Chapter 20
The Use of Econometrics in International Economics

Hartmut Egger and Peter H. Egger

Abstract This chapters reviews the evolution of the use of econometric methods in key fields of international economics. It highlights research on the estimation of gravity models, on the estimation of the determinants and consequences of various preferential (legally discriminatory) agreements about trade, investment, taxation, and other trade-relevant economic aspects, and the impact of trade or other trade-related outcomes on local labor markets as three particularly important domains in terms of research output.

20.1 Introduction

International economics – in particular reasoning about the causes and effects of international trade – is one of the oldest fields of economics. Keeping track of the sales of produce – foremost the one coming into a region from elsewhere – constitutes a major interest for *authorities* from legal landlords to criminal organizations with an interest in partaking in the value of sales by way of legal taxes, legal or legal rent extraction, or the protection of local factor owners. Not surprisingly, the latter leads to a wealth of data on trade starting with historical accounting-type data from Assyrian times (see Barjamovic, Chaney, Coşar & Hortaçsu, 2019) and around the times of the Roman empire (Flückiger, Hornung, Larch, Ludwig & Mees, 2022, Boehm & Chaney, 2026) to modern transaction-type data on trade collected at customs or from tax data.

What makes trade data special is that the value and, occasionally, separately the price and quantity, of goods sold are collected and available for many (ideally all)

Hartmut Egger
University of Bayreuth, Bayreuth, Germany, e-mail: hartmut.egger@uni-bayreuth.de

Peter H. Egger ✉
ETH Zurich, Zurich, Switzerland, e-mail: pegger@ethz.ch

customer markets for any producer and for many (ideally all) producer markets for any customer. This permits addressing customer demand – from business to business (B2B) or from final consumers to business (B2C for sales), often the sum of the two – for pairs of suppliers and customers at different levels of aggregation.

The literature on the determinants of this demand and, particularly, on the impact of frictions – natural or man-made – on demand (nominal or real) is the object of interest in a large research agenda focusing on the so-called *gravity equation*. Due to the volume of research devoted to this agenda, the first section of this chapter will be devoted to the gravity equation. A key feature of empirical work on gravity equations is that the data fundamentally come as panel data, often as high-dimensional panel data. One particular challenge regarding empirical research in this context is the need of respecting strong theoretical foundations guiding the functional form and parametrization of estimating equations. This is the case, because, when respecting these foundations, the estimated parameters – foremost ones related to variable trade costs but also ones related to the supply potential of producers and to fixed market-entry costs – can be used to inform equilibrium models used for counterfactual analysis.

Trade frictions or trade freeness are at the center stage of the literature on gravity models, and what can be changed in the short run are mainly man-made barriers to trade such as tariff or nontariff policy barriers. Tariffs are a form of taxes, while nontariff barriers (such as quotas, sanitary and phytosanitary provisions, etc.) are not. There is a rich micro-theoretical literature analyzing the costs and benefits of having such instruments in place for producers, consumers, and the government itself. Quantifying these effects is interesting for academics as well as policy makers, and what it requires are trustworthy parameters obtained from empirical research. Not surprisingly, significant efforts are made to obtain such parameters from various trade-related policy variables, including measures of tariff and nontariff barriers themselves as well as coarser measures of their relaxation within trade agreements. As one would expect, significant attention is put on the endogeneity of man-made policy barriers and their relief as well as on assumptions related to their effects on trade.

A last section of the chapter surveys a smorgasbord of further topics in econometric work related to trade. We begin with the effects of trade on local labor markets and with worker-flow models, both of which share with gravity models the need to model flows across high-dimensional origin-destination structures. We then turn to exchange-rate and tariff pass-through, where the focus shifts from trade quantities to the transmission of cross-border cost shocks into prices. The section finally discusses stock-market event-study designs, border and discontinuity designs, and the estimation of firm selection, sorting, and jointly determined firm-level outcomes.

While the determinants of trade are important for consumers, what factor owners mostly care about is what trade changes for them in terms of factor demand and income. But also there, the supplier-customer disaggregation of trade permits tracing factor-demand and -income effects to particular sources. We will devote the second smorgasboard subsection to this line of interest and the methods proposed to address the relevant questions. Because factor demand depends on trade and trade is endogenous and a function of factor prices as per the insights of the aforementioned gravity-model literature, it should not come as a surprise that endogeneity and identification issues are of particular importance to that strand of research.

Another section in the smorgasboard addresses the literature on the pass-through of costs and expenses on prices.

Stock-market effects of announced trade-policy measures occur prior to their coming into effect. Related research is very different from the one discussed in the first two chapters in that it uses high(er)-frequency data on stock prices in conjunction with event-study designs to estimate the associated effects.

Finally, the so-called *new trade theory* with the work of Melitz (2003) started a rich structural literature in international economics and the endogenous selection of heterogeneous suppliers into markets and the market-specific truncation of their distribution. Selection can be motivated by the existence of fixed costs (see Melitz, 2003, Chaney, 2008, or Arkolakis, 2010) or by the existence of a choke price even in the absence of fixed market-entry costs (see Melitz & Ottaviano, 2008). In any case, with selection and sorting the truncation of the distribution of producers in a market is important, and specific methods had been proposed to address said truncation, which is why this research deserves a specific discussion. We present related research in the last section, which addresses the consideration of discontinuities in the trade literature in general. Firm selection is only one source of such discontinuities, as will become clear there.

20.2 The Gravity Model

20.2.1 Some Basics

In its simplest form, one could portray the gravity equation of trade as a double-indexed, cross-sectional problem. The left-hand-side variable are typically either then bilateral exports or the bilateral imports between two trading entities, which could be firms regions, or countries. The customary gravity equation for bilateral exports is typically stated as a multiplicative function of five terms: a constant, *supply potential* carrying the exporter index, *demand potential* carrying the importer index, *trade freeness* (the inverse of trade cost) carrying the exporter-importer-pair index, and a residual term. Clearly, this generic form covers the famous (in its application to international economics ad hoc) Newtonian gravity equation. Measuring the supplier and buyer masses (sizes) by country GDP trade freeness as distance between the exporter and the importer to some (negative) exponent.

Ad-hoc, Newtonian-type gravity equations had been postulated for bilateral exports or imports between countries by researchers starting with Tinbergen (1962).[1] Tinbergen (1962), Pöyhönen (1963), and Pulliainen (1963) were probably the first to introduce gravity equations of bilateral exports or imports as a function of (at least) the product of two countries' GDP and inverse geographical distance between them. Since the form was multiplicative, taking logs and estimating linear models by ordinary least squares seemed innocuous at the time. What is robust in exponential as well as log-linear regression models is that the estimated exponents on exporter and importer GDP are positive and not too different from unity. And the exponent on bilateral distance is negative and not too different from minus unity. However, a host of concerns were voiced in the course of decades since with regard to such ad-hoc models. First, historical gravity models suffer from an ignorance of what is called the *three-body* problem in physics. If the attraction of two countries changes (for instance, due to policy changes through tariffs or trade-agreement membership), this will be irrelevant to the intensity of trade between those two countries and others and between third countries altogether. Second and related to the previous point, GDP is a function of exports and imports and can neither be exogenous for the importer nor the exporter. Third, distance is coarsely measured between entities such as countries. Fourth, knowing the coefficients on right-hand-side variables in a gravity equation does potentially not provide an interesting background for neither economists nor policy makers. If big shocks materialize (for instance tariffs as implemented under the Trump I and II administrations in the United States, the implementation of free-trade among the member countries of what is now called the European Union or its significant, so-called *Eastern* enlargement round in 2004), one would expect this to have consequences for not only trade but also for GDP (as per the accounting definition of GDP as an function of a country's total exports and imports), and eventually even on population (through migration and fertility). Moreover, big shocks will not only have trade-creating or -destructing consequences for the directly treated countries, but they will lead to a deflection and diversion of flows to and from third countries. However, the pioneers of the use of gravity equations spurred an interest which eventually led to a recognition of the mentioned shortcomings. Specifically, Pöyhönen (1963) focused on the country-specific magnitude of – ex-post computed – residuals (estimates of random country exporter and importer effects). One could say that this stimulated research concerned with so-called trade potentials – the expected level of bilateral exports between any pair of countries, if trade were *normal* by estimated standards. On the other hand, it may be seen as an early recognition of the

[1] Even prior to Tinbergen, Stewart (1948) postulated a gravity equation to parameterize the strength of interactions – he called it the *energy between* – the members of two social groups as a multiplicative function of the population size of these groups and the inverse distance between them. He may be the father of the use of, including term, *gravity equations* in the social sciences at large.

gravity equation to naturally have a panel form with repeated observations of the same exporters and importers across pairs in the data. Linnemann (1966) was the first to devote a whole book to the gravity equation and its use in international economics. He deserves credit for being the first to acknowledge the joint determination of trade flows, GDP, and prices in an economic system. However, Linnemann assumed that prices were not specific to countries but common to the world economy. And GDPs were not micro-founded on the production side. What is more, his theory did acknowledge the interdependence of trade and GDP, but it did not deliver a multiplicative structural form of the gravity equation, which serves as the workhorse ever since Tinbergen (1962).

20.2.2 Historical Ad-hoc versus Modern Structural Models of Bilateral Trade

As mentioned above, Tinbergen (1962) and Pöyhönen (1963) were arguably the first to propose log-linear models of bilateral trade that resemble the form of the gravity equation in physics. What that work kicked off was an interest in the composition of one might call the trade-freeness component in logs (the negative of log trade costs). Ever since Tinbergen (1962), the interest in postulating a trade-freeness function and the coefficient of observable variables used therein became one of the cornerstones of the interest in empirical gravity equations.

It became customary to postulate trade freeness or trade costs in logs as an additive function of two terms: (i) log one plus the ad-valorem tariff rate set by the importer on goods of the exporter times a parameter; (ii) a parameter-weighted sum of log nontariff trade costs. It should be noted that the log plus one tariff charged by an importer is typically the same in a year for a given product across exporters, as long as the exporters are all members of the World Trade Organization (this tariff is called the most-favored-nation, MFN, tariff rate), and it is zero for for products facing a preferential tariff in trade agreements (with exceptions for transition periods). Hence, the log plus one tariff rate is in most cases bounded from below by zero, unless there are import subsidies.[2] The ad-valorem tariff factor carries the probably most important structural parameter in modern structural gravity models. This parameter is referred to as the *trade elasticity* – the price elasticity of demand in customary quantitative trade models. The term *trade elasticity* is actually a misnomer, because the elasticity of trade with respect to trade costs or tariffs depends on it but also on other factors. Specifically, the function (or the structural model)

[2] Clearly, the portrait here is over-simplifying. First of all, not all tariffs are ad-valorem rates (in the sense of a tax surcharge on prices in percent). For instance, most countries tax oil and refined oil products by volume (gallon or liter. Such tariffs are called *specific* (as opposed to ad-valorem). Switzerland is the world champion in using specific tariffs rather than ad-valorem ones (per bottle of wine, etc.). In the absence of ad-valorem tariffs, it became practice in the literature to establish ad-valorem equivalents. This is to determine what an ad-valorem tariff would have to be to mimic the tax effect of a specific one. Clearly, this approximation is potentially very bad, if product prices have a large variance and/or if large tariff changes occur.

through which trade depends on tariffs is nonlinear, so that the elasticity of trade with respect to ad-valorem tariffs is local and depends on the economic state of the model for each country pair specifically. While the *trade elasticity* is a fundamental parameter involved in this function, it is not an elasticity in the proper sense of the word. The other, non-tariff determinants of the trade-freeness (or trade-cost) function include log bilateral distance and a host of mostly binary indicators on time-invariant common land borders (contiguity), common official language, or common history, to time-variant binary trade-agreement or customs-union membership indicators. The parameters on the nontariff factors, as these variables are not ad-valorem measures, and should be interpreted as composite products of the trade-elasticity parameter and other parameters which convert these measures to ad-valorem equivalents.

