM model can be estimated using as the dependent variable either the level of the bilateral gross migration flow in (7), or the empirical counterpart q_{jkt} of the ratio of choice probabilities in (6). This second option requires estimating, through OLS, the following equation:

$$q_{jkt} = \ln(\phi_{jkt}) + \ln(y_{kt}) - \ln(y_{jt}) + \ln\left(\frac{\eta_{jkt}}{\eta_{jjt}}\right) \tag{13}$$

Santos Silva and Tenreyro (2006) made the point that the assumption that $E(\eta_{jkt}) = 1$ does *not* imply that $E\left[\ln\left(\eta_{jkt}/\eta_{jjt}\right)\right] = 0$, and that the heteroskedasticity of η_{jkt} entails that the expected value of $\ln\left(\eta_{jkt}/\eta_{jjt}\right)$ in (13) will be a function of the value of the regressors, thus making OLS estimates biased and inconsistent. This, in turn, calls for relying on the bilateral gross migration flow as the dependent variable as in (7), and estimating the model with Poisson Pseudo-Maximum Likelihood, PPML. This choice requires to *always* include origin-time dummies among the regressors, to control for the resistance term Ω_{jt} and for the number of potential migrants s_{jt}, while the inclusion of these dummies is, as discussed in Section 2.2, not strictly necessary when estimating (13).[14]

The choice of the estimation technique for the gravity model of migration confronts the researcher with an important trade-off: the reliance on linear models through the logarithmic transformation widens the menu of estimators that can be adopted, as discussed in Section 4.2, to deal with multilateral resistance to migration, while Bertoli and Fernández-Huertas Moraga (2012) represents, to date, the only paper that deals with multilateral resistance to migration with PPML under more general distributional assumptions than Ortega and Peri (2013)[15] through a richer structure of fixed effects.

4.5.1 Presence of zeros in the data

The case for relying on PPML is strengthened when the dependent variable takes zero values, as Santos Silva and Tenreyro (2011) have shown that this estimator performs well even in the presence of a large share of zeros in the data. An alternative with linear models is

[14] The estimation of (13) with the CCE estimator proposed by Bertoli and Fernández-Huertas Moraga (2013) allows to deal with heteroskedastic disturbances in (7).

[15] PPML estimates are always consistent with heterogeneity in the propensity to migrate when origin-time dummies are included.

represented by a two-stage selection model *á la* Heckman adopted by Beine, Docquier, and Ozden (2011). Identification is improved by the availability of a variable that can be excluded from the second stage equation, but credible exclusion restrictions are hard to find with data that have a longitudinal dimension.

4.6 Omitted variables and instrumentation

The existence of omitted variables drives a wedge between the deterministic component of utility $w_{kt} - c_{jkt}$ in (2) and its empirical counterpart. This calls for estimation approaches that are consistent with more general distributional assumptions on ϵ_{ijkt} in (2), as omitted variables end up in the error term and can give rise to a correlation in the stochastic component of utility across destinations. Controlling for multilateral resistance to migration can make instrumentation unnecessary as long as the endogeneity problem is not due to reverse causality or as long as the resistance terms capture a big part of the omitted factors.

Second, if the two above conditions do not apply, instrumentation of some of the key variables might be needed. Three issues arise in that respect. The first issue is of course to find an instrument that is correlated with the key variable of interest and not correlated with the bilateral flows. The existence of such an instrument is subject to discussion. The presence of serial correlation in the error term of specification (4) invalidates the use of internal instruments, i.e., past bilateral flows in a panel set-up. This means that external instruments should be favored. For instance, networks are clearly endogenous in equation (4). Endogeneity might come from omitted variables, e.g., networks are correlated with unobserved cultural proximity, but in some cases also from some kind of reverse causality, e.g., flows are computed from stocks which is the macro proxy of networks. To that purpose, Beine, Docquier, and Ozden (2011) use the existence of guest worker programs at destination (that came to an end in the late 1960s) to instrument for networks. Another example is provided by Beine, Ragot, and Noel (2013), who instrument education fees affecting the migration of international students with the share of public universities in the destination country.

The second issue is that instrumentation preferably needs to take place in a Poisson regression set-up, as discussed in Section 4.5 above. To that purpose, Tenreyro (2007) proposes to combine PPML estimation and instrumentation using a GMM-type of estimator. Beine, Ragot, and Noel (2013) implement that approach in the context of international migration of students. Nevertheless, the estimation might face in practice important problems of convergence towards the optimal values of the estimates and one cannot rule out the existence of local maxima in the support of admissible values for the key parameters. Finally, if multilateral resistance to migration is still an issue, the instrumentation procedure should ideally account for it, both in the first and in the second stage.

5 Conclusions

The use of bilateral data for the analysis of international migration is at the same time a blessing and a curse. It is a blessing since the dyadic dimension of the data allows to analyze many previously unaddressed questions of the literature. The development and the use of country-pair flows and stocks of international migration allow to identify many important determinants such as the network effect, the role of poverty constraints or the impact of cultural links between countries. This paper reviews some of the recent studies using this type of data in order to identify the important factors affecting international migration flows. Our review demonstrates that significant efforts have been conducted by many scholars and that overall we have a much better knowledge of the important determinants.

Still, the use of bilateral data is also a curse. The methodological challenges that are implied by the use of this type of data are numerous and our paper covers some of the most important ones. We show that a good connection with the underlying micro foundations is desirable, something very much in line with the literature on trade. The reference to the underlying theoretical frameworks such as the RUM model clarifies the need to account for important issues such as multilateral resistance to migration. In turns this has strong implications for the econometric estimation methods that need to be used. Additional issues such as the presence of many zero observations or endogeneity concerns due to ommitted factors have also strong implications for the choice of the appropriate econometric techniques. Fortunately, the recent evolution of the literature suggests that scholars are increasingly aware of these challenges.

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