As mentioned above, in ad-hoc gravity models, the country-specific (or, more generally, the single-indexed) factors were originally modelled as to consist of log GDP and later of log GDP and log population.

However, a key problem of ad-hoc models is that they confuse parameter estimates with marginal effects. After all, as said, GDP is a function of aggregate exports and imports (as well as tariff revenues) in the most simple accounting relationships, and this implies that log GDP of the exporter and the importer are functions of trade freeness and trade costs and, in fact, the trade freeness not only of one particular but of all pairs of trade partners in the global economy.

Theoretical foundations in J. E. Anderson (1979) and, particularly, in J. E. Anderson and van Wincoop (2003) and in Eaton and Kortum (2002) paved the way for an explicitly structural treatment of endogenous export supply and import supply potential in estimation.

What J. E. Anderson and van Wincoop (2003) and Eaton and Kortum (2002) proposed is a general-equilibrium-theory-founded decomposition of the exporter-supply and importer-demand potential components into an exogenous and an endogenous component each. The interpretation of the exogenous country-specific factors depends on the respective model. Regarding exporter-supply potential, what is exogenous for exporters is the average productivity in Eaton and Kortum (2002), the Armington preference parameter towards an exporter's output in J. E. Anderson and van Wincoop (2003), or exporter population of labor force as a correlate of the mass of producers in Bergstrand, Egger and Larch (2013). The endogenous exporter supply component are factor prices Eaton and Kortum (2002) or Bergstrand et al. (2013) and goods prices in J. E. Anderson and van Wincoop (2003). The exogenous importer demand potential is proportional to the working population in an importing country. And the endogenous importer component is a multiplicative function of per-worker income and the consumer price index. It should be noted that the mentioned endogenous exporter- or importer-specific factors here are typically still treated as non-stochastic in the estimating equation.

On the income side of macro accounting, GDP can be understood as the product of the factor bundle and the associated bundle costs. With a single factor of production, (equipped) labor, GDP is the product of the working population times per-capita income. With this notion, one can replace and per-capita income term in the exporter-supply and importer-demand potential terms by GDP over labor. In the model of Krugman (1979) as used in equation (9) of Bergstrand et al. (2013) the exporter term corresponds to an exporting country's population (or labor force) exponentiated by one minus the trade elasticity. The endogenous exporter term is exporter country GDP exponentiated by the trade elasticity. Moreover, they parameterize the importer term by importer GDP divided by the price index exponentiated by the trade elasticity. It is important to understand that the such-exponentiated inverse importer price index is nothing else than the trade-freeness-weighted sum of all exporter terms (exogenous times endogenous). And exporter GDP is the sum of all bilateral sales including domestic ones. This establishes market clearing, whereby all income is earned from sales or the value of consumption equals the value of income. Through the latter the endogenous component of the exporter-specific factor depends on all trade costs worldwide through the structure of the summed gravity equation, and the the exporter- and importer-specific components depend on each other. Obviously, with such a structure, the derivative of the log gravity equation with respect to trade freeness is not unity, that with respect to log ad-valorem trade costs is not the trade elasticity, and that with respect to the nontariff trade-freeness factors is not the true parameter on them.

Specifically, the structure of the importer-specific term in the gravity equation motivates two conclusions. First, with proper measurement of expenditure and proper parametrization of the trade freeness and the exporter-specific term, only the trade-cost-function parameters are unknown, and there is no need for fixed-effects (estimation. Second, suppose that there are some unknown exporter-specific and importer-specific log trade-freeness components. Then, any importer-specific trade-freeness term would cancel out, because both the trade freeness term the importer-specific term (in the denominator) are proportional to it. Any exporter-specific trade-freeness term would not cancel out but assume a part in the exogenous exporter-specific component of the gravity equation. If the latter term is not observable, it could be captured by an exporter-fixed effect. Still, there would not be any need for including an importer-specific fixed effect, as, conditional on importer expenditure, it is a function only of the exporter-fixed and the trade-freeness terms. Once the exporter-fixed effect and the trade-freeness parameter are known or estimated, the importer-fixed component can be constructed. Unknown importer-fixed effects must lie in the domain of expenditure being mismeasured (which could be due to existence of an outside sector as in Eaton & Kortum, 2002, or to trade imbalances as in Dekle, Eaton & Kortum, 2007, etc., in canonical gravity models).

But the main interest in the estimation of ad-hoc and structural gravity models has always been in the estimation of trade-cost (or trade-freeness) function parameters such as β and γ_k in stochastic versions of the gravity equation with a multiplicative residual in the exponential (multiplicative form) or a log residual in the log-additive form of the gravity equation.

20.2.3 Functional Form: The Log versus Non-log of Gravity

For a long time since the early days of the estimation of gravity models of trade the leading approach was a log-linear transformation of the gravity equation which is multiplicative in its original form.

Particular emphasis has been put on the use of exporter- and importer-specific effects in cross-sectional gravity models (see Mátyás, 1997, 1998), and the use of exporter-, importer-, and time- or of interacted exporter-time-, importer-time, and exporter-importer fixed effects in longitudinal data (see P. H. Egger, 2000, Baltagi, Egger & Pfaffermayr, 2003).

However, log-transforming multiplicative structural estimating equations can run at risk of obtaining biased regression parameters if the variance of the disturbances is related particularly to the conditional mean of the regression, leading to heteroskedasticity. This had been demonstrated to be of great importance by Santos Silva and Tenreyro (2006) with gravity models of international trade. The latter authors proposed exponential-family models and, particularly Poisson pseudo-maximum-likelihood models (PPML) for estimation.

Under a multiplicative model structure and under the expectation of the residual term being unity conditional on the exporter-specific supply-potential (often fixed effects), importer-specific demand-potential (often fixed effects), and the parameterized trade-free-ness function, PPML is consistent, even if the distribution of the multiplicative residual is not Poisson. This is a powerful result in favor of PPML estimation. And the approach is amenable to two-way (exporter- and importer-) fixed-effects estimation without incurring an incidental-parameters problem.[3] However, the use of three-way interacted effects in triple-indexed gravity models still poses a challenge for the estimation of at least some generalized-linear (GLM) exponential-family models, including PPML.

The literature established that PPML has advantages regarding point estimation and fixed-effects estimation. However, two issues remain. First, are the data at hand fitted best by PPML or other GLMs? Second, if the estimates are consistent, are they

[3] In case of an incidental-parameters problem, the inclusion of exporter- and importer-fixed effects (which themselves are not necessarily of interest to the empirical researcher) would lead to a bias in the parameters of the trade-cost function. However, those fixed effects can be conveniently be partialled out rather than being estimated on binary indicator variables with PPML estimation. See P. H. Egger and Nigai (2014), Fally (2015), Weidner and Zylkin (2021), and Freeman, Larch, Theodorakopoulos and Yotov (2025) on estimating fixed effects in multiplicative gravity models.

efficient? P. H. Egger and Staub (2016) suggested considering deviance residuals to check PPML against other GLMs and eventually select the best model. And the presence of country(-time) clusters in aggregate trade data may call for clustering of the standard errors. And is simple clustering appropriate? The results in Pfaffermayr (2023) indicate that off-the shelf corrections may be biased. As an alternative to clustering, bootstrapping can be used. But which bootstrap is the appropriate one with so-strangely connected dyadic gravity data (see Zylkin, 2024).

Little attention appears to be paid to these issues in applied work. Historically, gravity modelers operated under the assumption of identically and independently distributed residuals. the consideration of heteroskedasticity and, more so, interdependence is very recent and no consensus leading to an *industry standard* was achieved yet.

20.2.4 High-dimensional Data

As outlined above, gravity models of trade involve sales from exporters (or sellers) to importers (or customers) at a minimum. Hence, even cross-sectional gravity models as used by Mátyás (1997), Eaton and Kortum (2002), J. E. Anderson and van Wincoop (2003) and many others involve double-indexed and, hence, panel data. However, some gravity models use data with an additional sector or product dimension (see, e.g., Bergstrand, 1989, Caliendo & Parro, 2015, French & Zylkin, 2024, or J. E. Anderson & van Wincoop, 2004). And they can be origin-region-sector by destination-region-sector by time variant (see Burman et al., 2026). With labor-flow data, they can carry region-sector-occupation indices for the origin as well as the destination as well as a time index (see Artuç & McLaren, 2015). Hence, gravity models are naturally of a high-indexed (at least double-indexed) data dimension. Accordingly, it has become customary to use high-dimensional (at least two-way) random-effects or, even more so, fixed-effects models. See Mátyás (1997, 1998), P. H. Egger (2000), Baltagi et al. (2003), P. H. Egger and Pfaffermayr (2003), Fally (2015), Weidner and Zylkin (2021), or French and Zylkin (2024).

The use of high-dimensional fixed effects does not pose a problem whatsoever in log-linear gravity models, where so-called within transformations exist for balanced or unbalanced data. However, this is not the case for nonlinear models, where within-type transformations do not generally exist and fixed effects cannot always be partialled out. However, fixed effects can be readily partialled out in two-way (exporter-time and importer-time) PPML models as well. But the analysis of gravity models does not generally involve continuous outcomes only. For instance, there is an interest in zeros in trade-flow data (see Helpman, Melitz & Rubinstein, 2008), and for binary-choice models partialling out high-dimensional (or even two-dimensional) fixed effects is not generally possible. As an example, neither partialling out is possible nor estimating them as parameters on dummy variables does deliver unbiased estimates of exporter and importer effects in cross-sectional probit models of the so-called extensive margin of trade. In the latter, a binary indicator for whether or not one country exports to the other is used as the dependent variable.

While in some GLMs point estimates and standard errors can be estimated consistently with high-dimensional fixed effects, in others this is not possible. Hence, the high data dimensionality in conjunction with the need of including high-dimensional fixed effects poses a challenge in nonlinear gravity models.

20.2.5 Masses of Zeros

Depending on the outcome – aggregate bilateral export or import (Helpman et al., 2008, Santos Silva & Tenreyro, 2015), foreign direct investment (Davies & Kristjánsdóttir, 2010), migration (Bohara & Krieg, 1996), or commuting (Dingel & Tintelnot, 2026) – and on the level of cross-sectional aggregation (country pair, country-sector pair, region-sector-pair, etc. – as well as the time frequency – years, year-intervals, quarters, months, days – flow data can contain a smaller or a substantial mass of zeros. Clearly, a log transformation leads to a loss of observations of zero flows,[4] while using an exponential-family model on the multiplicative process does not. In the history of gravity models since Tinbergen (1962), zeros had been neglected for the most part. And even today, resorting to the estimation of exponential-family models such as PPML is deemed sufficient.

However, a large mass of zeros naturally calls for a separate process to model zero versus positive outcome and the extent of positive outcome. PPML only serves to no discarding zeros. Many zeros in place suggest that the zero-nonzero (selection) process and the process for positive outcomes are different. Then, PPML on pooled zero and nonzero data can lead to severly biased parameter point estimates.

For instance, Helpman et al. (2008) propose the use of Heckman-type estimation of log-linear cross-sectional gravity models for trade flows with two-way (exporter and importer) fixed effects. P. H. Egger, Larch, Staub and Winkelmann (2011) propose the use of two-part-model type estimation of exponential-family models with two-way fixed effects. Work on other outcomes used similar strategies to address mass-of-zeros problems in bilateral stock or flow data with or without time variation.

A key feature of all these models is the reliance on a binary-choice model which addresses the zero mass in the data and the use of as many fixed effects as there are used in the process for the continuous outcome. Controlling for fixed effects can be conveniently done in a correlated random-effects framework with probit models

[4] Other transformations such as the hyperbolic sine transformation do not. However, applying such transformations is not innocuous, and they may lead to substantial parameter bias.

(Wooldridge, 2010, 2019) or even with partialling out the fixed effects with a logit structure (Stammann, 2023). However, combining such strategies with GLM estimation for the flow-data equation is rarely done in applications. But with the trend of using more and more disaggregated data the need for doing so will ever increase.

20.2.6 Dynamics

There is a large degree of persistence in data on bilateral trade flows and bilateral FDI (see P. H. Egger, 2001, for estimates of an ad-hoc gravity-type model). A host of different potential reasons are given in the literature for inertia in trade data.

One is that trade or bilateral-investment frictions should be interpreted as a broad concept, including information costs. Then, the trade-cost or investment-cost function can depend on lagged trade flows or lagged direct-investment stocks (see P. H. Egger, 2001). Jung (2009) formalizes this notion by proposing a model, where bilateral trade flows accumulate over time into an invisible asset as a state variable which can be associated with trust. Also in this framework, trade costs in a broad sense depend on this state variable, which is a function of lagged bilateral trade flows.

P. H. Egger, Foellmi, Schetter and Torun (2025) provide a structural approach towards a dynamic gravity framework based on the idea of market-entry costs which drift downwards with a longer tenure of incumbent firms in a market. This leads to a greater likelihood of younger firms in it to exit a market and older firms in it to stay. A problem for quantitative work building on this idea is that typical data do not provide any information on the market tenure of the firms behind the reported trade flows, which limits the acknowledgment of this aspect of dynamics.

Larch, Navarro and Novy (2026) propose a model where price stickiness leads to dynamic adjustment as a micro-foundation for dynamics in a gravity model of international trade.

20.2.7 Spatial Interdependencies

The deterministic data-generating process of the data underlying general-equilibrium-based gravity equations is triangular. An inspection of the multiplicative aggregate cross-sectional gravity equation suggests that the single-indexed exporter and importer terms depend on each other, that the individual exporter terms depend on each other, and that each country's aggregate sales as well as income and consumption depend on all countries' exogenous parameters. As a consequence, the marginal effect of log trade freeness on bilateral exports is not unity, and that of log tariff rates is not the trade elasticity, as mentioned above. Referring to the parameter on the log one plus tariff rate variable as the *trade elasticity* (with respect to trade costs) is a misnomer, because the true trade elasticity is fundamentally heterogeneous across country pairs as per the customary structural gravity model (see Arkolakis, Costinot & Rodríguez-Clare, 2012). In other words, a marginal effect of trade costs in the nonlinear general equilibrium model depends on the outset state underlying the bilateral trade-flow vector. This does not come as a surprise to econometricians used to evaluate marginal effects in nonlinear stochastic models.

A customary assumption is that the elements of the trade-freeness (or trade-cost) function are, if not exogenous, then at least stochastically independent. However, some research permits trade costs to be a function of other countries' weighted trade flows, which leads to a gravity equation with a so-called spatial lag. For instance, Porojan (2001) includes the weighted bilateral log exports of neighbors as an element in the log trade-cost function.

Yet other models consider the components of the export-potential shifter or of the trade-freeness parameter (the latter through the trade-cost function) to exhibit a spatially- or network-weighted pattern. Such patterns can be motivated as follows.

First, note that the sales-potential shifter for an exporter depends on either the labor force or productivity, there. In many models, the size of the labor force or population in the exporting country is fixed and not a function of trade freeness. However, big shocks to trade freeness – originating from natural disasters such as droughts reducing the capacity of the Panama Canal, wars which lead to a reduction of transport capacity in the Suez Canal or the Strait of Hormuz, the Trump I and II tariffs, etc. – can lead to changes in in labor-force-participation decisions, in unemployment, in decisions about part-time versus full-time work, eventually in mortality or fertility choice, etc. For instance, Allen, Arkolakis and Takahashi (2020) present a model, where L_i carries an unknown coefficient (e.g., due to mobility in and out of the labor force) and is endogenous theoretically (in the deterministic model) as well as stochastically. Desmet, Nagy and Rossi-Hansberg (2018), P. H. Egger, Loumeau and Loumeau (2023), or Cai, Caliendo, Parro and Xiang (2022) present models where an exporter's supply potential is a function of endogenous local labor due to mobility (migration) as well as trade through an endogenous productivity channel. That productivity depends on the availability of labor is associated with the presence of Jonesian agglomeration effects. And in P. H. Egger et al. (2023) or Cai et al. (2022) there are migration- as well as trade-related cross-regional spillovers. Hence, there are two sources of cross-sectional dependence of the exporter or supplier fixed effects in that work: one are cross-regional explicit spillovers which lead to an endogeneity of productivity and local labor, which are exogenous in Eaton and Kortum (2002) or Arkolakis et al. (2012), and one are cross-sectional general-equilibrium interdependencies of the factor costs through the trade-balance condition.

Yet other work assumes that the trade-freeness measure itself may involve some triangularity. In so-called spatial general-equilibrium models (where, apart from output, factors are moving in space), transport is endogenous and depends on existing routes (see Desmet et al., 2018, or Allen & Arkolakis, 2022). Changing routes somewhere may change the transport costs for traffic not only between two given spatial units (or nodes in the transport network) but also all those that share a segment or all of the route with them. And route sharing may lead to congestion and exert yet further spillover effects in the trade-freeness (of trade- as well as mobility-cost) matrix (see Allen & Arkolakis, 2022). Foellmi, Hepenstrick and Torun (2024) address the role of the so-called triangle inequality condition about trade costs. If firms minimize the costs of delivery, the cost minimization extends to goods shipments and routes. Clearly, this condition is relevant whenever trade costs are imputed by fast-marching algorithms in spatial economics as, e.g., in Allen and Arkolakis (2014), (Desmet et al., 2018), or (P. H. Egger et al., 2023). A minimization of shipment costs implies that the triangle inequality (TI) of international trade costs must hold for any three countries to avoid cross-border arbitrage. However, the fundamentals underlying shipment costs may change, e.g., due to sanctions, natural disasters, due to other root causes of a disruption of shipment routes, an improvement of existing or an implementation of new routes, bridges, tunnels, etc., and existing routes may disappear and new routes may emerge as being cost-minimal. Then, infrastructure improvements as in Allen and Arkolakis (2014), P. H. Egger et al. (2023), or Allen and Arkolakis (2022) cause endogenous changes to routes and shipment costs. The important consideration here is that the transport network operates on a lattice, and the cancellation of transport legs (edges in network jargon) or the implementation of new ones results in a restructuring of the network with potential effects of a new leg between two units (nodes) in the transport network on other nodes. We might add that strategic considerations in the setting of tariffs and the membership in trade agreements may be associated with similar triangular arguments in the trade-cost system outside of the lattice considerations regarding transport. For instance, P. H. Egger and Larch (2008) and Baldwin and Jaimovich (2012) suggested that the extension of preferential tariffs between some member countries does not only cause trade deflection (from outside a trade agreement to its inside), but it also creates an incentive to outsiders to participate in existing trade agreements or form ones of their own. This results in two effects: (i) an interdependency in the trade freeness across country pairs, and (ii) third-country effects of trade-agreement membership on trade flows.

A third strand of work considers triangular relationships between the stochastic terms of the gravity equation. For instance, LeSage and Kelley (2008) and (LeSage & Thomas-Agnan, 2015) propose thinking of gravity models as a specific representation of stochastic models for origin-destination flows (of goods, people, etc.). They discuss various sources of spatial interdependence in such models and illustrate how shocks cause origin-, destination-, and pair-specific repercussions in the system.[5]

P. H. Egger and Pfaffermayr (2016) present an error component model with exporter, importer, and random pair components, all of which may feature a form of spatial dependence. They propose a spatial random effects model with a higher-order Cochrane-Orcutt weighted least-squares approach in a log-linear gravity framework to this end. Jin, Lee and Yu (2023) present quasi-maximum likelihood (QML) estimators for log-linear gravity models which feature spatially autocorrelated (SARAR) or spatially autocorrelated with moving average (SARMA) processes.

Sellner, Fischer and Koch (2013) and Krisztin and Fischer (2015) propose a Poisson model with a spatial filtering approach, which addresses triangular residuals in an exponential-family gravity framework as proposed by Santos Silva and Tenreyro (2006) under the assumption of independence of the residuals.

20.2.8 Estimating Parameters on Endogenous Trade-cost Measures

20.2.8.1 Endogenous Policy-related Trade Costs

A key focus with the estimation of gravity models lies in the estimation of the trade-freeness measure and, hence, the estimation of the trade-cost function. That function can be understood as to be composed of *natural* (not man-made or, at least not influentiable in the short run) factors and *policy* factors. With bilateral policy variables targeting trade, the following candidates are most important:

- bilateral log tariff rates (they are defined as log one plus the tariff rate (expressed as a fraction);
- binary trade-agreement-membership indicators;
- World Trade Organization (WTO) membership indicators;
- currency-union-membership indicators.

Several issues should be noted here. First, the log ad-valorem tariff factor is bilaterally indexed. Note that under WTO rules, WTO-member countries must extend so-called most-favored-nation (MFN) status to all other WTO members. Hence, while importers can have their own chosen (average) tariff, that tariff must be the same to all exporters that are members of the WTO. However, the bilateral variation across exporters can result in compliance with WTO rules from the following provisions:

- *trading blocks* (preferential trade agreements) that are notified to the WTO offset tariffs for some or all goods, depending on the agreement type; and in transition

[5] Note that the structural gravity model of trade does embed nonlinear interdependencies in the origin and destination components due to structural model constraints as well (see J. E. Anderson & van Wincoop, 2003, for an explicit representation of such interdependencies through so-called multilateral resistance terms).

periods after entry of such an agreement, tariffs may temporarily be set between the MFN and the zero rate;

- Generalized System of Preferences (GSP) tariffs as a means to preferentially support developing countries; GSP preferences tend to be unilarerally extended by developed countries towards developing economies, and the unilaterally can eliminate tariffs on specific products by this token;
- under Article 21 (National Security), an MFN status could be revoked in order to provide safeguards to domestic suppliers or customers (e.g., the Trump II tariffs had been invoked under this umbrella; antidumping tariffs are another example).

In general, tariffs are of crucial interest, not only because they eventually (when being ad-valorem) permit identifying a key parameter, the *trade elasticity*, but also because they are man-made and can be changed. At the same time, tariffs are beast that is hard to tame for several reasons.

First, in spite of a natural interest in them, they are surprisingly hard to come by. Institutions such as the World Trade Organization (WTO), the World Bank, or the United Nations Conference on Trade and Development (UNCTAD) all report tariffs, most notable are the so-called WITS and TRAINS databases. However, in practice tariffs are imposed in a country-specific way on products at very detailed level of aggregation, referred to as the tariff-line level. This level of aggregation is finer in many cases than any trade data are reported at. Therefore, all tariff data accessible to researchers through WITS or TRAINS or other databases covering several countries are typically already aggregated at the finest reported level. And this aggregation can be simple (without trade-volume weighting) or weighted with imports. Weighting introduces variation in tariff data even when the statutory line-level tariffs are constant. And the further one aggregates up (e.g., to the country-pair level), this problem becomes larger. Weighting can lead to average tariffs oscillating up and down in spite of an overall downward trade at the line level.

Second, reported tariff data contain large amounts of missing values. And missing tariff data may lead to large measurement error of applied tariffs at the product level. For instance, upon the enforcement of trade agreements, it is customary to define a phase-in period during which MFN tariffs must be eliminated. Weighting, misreporting and under-reporting of tariffs at the line level and at the disaggregatd product level might suggest oscillating patterns for applied tariffs nonetheless. Teti (2020) documents the gravity of this problem and provides a correction.

Third, the effect of WTO membership or of preferential-trade-agreement (PTA) memberships depends on the gap in applied (at least in expected applied) tariffs before and after the membership. This makes the predicted effects of such memberships fundamentally heterogeneous, even without considering the heterogeneity in the design (the provisions covered) in PTAs. This issue is typically ignored. A proper quantification of the (tariff and nontariff) effects of WTO and PTA membership should be anchored in tariff measures as well as the design and types of provisions implemented in agreements. This is rarely the case. Ever since Aitken (1973), the focus is mainly on the average impact of (allegedly homogeneous) trade agreements. Trade agreement membership is either associated with a homogeneous outside tariff world or an absence of tariffs as in Aitken (1973), or it is associated with tariff reductions only (ignoring any nontariff provisions, changes in regulation, etc.; see Caliendo & Parro, 2015).

Effects of bilateral tariffs on outcome

Because tariffs are set by governments, it is natural to consider them as endogenous in the deterministic structural model. Then, it is natural to consider them as stochastic (endogenous) in estimating equations of the gravity model. Some earlier work had considered various instrumental variables to this end (see Bohara & Kaempfer, 1991, Smith & Urpelainen, 2014, or Xu, 2025).

Caliendo and Parro (2015) considered a ratio estimator, in their case, for cross-sectional data within sectors (or products). They specified a numerator and a denominator which consisted of three multiplicative components each. The numerator is a multiplicative function of the bilateral exports of three countries: i to j, h to i, and j to h. The denominator is a function of the reverse exports between the same countries. If all trade costs but tariffs are symmetric, the six-fold ratio of bilateral exports is a function of the sixfold ratio of corresponding bilateral tariffs and a sixfold ratio of residuals only. Caliendo and Parro (2015) ignore the repetitive component structure of the error term and assume it to be independently distributed. They log-transform the export term as well as the tariff term and estimate the parameter on the tariff term – which is nothing else than the trade elasticity – by OLS.

With this strategy (of using ratios or multiple log differences) a host of fixed effects are conditioned out. This serves to address endogeneity concerns regarding single-indexed determinants of the gravity equation[6] but also all symmetric bilateral trade-cost or trade-freeness factors (such as indicator variables for trade-agreement and other memberships). Other sources of endogeneity of tariffs are ruled out. What is of concern with the chosen ratio estimator is the lack of treatment of repeated double-indexed (country-pair) residuals in the ratio error term, which leads to inefficiency. Moreover, the presence of zeros in bilateral trade flows can lead to a loss of large amounts of data (and selectivity) in the regression. While we outlined the model for aggregate trade flows, Caliendo and Parro (2015) use it for sector-level trade flows, where zeros are even more prevalent than in aggregate country-pair trade data. Finally, for quantifying the impact of trade-agreement membership in equilibrium – Caliendo and Parro (2015) focus on the case of the North American Free Trade Agreement (NAFTA) – knowing tariffs and the trade elasticity is not enough. After all, most deeper trade agreements involve changes in nontariff barriers (e.g., through the necessary adoption of standards), and those can by design not be estimated with the approach above. Hence, the benefits of using the ratio estimator rather than fixed-effects estimation are unclear.

[6] Those are objects such as exporter potential or importer potential.

The work of Bohara and Kaempfer (1991), Smith and Urpelainen (2014), Caliendo and Parro (2015), or Xu (2025) presents examples of a selection on unobservables (addressed through instrumental variables or fixed-effects estimation). In contrast, P. H. Egger & Erhardt, 2024 present a selection-on-observables framework to address endogenous policy trade costs (through tariff and nontariff barriers). The argument is that governments and policy markers, who pursue consumer-utility-maximizing strategies, rely and depend on the same fundamental parameters that are involved in the determination of trade flows. Then, exogenous endowments, technology, natural (non-policy trade frictions), and fundamental trade elasticities (which characterize consumer preferences) are all (apart from some policy setting costs) that is needed to specify tariff and nontariff barriers optimally. They propose a generalized propensity score (GPS) framework to address this problem.

Effects of binary agreement membership on outcome
Several remarks are warranted regarding preferential-trade-agreement (PTA) or currency-union (CU) membership indicators. First, such indicators are usually binary. Initially, empirical work considered all trade agreements to be the same and all currency unions to be the same as well. The catalogue of potentially trade-relevant – maybe not intentionally so – agreements that are formulated in a binary way and had been found to matter for trade as well include bilateral investment agreements, environmental agreements or political cooperation agreements.

For instance, Aitken (1973), Baier and Bergstrand (2004), Baier and Bergstrand (2007) present estimates of the effects of symmetric PTAs on bilateral trade flows. Tobin and Busch (2010) and Bergstrand and Egger (2013) focus on the impact of bilateral investment treaties on direct investment. Yet other work including P. H. Egger, Larch, Pfaffermayr and Winner (2006), Blonigen, Oldenski and Sly (2014) focuses on bilateral tax agreements and their impact on direct investment. Glick and Rose (2002) or P. H. Egger (2008) focus on common currency unions and their effects on trade flows. Larch and Wanner (2022) present work on bilateral environmental agreements. A. Rose (2005) presents effects of political unions such as the one associated with bilateral OECD membership on trade flows.

All of the mentioned indicators shift the trade-freeness in logs with bilateral exports or imports as the dependent variable. With bilateral direct investment or bilateral migration as the dependent variable, the interpretation of of the bilateral term would be investment freeness or mobility freeness, respectively, but the general econometric arguments about the function and econometric issues would be the same or at least sufficiently similar.

The specific issues about all agreement-membership indicators are the following

- **Static effects and random assignment:** Historically, most of the work on the effects of agreement membership (foremost the one of preferential trade agreements on bilateral trade) was static (in cross section or pooled cross-section-time data). Moreover, historically, it was assumed that the assignment to agreements was random (see, e.g. Aitken (1973) for an early example of estimates of PTA effects on bilateral trade), at least conditional on country-pair fixed effects (see, e.g., Baier & Bergstrand, 2007, and P. H. Egger, Larch & Yotov, 2022, for PTAs, Glick & Rose, 2002, for CUs; or A. K. Rose, 2007, for WTO membership on bilateral trade flows).

- **Static effects under self-selection into agreement membership on observables:** Some more recent work considered self-selection of countries with selection on observables. Two dominant approaches can be distinguished here:

  – With **propensity-score matching** the agreement-participation propensity is first estimated as a function of all observables which determine the membership participation and/or bilateral outcome. Subsequently, the treatment effect of agreement membership on trade, investment, migration, or other (origin-destination) pairwise outcome is estimated by weighted regression of among sufficiently narrowly defined pairs based on the score. For instance, H. Egger, Egger and Greenaway (2008) or Baier and Bergstrand (2009)present such estimates in the context of trade-agreement membership and trade flows as outcomes. One prerequisite for this approach to produce consistent effects is that the observable covariates determining the score are balanced. Otherwise, the propensity score (of agreement membership) could not be treated as a compact metric of all the covariates behind it. In the absence of balancing, score similarity between two pairs could emerge in spite of individual covariate dissimilarity, which would invalidate the approach. What is and needs to be done is testing, whether score similarity indeed is associated with covariate similarity. The latter is called the balancing property.

  – With **enforced covariate balancing**, the balancing of covariates between the agreement-membership treated and the compared untreated is ensured. This approach still rests on the same other assumptions as propensity score matching (as an approach of selection on observables). However, it cannot fail because of an eventual lack of covariate unbalancedness. P. H. Egger and Tarlea (2021) apply entropy balancing as one version of such an approach to consider the effects of trade agreement membership on trade flows.

- **Static effects under self-selection into agreement membership on unobservables:** The classical approach here are estimates based on instrumental variables. Typically a Heckman-type control-function approach is considered in this regard. P. H. Egger et al. (2011) present a cross-sectional exponential-family (Poisson pseudo.maximum likelihood) model for bilateral exports, where country pairs can self-select into trade agreement membership. P. H. Egger and Pfaffermayr (2004b) propose a log-linear (country-pair-time) panel-data model of bilateral stocks of foreign direct investment, where countries can select into bilateral investment agreements.
- **Static models with heterogeneous treatment effects:** It should be noted that trade and other agreements differ starkly in their content (see Mattoo, 2020, for a description of the dimensions of heterogeneity of trade agreements). This means that earlier work assuming symmetric homogeneous agreement membership is at

risk of measuring an artifact parameter. In this regard, note that, because MFN tariffs differ substantially between the WTO members, the so-called preference margin – the difference between MFN log ad-valorem tariff rate and the preferential tariff of zero – varies substantially too. Moreover, some trade agreements are customs unions (with a common external tariffs) but most are free-trade areas (where all members have their own external tariff). And trade agreements differ in terms of the products covered (many exclude agricultural goods), non-tariff, investment, labor, or environmental provisions spelled out in them. However, relatively few studies consider such heterogeneous design and effects in estimation and quantitative analysis. P. H. Egger and Nigai (2015) estimate and quantify effects of the membership in deep, versus medium, and shallow trade agreements using cross-sectional data. They find that the difference in the treatment effects (those are direct effects prior to general-equilibrium repercussions) between different agreement types is startling. P. H. Egger et al. (2022) distinguish between deep and shallow agreements with longitudinal panel data and also find differential effects from average and shallow agreements. Guillin, Rabaud and Zaki (2023) consider deep versus shallow trade-agreement-membership effects on services trade flows. All of the mentioned work considers the depth of trade-agreement membership to be randomly assigned, if not in general then at least conditional on country-pair fixed effects.

- **Static models with multiple agreements and selection on unobservables:** P. H. Egger and Wamser (2013a, 2013b) present a log-linear (country-pair-time) panel-data model, where countries can simultaneously select into goods-trade, services-trade, bilateral investment, and currency-union membership. Bilateral goods trade, bilateral services trade are simultaneously affected by all of those agreements. A multivariate control-function approach is chosen for the analysis to this end.

  It should be noted that the work on multiple agreement types and the one on different agreement depths share some commonalities. In some sense, treatments of agreement membership of different intensity – when being cast in a binary setting with multiple binary treatment indicators – is similar to the one of a membership in different agreement configurations (e.g., trade agreements only, investment agreements only, trade as well as investment agreements). In an interacted design of the latter type, agreement membership by interacted type is exclusive (can only happen in one category) as is the depth of agreement membership.
- **Dynamic models of treatment adoption and effects:** Very recent work on the effects of agreement membership on trade outcomes considers dynamics in the adoption of agreement status (by way of duration analysis or by way of staggered treatments). For instance Bergstrand, Egger and Larch (2016) motivate a duration analysis of the participation in trade agreement membership. They choose this type of model based on the observation that, for most country pairs, entering a preferential trade agreement (PTA) is an absorbing state. Also Arroyo and Castillo-Ponce (2019) consider a duration analysis for this purpose. Conversely P. H. Egger and Pfaffermayr (2013) and Nagengast and Yotov (2025) consider an analysis with staggered treatment effects, motivated by the fact that most country

pairs allow for a transition period during which the provisions of agreements have to be implemented. P. H. Egger and Pfaffermayr (2013) focus on the formation of the European Union (EU). They disentangle the foundation phase and different enlargement phases as well as the countries entering the EU in those specific phases. They then track these different enlargement groups (i.e., countries associated with different phases of EU integration) with enlargement phases and estimate treatment effects in log-linear fixed county-pair-effects models associated with the EU foundation and enlargements by country type. Nagengast and Yotov (2025) focus on a broader set of countries and estimate cohort as well as duration (staggered) effects of PTA membership in high-way fixed-effects Poisson pseudo-maximum-likelihood models with aggregate bilateral exports as the dependent variable. P. H. Egger and Huang (2025) combine a selection-on-unobservables approach with a staggered treatment effects design in the context of trade-agreement membership effects on sector-level trade flows. They find that, conditional on their chosen set of instruments determining the self-selection into PTAs, the treatment effect of trade-agreement membership differs significantly from the one that assumes random assignment conditional on the fixed effects and the staggered design.

However, most if not all of the mentioned work treats agreement membership as symmetric or homogeneous, and in practice this is not always the case. In that sense, much of the applied work today follows in spirit the practice applied already in Tinbergen (1962) and Aitken (1973).

20.2.8.2 Other Sources of Endogeneity in the Trade-cost Function: Omitted Variables and Misspecified Functional Form

Only a smaller body of work using gravity models addresses concerns of endogenous country-specific variables. In general, most of the work considers fixed country (or country-time, or region or region-time) effects to avoid endogeneity concerns. The strand of work which addresses endogeneity concerns beyond this mostly focuses on the cases of endogenous time-variant trade costs (see Baier & Bergstrand, 2004, Bergstrand & Egger, 2013, P. H. Egger & Wamser, 2013b).

However, while time-invariant determinants of trade costs – such as bilateral distance, common official language, etc. – may not be affected directly by economic behavior in the short run, such variables may still be stochastic (endogenous) due to measurement error, omitted correlated variables, etc. P. H. Egger and Pfaffermayr (2004a) suggest that bilateral distance may be endogenous for those reasons. Then, as long as the parameter on log distance or measures thereof is of interest (see, e.g., Eaton & Kortum, 2002, J. E. Anderson & van Wincoop, 2003, 2004; Disdier & Head, 2008), resorting to country-pair or region-pair fixed effects is not an option. Yet, relying on pooled or random-effects estimation is not an option either due to endogenous time-invariant effects. P. H. Egger and Pfaffermayr (2004a) propose an instrumental-variables approach following Hausman and Taylor (1981). P. H. Egger

(2005) uses the same idea for identifying the parameters on endogenous country-level variables in country-pair data of bilateral trade.

Two specific sources of endogeneity are addressed in the literature on endogenous transport infrastructure and on a (disregarded) nonaparemtric form of the trade-cost function.

- **Interregional trade and transport infrastructure (historical and other instrumental variables).** The modern quantitative literature of economic geography considers subnational regions rather than countries as the spatial units of interest. In this context, trade flows are typically not observed, but they are implicitly taken into account by measuring transport costs for goods and people (see, e.g., Allen & Arkolakis, 2014; Desmet et al., 2018). Clearly, this brings man-made transport routes from highways and railways to bridges and tunnels into the limelight (see Baum-Snow, 2010; Allen & Arkolakis, 2014; Faber, 2014; Baum-Snow, Henderson, Turner, Zhang & Brandt, 2016; Baum-Snow, Brandt, Henderson, Turner & Zhang, 2017; Allen & Arkolakis, 2022; Jaworski, Kitchens & Nigai, 2023). This literature proposes a number of instruments from using terrain attributes to approximate construction costs (e.g., Faber, 2014) over historical road locations (e.g., Baum-Snow et al., 2016; P. H. Egger et al., 2023) to optimal-transport-theory-based instruments (e.g., P. H. Egger et al., 2023, use instruments following the optimal-transport literature as proposed by Monge, 1781, and Kantorovitch, 1958).
- **Nonparametric trade-cost functions.** A smaller literature in trade is concerned with the potential biases resulting from restrictively parameterized trade-cost functions. For instance, Eaton and Kortum (2002) propose using sextile dummies about country-pair geographical distance instead of a log-linear functional form in distance. However, their estimates do not reject a log-linear form of the trade-cost function in distance for international trade flows. This result is corroborated by the findings in Henderson and Millimet (2008). Rather than using international trade data, Hillberry and Hummels (2008) use subnational interregional sales data for the United States (such data had been used at a more aggregated level also by J. E. Anderson & van Wincoop, 2003). Their findings suggest a non-log-linear impact in particular at the very-low-distance level. However, because they do not estimate customary models, their results are somewhat hard to put in context with the wider literature. P. H. Egger and Lassmann (2015) use a nonparametric regression-discontinuity approach language borders from within Switzerland to address endogenous buyer-seller selection. Blank and Egger (2021) estimate nonparametric fixed-effects models to assess the bite of trade frictions on cross-border services trade flows. And P. H. Egger and Erhardt (2024) develop a multidimensional generalized-propensity-score estimation strategy to assess a nonparametric relationship between endogenous tariff and nontariff trade-policy barriers on product-level goods-trade flows.

20.3 A Smorgasbord of Further Topics

20.3.1 Local Labor Market Effects of Trade

Autor, Dorn and Hanson (2013) initiated a vibrant literature on identifying the effects of trade shocks on local labor markets. Their focus was on the so-called China shock: the emergence of China as one of the largest exporters on the globe and its impact on local labor markets in the United States. Clearly, trade flows (exports and imports) are endogenous. To guard against this, they propose following Bartik (1996) in using so-called shift-share instruments. The idea is to measure the relative regional exposure at the cross-sectional level (e.g., as sector-level employment shares between local labor-market zones, in the case of Autor et al., 2013, commuting zones) as a pre-determined quantity in some initial period and interact it with a country-wide (supra-regional) time-variant metric imports, price development, demand, etc., by sector. The result is a measure that exhibits some triple-indexed variation across local labor markets, sectors, and time. This measure can serve as an instrumental variable for various such triple-indexed but endogenous drivers of local labor-market changes. Unlike directly measured local sector-level import demand, this metric can capture the exogenous variation in order to identify causal effects of import shocks – such as the China shock – and other events on local labor-market outcomes including employment, wages, etc. The key assumptions for identification and inference are three:

- the instrument varies sufficiently across labor markets within a sector so that the identification of treatment effects is possible from between local labor markets;
- the cross-sectional shares (of, e.g., employment across sectors) are indeed predetermined and not a function of expectations, unobserved regional trends, etc.
- the instrument is conditionally independent between the local labor markets (i.e., commuting zones indeed measure segregated labor markets where shock effects do not dissipate across borders);
- and the shocks are independently distributed across, at least, sectors but also trading partners with whom local labor markets enjoy trade relationships prior to the shock.

Considering the enormous impact of Autor et al. (2013); Autor, Dorn and Hanson (2016), it does not come as a surprise that a vibrant literature unfolded concerning the assumptions underlying identification and the effects as well as inference.

Goldsmith-Pinkham, Sorkin and Swift (2020) provide a framework for assessing the identifying assumptions behind Bartik-type instruments. In a canonical shift-share design, a local labor market's exposure is constructed by interacting its predetermined industry shares with national industry shocks. Their key insight is that such an instrument can be interpreted as a weighted combination of many instruments based on the initial industry shares. Identification therefore requires that the relevant local industry shares are as good as randomly assigned, conditional on controls: regions that were initially specialized in high-shock industries should not have had different potential outcome paths for reasons unrelated to the mechanism studied. This perspective suggests several diagnostics. First, researchers should examine which industry shares receive the largest identifying weights in the Bartik instrument. These weights indicate which share components contribute most to the resulting IV estimate. Second, researchers should check whether these high-weight shares are systematically correlated with predetermined regional characteristics that could point to alternative channels. Third, they should test for pre-trends: regions more exposed through their initial industry structure should not already have been on different outcome trajectories before the start of the investigation window. Finally, when the individual share-based instruments are used separately, over-identification tests can be informative about whether the different components of the Bartik instrument point to a common effect.

Fischer, Herkenhoff and Sauré (2023) address some of the concerns related to the source of shocks in the China-shock literature on local labor markets. They particularly distinguish shocks that are foreign (associated with changes in China) versus bilateral (associated with trade policy, transport, etc.). Specifically, they highlight issues of triangular feedback due to general-equilibrium effects in the multilateral price system which may invalidate Bartik-type instruments to identify the consequences of large trade shocks. They propose some solutions to this end and also address issues with inference related to the correlation of shocks across trading partners (in the particular case, China and other countries).

Adao, Kolesár and Morales (2019) demonstrate that standard errors and test statistics in shift-share designs need to be adjusted to accommodate underlying clustering. If not doing so, standard errors and test statistics may be downward biased.

Borusyak, Dix-Carneiro and Kovak (2026) illustrate that, in a location-choice model with local shocks, the population share in a place is not only a function of this place's attributes but, by optimization of the individuals, of the expected utility across all locations. This suggests that, with mobility between spatial units as well as sectors, the population shares across regions and the labor shares across regions and sectors depend on the expected utility (which depends on the expected wages) everywhere. This makes labor shares in a place dependent on expected future shocks not only in the very place people find themselves in but everywhere, and it has important implications for the interpretation of parameters on local shocks. Hence, the full weighted shock vector across "jobs" (regions and sectors) matters for the allocation of the population and labor (residency and employment). Only controlling for local shocks eventually entails a misspecification of the estimating equation.

Yi, Müller and Stegmaier (2024) emphasize that specific skills exhibit a large variation in terms of theor cross-sectoral transferability. They highlight that important interactions exist between the local industry structure – where industries differ regarding the intensity in which they use different skills – and the transferability of skills. Based on this notion, they develop an index of labor mobility between industries which depends on skill transferability. They find that adverse trade shocks affect workers particularly badly in sectors with a low degree of out-transferability of skills.

20.3.2 Worker Flows Across Jobs

We mentioned above that worker-flow models exhibit a gravity-model structure which is closely aligned with the model discussed in the first part of the chapter. However, let us highlight a few specific aspects here.

With worker flows, what would be the exporter and importer indices in a trade-gravity equation assume the meaning of source and destination jobs in two consecutive time periods. A job is typically itself a multi-indexed attribute and can subsume indices for regions, sectors, skills, and occupations. As with trade-gravity equations there are origin-ob-time and destination-job-time fixed effects. And what is the trade-freeness parameter in trade-gravity is a mobility-freeness parameter – here, for job pairs – in job-flow gravity models. Artuç and McLaren (2015) postulate a structural mobility equation for worker flows from one job to another that has the customary multiplicative form of origin-, destination, and pair components (apart from a residual term). As said, what is specific here is that job flows occur between consecutive time periods, whereas trade is usually modelled within a time period.

Artuç and McLaren (2015) derive this exponential-family estimating equation from a dynamic structural model of job choice with forward-looking workers. What is key here is that the equation is derived from a location-choice model, where workers are heterogeneous in terms of their preferences about jobs, and this heterogeneity is governed by a Gumbel distribution with some dispersion parameter so that the mean of worker-time i.i.d. preference shocks is zero and the variance is proportional to the squared Gumbel dispersion parameter. Because of this, all model parameters (including the origin and destination fixed effects) are scalled by the inverse of the Gumbel dispersion parameter. This is important, because, for any counterfactual analysis of the structural model, an estimate of the shape parameter is required. It should be noted that the inverse of the Gumbel-distribution parameter can be viewed as the counterpart to the so-called trade elasticity in trade-gravity models. Hence, the Gumbel shape is as elemental as the trade elasticity for any equilibrium-consistent counterfactual analysis (see Arkolakis et al., 2012). However, while the so-called trade elasticity can be readily estimated as a parameter on log one plus ad-valorem tariff rates, no log ad-valorem mobility-cost measure exists for pairs of jobs.

Artuç and McLaren (2015) use a discount factor (for which they assume a customary value), and they introduce an auxiliary origin-specific variable which is a known function of the fixed effects in the model. Using data on the distribution of workers across jobs (which are row or column sums of the worker-flow matrix) and estimates of the fixed effects for at least one pair of consecutive years, one can readily construct an estimate of the aforementioned auxiliary parameter which is specific to origin jobs and time periods.

They then devise a log-linear (heteroskedastic) estimating equation of this auxiliary parameter as a function of expected wages as well as sector-time-indicator and time-trend variables,[7] and a heteroskedastic residual.

This equation permits identifying a parameter β/ν on expected wages, where they (have to) assume β based on other work in the macro literature so as to estimate $1/\nu$, which is nothing else than the aforementioned inverse of the Gumbel parameter. Artuç and McLaren (2015) take the "*expected wage [...] from the data*", which indicates that this strategy is only viable with perfectly-foresighted workers (see Dix-Carneiro, 2014). With imperfect foresight, the expected wages have to be simulated from the model, which is only feasible at known β as well as ν. In any case, a counterfactual analysis with perfectly foresighted individuals is presented in Artuç, Chaudhuri and McLaren (2010), Artuç and McLaren (2015), Caliendo, Dvorkin and Parro (2019), and elsewhere.

20.3.3 Individual Worker Flows Across Firms

When considering employment that is aggregated to some region, sector, occupation or other level from the individual worker, what can be identified at best are determinants of net flows of workers. Even with worker flows that are aggregated to region-sector-skill-occupation pairs of cells this is the case to some extent, as many workers that are classified as "stayers" may have changed their employer affiliation within the cell. Moreover, when abstracting from individuals, important unobserved individual-level factors cannot be conditioned on when analyzing job switching. As a result, parameters of interest on trade-shock variables could suffer from an omitted-variables bias.

This can only be overcome when keeping the analysis of job-choice (including employer-choice) at the level of the individual worker. However, for individuals even more so than for aggregates, state dependence is an important feature of the data. Individuals, who stay for a long time with one employer have a particularly high likelihood of keeping to do so in the future. Individuals, who change their employer have a higher likelihood of changing again, etc.

Heckman (1978, 1981) puts forward two possible explanations for this phenomenon: "true state dependence" (the lagged state enters the model as a structural determinant), and "spurious state dependence" (due to the presence of unobserved individual effects). The two can obviously only be distinguished when

[7] Depending on the data structure behind what is called a "job", the regressors could include dummies for region-time, skill-time, occupation-time, sector-time fixed effects, and even some interactions of such effects, as long as they are not perfectly collinear with the expected wages.

not aggregating individual data.

P. H. Egger, Pfaffermayr and Weber (2007) present a multinomial fixed-effects model of individual job transitions between different sectors of the economy (including unemployment and out of labor force) in response to trade shocks. Specifically, they present a dynamic multinomial fixed effects model, which permits disentangling true and spurious state dependence following Honoré and Kyriazidou (2000). A drawback of this model and other fixed-effects-logit-type models is that the fixed effects are conditioned out and not estimated as parameters. Accordingly, to evaluate response probabilities a distribution of the fixed effects has to be assumed and drawn from to evaluate effects. See also Hijzen, Pisu, Upward and Wright (2011) for a similar approach in a different data context.

20.3.4 Exchange-rate Pass-through

While the previous sections focus on how trade shocks affect quantities, employment, and worker movements, we now turn to the related question of how cross-border shocks, such as exchange rate changes, impact prices. In this respect, exchange-rate pass-through (ERPT) measures how much prices in the buyer's currency change when the nominal exchange rate moves. It is an important concept in international economics and links exchange-rate changes to inflation, relative prices, and welfare (see Burstein & Gopinath, 2014; Itskhoki, 2021 for recent literature reviews). In a benchmark with flexible prices set in the exporter's currency and constant markups, a depreciation of the buyer's currency raises the buyer-currency price of imports one-for-one. Yet, this benchmark is rarely observed. Pass-through is typically incomplete, differs across stages of the pricing chain, depends on the currency in which transactions are invoiced, and varies across countries, industries, firms, and states of the macroeconomy.

This observation points to the importance of distinguishing price concepts. At the border, the relevant object is the import price of goods, expressed in the destination currency. At the producer level, researchers often use a producer-price index in the origin country as a proxy for exporters' production costs. At the retail level, the focus is on the final consumer price in the destination market, provided that such origin-specific consumer prices are observed. Pass-through is typically higher into border prices than into consumer prices, where local distribution costs and retail markups also matter.

A standard aggregate regression relates price changes to current and lagged exchange rate movements. The specification typically controls for cost shocks, destination market conditions, origin-destination fixed effects, and common macroeconomic shocks. In import-price regressions, cost-side controls are often proxied by foreign producer prices or wages. In consumer-price regressions, they may instead include foreign cost measures, domestic cost controls, or the costs of delivering imported goods to final consumers. In multi-period settings, The coefficient for the exchange-rate change measures contemporaneous pass-through, while the sum of coefficients over several lags determines cumulative pass-through over the corresponding horizon. If the origin dimension is not observed, researchers typically use destination-level consumer prices and consider effective instead of bilateral exchange rates — an approach that has become less relevant due to better data availability over the recent past.

Specifications of this type are closely related to the empirical tradition surveyed by P. K. Goldberg and Knetter (1997) and to the cross-country evidence in Campa and Goldberg (2005). Three findings from this aggregate literature are particularly relevant. First, exchange-rate changes are passed through more strongly to border prices than to consumer prices, consistent with the role of local distribution costs and retail markups (Burstein & Gopinath, 2014). Second, aggregate regressions reveal substantial cross-country heterogeneity. The United States, for example, has often been found to display comparatively low import-price pass-through, whereas many smaller and emerging economies exhibit higher pass-through. Third, the macroeconomic environment matters. Earlier work linked lower pass-through to low and stable inflation, because firms have weaker incentives to adjust prices when inflation is expected to remain contained (Taylor, 2000; Choudhri & Hakura, 2006). More recent evidence shows that pass-through onto consumer-price inflation has remained low and stable in advanced economies. At the same time, it declined in emerging economies after the global financial crisis, with this decline related to lower inflation (Jašová, Moessner & Takáts, 2019).

For empirical researchers, this aggregate approach highlights several important choices. First, the concept of price matters, because border prices, producer-price indices, unit values, and consumer prices measure different things. Second, the sign convention for the exchange rate must be clear, because the exchange rate can be defined as domestic currency per unit of foreign currency and vice versa. Third, the timing is essential: contemporaneous, one-year cumulative, and long-run responses can differ substantially. Fourth, persistence in long time series requires attention. Many pass-through regressions are estimated in differences because exchange rates and price levels often move slowly over time. This approach is well suited for short- and medium-run pass-through. If the researcher is interested in long-run pass-through instead, one first needs to ask whether import prices, exchange rates, and foreign costs move together in the long run. If they do, an error-correction model can combine short-run exchange-rate effects with gradual adjustment back to the long-run price relationship. If they do not, regressions in levels may be spurious. Finally, exchange-rate changes are not always exogenous shocks. They can be correlated with monetary policy, foreign costs, commodity prices, global demand, and risk premia. Reduced-form ERPT estimates capture conditional correlations. For a causal interpretation, researchers must isolate the specific source of exchange-rate variation. Common identification strategies include structural VARs, external instruments, high-frequency surprises, or narrative events (Forbes, Hjortsoe & Nenova, 2018).

The more recent literature has shifted from aggregate indices to micro data and from reduced-form pass-through elasticities to structural interpretations of firm pricing. This shift was made possible by access to customs data, firm- and plant-level price surveys, scanner data, and the micro data underlying official import and export price indices. With this more granular data, researchers can distinguish whether prices adjust from how much they adjust when they do. This approach isolates the moment a firm or product resets its price and maps the scale of that adjustment against accumulated exchange-rate and cost changes. Broadly speaking, it thus evaluates pass-through conditional on a price update. It thereby answers the following key question: given that a price is changing, how much of the accumulated currency shock does the new price absorb?

Unlike aggregate models, this micro-level framework distinguishes between the intensive and extensive margins. Aggregate specifications conflate the decision to change a price with the actual magnitude of that change. Using U.S. trade micro-data, Gopinath and Rigobon (2008) and Gopinath, Itskhoki and Rigobon (2010) demonstrate that border prices remain sticky in the invoicing currency. Crucially, they find that pass-through remains incomplete even after accounting for actual price changes. Hence, incomplete pass-through is not only a consequence of nominal prices being fixed for some time. It also reflects desired markup adjustment, cost structure, and currency choice.

A simple structural interpretation starts from the observation that the desired buyer-currency price consists of two components: marginal cost in the destination currency and a destination-specific markup. Full pass-through requires marginal cost to track exchange-rate movements and markups to remain fixed. Both conditions may fail. Firms often use imported inputs from vairous countries, pay for inputs in different currencies, and face different competitors across destination markets. Moreover, depending on their market power, they may offset exchange-rate shocks by changing markups rather than prices. This is the pricing-to-market mechanism emphasized by Dornbusch (1987), Krugman (1987), and Knetter (1993), but the newer literature estimates these mechanisms using detailed firm- and product-level information.

Firm heterogeneity is central to this interpretation. High-productivity or high-market-share exporters often adjust markups more strongly and pass through less of an exchange-rate shock into destination prices (Berman, Martin & Mayer, 2012). Imported inputs provide a natural hedge. While a depreciation boosts export revenues in the domestic currency, it simultaneously inflates the local cost of foreign inputs. These offsetting forces reduce the effect on marginal costs (Amiti, Itskhoki & Konings, 2014). Combining firm-level import and export data with price information, Amiti, Itskhoki and Konings (2019) show that large firms adjust their prices not only in response to their own marginal costs, but also in response to competitors' prices. This strategic complementarity in pricing lowers cost pass-through and can explain why exchange-rate shocks are partly absorbed in markups.

Currency choice is another major component of the modern ERPT literature. The traditional distinction is between producer-currency pricing and local-currency pricing. Under producer-currency pricing, the export price is sticky in the exporter's currency. Consequently, the buyer-currency price moves mechanically with the exchange rate until the exporter changes its price. Under local-currency pricing, the price is sticky in the buyer's currency, excluding an immediate pass-through effect. From this perspective, firms can use the invoicing currency to hedge against currency volatility. The choice effectively dictates who bears the short-run exchange rate risk: the buyer or the seller. When prices are sticky, companies strategically minimize the gap between their fixed price and the flexible-price benchmark. Local-currency pricing is therefore more attractive when desired pass-through is low, while producer-currency pricing is more attractive when desired pass-through is high (Engel, 2006; Gopinath et al., 2010).

The literature has also shifted attention from bilateral producer or buyer currencies to dominant-currency pricing. A large share of world trade is invoiced in a small number of vehicle currencies, especially the U.S. dollar (Gopinath et al., 2020; Boz et al., 2022). As a consequence, import prices may respond more to the exchange rate vis-à-vis the invoicing currency than to the bilateral exchange rate between the producer and the buyer (Gopinath et al., 2020). This has important implications for empirical estimation. Consider a country importing goods from non-U.S. partners using dollar invoicing. A depreciation against the dollar will raise import prices, even if the bilateral exchange rate with the actual producing nation remains stable. Pass-through regressions based only on bilateral exchange rates may thus miss an important component of price adjustment. The choice of invoicing currency is endogenous and persistent rather than fixed. It depends on firms' marginal-cost exposure, strategic complementarities in price setting, transaction costs, and the currency choices of other firms in the same market (L. S. Goldberg & Tille, 2008; Amiti, Itskhoki & Konings, 2022).

Empirical researchers must navigate several critical caveats. First, aggregation is far from harmless. Price indices naturally merge products with vastly different price durations, expenditure values, invoicing patterns, and survival probabilities. Unit values may confound price changes with changes in product quality. Moreover, pass-through dynamics can be state-dependent and asymmetric. Large exchange-rate movements may be more likely to trigger price adjustment and be passed through more strongly, while depreciations and appreciations may produce different responses. A recent meta-analysis of consumer-price pass-through documents substantial heterogeneity across studies and finds larger pass-through for depreciations than for appreciations (Iorngurum, 2025).

Open questions concern the aggregation of firm-level pass-through into aggregate inflation and expenditure switching, the role of global value chains, the stability of invoicing-currency choices under changing monetary and geopolitical conditions, and the separation of markup adjustment from marginal-cost adjustment. Progress on these questions requires data linking prices, quantities, input sourcing, destination markets, invoicing currencies, and competitors, and will push ERPT research even further toward structural micro-founded estimation.

Tariff pass-through represents a closely related area of research. As pointed out by Feenstra (1989), tariffs are similar to exchange-rate movements in that they act as bilateral cost shocks affecting destination-market import prices. Recent evidence from the U.S. trade war highlights this connection. Studies find high or nearly complete tariff pass-through to border prices (Amiti, Redding & Weinstein, 2019; Fajgelbaum, Goldberg, Kennedy & Khandelwal, 2020). Yet these effects are more muted and delayed at the retail level because intermediaries adjust their margins (Cavallo, Gopinath, Neiman & Tang, 2021). The importance of supply-chain transmission is documented by Flaaen, Hortaçsu, Tintelnot, Urdaneta and Xu (2025). Analyzing U.S. tariffs on European wine, they show incomplete pass-through at the border, while downstream markups amplified the ultimate burden for consumers. Expanding on these firm-level dynamics, H. Egger, Egger, Erhardt and Navarro (2026) show how firms hedge against trade-cost volatility through foreign-market entry choices and the choice between cost, insurance, and freight (CIF) and free-on-board (FOB) pricing contracts. The broader takeaway mirrors the ERPT literature. Pass-through is not a rigid, automatic response to cost shocks. Instead, it is shaped by a firm's position in the supply chain, contracting terms, distribution costs, market structure, desired markups, and available hedging strategies.

20.3.5 Stock-market Effects of Trade Shocks in Event-study Designs

A specific literature in international economics utilizes stock-market data (mostly with daily variation) to identify the effect of trade- or foreign-investment related events on stock-market outcomes. See Breinlich (2014), Moser and Rose (2014), Breinlich, Leromain, Novy, Sampson and Usman (2018), Davies and Studnicka (2018), P. H. Egger and Zhu (2020) for examples.

Consider the log stock-market return of a given stock on a day. Then, a model of the latter as a function of the average (market) log return and other variables predicting the "normal" value of log stock returns is estimated prior to an event time up until a period before the event time. This stochastic model is then used to predict log stock returns at times in a window from the event time onwards so as to obtain the log abnormal returns around the event, i.e., the difference between the data and the predictions of log stock returns.

The latter abnormal returns are then used in regressions to explore the role of the event – where some change occurs such as a trade or investment agreement being announced or denounced (as with Brexit) – to study the stock-market responses to the event.

What this literature clearly relies on at least the following assumptions: (i) that the process of the determination of stock-market returns itself is not changing around the event (otherwise, abnormal returns are both mismeasured and insufficient for the analysis); (ii) that individual stocks are all small enough to not have an important weight in the market index (otherwise, the parameter on the index in the regression determining residual stock market returns would be biased); and (iii) that no other important factors of influence occurred during the estimation windows (both to estimate stock-market returns as well as the determinants of abnormal returns).

20.3.6 Estimating Discontinuities in International Economics

Borders:
A remarkable finding in the literature is that national borders can entail a sharp discontinuity in business relations and sales flows between equi-distant pairs of spatial units. This finding was established by a vibrant literature on national versus regional border effects on trade (and also migration) flows, mostly in Canada and the United States. Early examples of that work can be found in McCallum (1995), Engel and Rogers (1996), M. A. Anderson and Smith (1999), Parsley and Wei (1999), Helliwell (1997, 2000, 2000); Helliwell and Verdier (2001), Coughlin and Novy (2013), or Gallego and Llano (2014).

J. E. Anderson and van Wincoop (2003) build on and reference earlier work addressing this point with data from the United States and Canada. Specifically, they use data on trade flows between U.S. states and Canadian provinces – within as well as across national borders – and identify a border effect that is smaller than in earlier work but persistent. A key insight they establish is that any trade barrier, subnational or national, induces direct country-pair-specific as well as multilateral effects in partial as well as general-equilibrium models of international trade. The multilateral effects always mitigate the direct ones. Ignoring this leads to upward biased estimates not only of border effects but of all trade-cost factors.[8] In a nutshell, theborder-effects literature of the 1990w and early 2000s was systematically prone to this bias.

Havranek and Irsova (2017) assess the question of border-effect discontinuities in a meta analysis and document that cleaner identification typically reduces the border effect. One way to approach the identification is by way of regression discontinuity

[8] J. E. Anderson and van Wincoop (2004) take this type of analysis to the sector level, without focusing on borders.

designs which operate on a less coarse level than the study of J. E. Anderson and van Wincoop (2003). What one needs for such an analysis are spatially disaggregated – ideally, individual-firm sales flows to customers (business or private) within and across borders. Such a design can control for a function of seller-buyer distance as a running variable that is nonparametric. As said, using such designs and data typically leads to smaller border effects. Bergstrand, Larch and Yotov (2015), Coughlin and Novy (2021), or Spornberger (2022) are examples of subsequent research building on J. E. Anderson and van Wincoop (2003).

Gopinath, Gourinchas, Hsieh and Li (2009) use unusually detailed data from a single grocery chain, which operates stores in the United States as well as Canada. The data come at weekly frequency and exhibit store-level as well as barcode-product-level variation. This enables the authors to zoom in at stores just on one and the other side of the U.S.-Canadian border. They find (i) a relatively high retail-price and whole-sale-cost discontinuity at the border; (ii) the retail-price gap is largely due to the whole-sale-cost gap; and (iii) the disconinuity in prices and costs is tightly co-moving with the exchange rate of the U.S. and Canadian dollars. They do not find any evidence of placebo discontinuities within national borders.

Another literature focuses entirely on intranational border discontinuities. Such discontinuities may emerge due to clearly segmented historical regions within countries such as the western and eastern German states with the former iron curtain separating them (see Nitsch & Wolf, 2013 for evidence of a persistent doscointinuity of domestic shipments across the former East-Western German border in international economics; see Redding & Sturm, 2008 for the costs of being located at historical foreign borders after reunification with mobile households in regional economics; and Ehrlich & Seidel, 2018 for persistent place-based policies and associated regional outcomes at domestic borders in regional economics), due to municipal-level tax setting (see Basten, von Ehrlich & Lassmann, 2017 for sharp discontinuities in housing prices at municipal boundaries due to the sorting of mobile households in regional economics), or due to prevailing well-segregated language zones within countries (see P. H. Egger & Lassmann, 2015 for an application documenting sharp patterns of foreign trade shares at domestic language borders in international economics).

Exporting-threshold Productivity Levels:
In the canonical model of international economics by Melitz (2003), firms are heterogeneous and, in terms of their output function as well as in terms of their domestic sales revenues, differ by a single parameter: total factor productivity (TFP). All factor costs and technology parameters beyond TFP are the same for the producers in a given market. Moreover, the fixed market-access costs are the same between firms in every customer market, but firms cannot segment markets but charge the same price to all customers. This gives rise to selection, whereby not all potential producers actually produce, and not all sellers sell to all markets. The toughest market is the one where the fewest firms sell, and the easiest market – arguably and by customary assumption the domestic one – is where most firms sell.

There is a prediction of strong sorting in the sense that the firms selling in the toughest market sell to all markets. More generally, all firms selling in a given market will also sell in all relatively easier ones. In a nutshell, firms differ only by one exogenous parameter, TFP, and that leads to heterogeneity in a host of endogenous variables, ranging from prices over quantity to market presence (the number and types of markets served).

The smallest firm in a market helps identifying the fixed market access costs. As the model of Melitz (2003) features monopolistic competition and considers the fixed costs being paid in the same factor bundle as variable costs, operating profits are a fixed parameter manifold of operating profits, and the operating profits of the smallest seller in a market equate the fixed costs of serving it. Hence, the marginal profits of serving a market are zero. This set of assumptions leads to the following predictions:

- total firm profits are an upward-sloping function of productivity with kinks at the threshold productivity levels for the different markets from lower to higher TFP levels;
- operating profits are an upward-sloping function of productivity with jumps at the threshold productivity levels for the different markets from lower to higher TFP levels.

Reducing the toughness of markets – by lowering variable trade or fixed market-access costs there leads to an entry of less-productive firms. Doing so may even change the toughness ranking of markets. And it will change the location of TFP-threshold parameters and, eventually, (with variable trade-cost changes) the segment-wise slopes or (with fixed-cost changes) the segment-wise intercepts of the operating-profits function and the location of the kinks of the total profit function.

The bottom line is: the threshold productivity levels are endogenous and a function of market size, variable trade costs, fixed trade costs as well as the fundamental (exogenous) latent productivity distribution of firms. And the threshold TFP levels are key to understand and quantify for intensive margins (such as prices, quantities, sales value, profits) as well as extensive margins (firm numbers, market scope, etc.) of international trade.

What is appealing about the model of Melitz (2003) is that it produces a very strong prediction regarding the identification of the cutoff firm and its associated productivity. Think of the domestic sales of a specific firm. Define compactly the market-specific demand shifters which scale all firms' demand as a constant in the domestic market, which domestic sales are proportional to, aligned with the theory underlying customary gravity equations. And define the market-specific supply shifters which scale all firms' sales. Domestic sales are also proportional to the latter. The following assumptions are commonly adopted:

- domestic sales frictions are zero, so that the domestic sales-freeness parameter can be set at unity;

- domestic sales vary across firms only due to their productivity and are otherwise multiplicatively shifted by the product of common supply and demand shifters.

In empirical work, it is customary to assume that productivity is Pareto distributed (see, e.g., Chaney, 2008, or Arkolakis, 2010). Then, ratios of individual firms' domestic sales or ratios of individual or cumulative quantiles of domestic sales (or the sales in any other specific market) can reveal the Pareto shape parameter based on a Hill (1975) type estimator, where individual or aggregate log sales in a market are regressed on a constant and log rank. With a Pareto distribution, the cutoff productivity is defined and can be estimated as a function of the average productivity and the Pareto shape. Conversely, the average productivity is defined and can be estimated when knowing/measuring the cutoff productivity with estimates of the Pareto shape parameter at hand.

However, the question is whether one associates the sales residual with productivity only. Moreover, clearly, the minimum as an extremum of a stochastic variable is hard to estimate from sampled data (see Simonovska & Waugh, 2014, for a discussion of associated problems). And if the true form of the data is not Pareto, the estimated the average productivity based on the cutoff productivity and the estimated Pareto shape will be biased. Conversely, the estimated cutoff productivity based on the average productivity and the estimated Pareto shape will be biased.

Costa, Sallusti, Vicarelli and Zurlo (2019) and Costa, Sallusti, Vicarelli and Zurlo (2022) rely on the Receiver Operating Characteristic (ROC) to identify the cutoff productivity level which optimally separates the subsample of exporters from that of non-exporters (domestic-only sellers) in firm-level data. Costa et al. (2019) and Costa et al. (2022) consider a stochastic version of total (domestic plus export sales) to estimate the cutoff productivity for exporting. However, with residual sales measuring more than just the scaled log productivity of firms, what is the exporter-cutoff refecting? With stochastics, some firms may just get a lucky (demand-)draw from abroad without being critically productive to export. Conversely, other firms can get an unlucky draw in spite of being productive. The ROC method permits searching for the critical cutoff productivity of exporters when trading off false positives and negatives with true ones. Of course, observing firms in their sales over multiple markets (not only the domestic and the aggregated foreign but several foreign markets) helps identifying the minimum export cutoff productivity (and, associated with it, the fixed domestic sales costs) even more precisely.

P. H. Egger and Wang (2026) do not rely on sales but on profit data of firms. They observe total profits as well as an exporting indicator (and domestic as well as export sales). In contrast to Melitz (2003), they allow firms to differ not only in productivity but also in fixed costs. With heterogeneous rather than identical fixed market access costs, there is not a single (minimum) cutoff productivity but a set. Hence, profit functions are not simply point- but set-kinked between domestic sellers and exporters.

They develop a nonparametric threshold estimator to identify the set of kinks associated with marginal exporters. The motivation for a nonparametric approach is as follows. In standard Melitz-type models in which productivity is the only source of firm heterogeneity, domestic sales are monotonically related to total factor productivity, so a scalar productivity cutoff can be mapped into observables in a relatively direct way. With heterogeneous fixed market-access costs, however, theory provides little guidance on the functional form linking observable fixed-cost shifters, such as cash flow, asset tangibility, or interest rates, to the theoretical fixed costs of exporting. Egger and Wang therefore allow this relationship to be nonparametric. Firms export when their productivity-to-fixed-cost ratio exceeds a critical threshold, which motivates a nonparametric threshold-set estimator in which the export cutoff is allowed to depend flexibly on observables proxying fixed market-access costs.

However, the data on firms' sales may inherit fundamental forms of heterogeneity that are hard to tackle with models that are functions of few parameters only. For instance, firms may differ not only with regard to their total-factor productivity but also with regard to cost shares of individual factors. And the production function may not follow a Cobb-Douglas form. Moreover, markups, trade frictions, market appeal, factor prices, and fixed costs may all be firm-specific. The latter poses challenges for estimation, which eventually defy a simplistic modelling approach as often used in macro-economic structural models, which served as a key inspiration for much of the mentioned empirical work.

Targeting multiple firm-level observables

Recent research moves past simple selection thresholds to model multiple firm outcomes jointly. The motivation is that empirically firm size — whether captured by sales or employment — wages, and export participation move closely together. In labor economics, this is reflected in the well-established employer-size wage premium (Brown & Medoff, 1989; Oi & Idson, 1999; Winter-Ebmer & Zweimüller, 1999). In international trade, a related empirical regularity is the exporter premium: exporters are typically larger and pay higher wages than non-exporters (Bernard & Jensen, 1999; Bernard, Jensen, Redding & Schott, 2007). In heterogeneous-firm models, total factor productivity is the natural common latent component linking sales, employment, wages, and export status. However, wages may also reflect rent sharing, fair-wage considerations, search frictions, screening frictions, and monopsony power (H. Egger & Kreickemeier, 2009, 2012; Helpman, Itskhoki & Redding, 2010; H. Egger, Kreickemeier, Moser & Wrona, 2022). In general, a model in which productivity is the only stochastic firm-level component may therefore be too restrictive to match the joint distribution of firm outcomes.

These insights have pushed researchers to estimate systems of correlated firm-level equations. In these setups, multiple latent shocks simultaneously drive continuous outcomes, such as employment, sales, or wages, alongside discrete decisions like exporting. A prominent example is Helpman, Itskhoki, Muendler and Redding (2017). They employ linked employer–employee data for Brazil to estimate a structural model of firm wages, employment, and export status using maximum likelihood. Allowing productivity, firm-specific screening or wage-setting components, and export-cost shocks to be imperfectly correlated, they can reconcile positive exporter wage and employment premia with the fact that export status is not perfectly predicted by firm size or productivity. Their estimation procedure builds on the broader class of limited-dependent-variable and sample-selection models that allow continuous and discrete outcomes to be modelled jointly (see Maddala, 1983).

Recent work extends this logic into richer environments of selection and sorting. For instance, Becker, Egger, Koch and Muendler (2025) leverage German plant–worker data and information on occupational task content to structurally relate export status, internal task allocation, plant size, and wage dispersion in a Melitz-type environment. Their model incorporates endogenous entry: because not all prospective plants become active producers, the observed distribution reflects selection. To capture this pattern empirically, they derive a maximum-likelihood estimator tailored to a setting with multiple correlated latent plant characteristics and discipline the structural parameters using plant-level outcomes and model-implied moments, such as export participation. They then use the estimated model for counterfactual exercises, studying how changes in fixed exporting costs affect endogenous task allocation, worker efficiency, and wage dispersion. This complements the preceding discussion of selection thresholds by shifting focus from entry cutoffs to jointly modelling multiple firm outcomes. The broader methodological lesson is clear: when theory predicts joint selection and sorting across several firm outcomes, the empirical model should preserve the covariance structure of productivity, entry costs, and labor market frictions, and other latent firm characteristics.

20.4 Conclusions and Outlook

This chapter reviews the main avenues of using empirical methods in international economics from the past to the present.

The most numerous examples of applications have been, in declining order, output-flow models of the gravity-equation form, factor-flow models which largely follow the same form, and pass-through models which abandon the assumption of fixed markups over marginal costs.

While there had been a lot of progress in every one of those fields of application, there is a wide array of developments possible. In particular, future research will certainly explore dynamics in both the structural motivation and empirical analysis of gravity models, the exploration of imperfect foresight and associated uncertainty in the structural modelling and empirical analysis of output-flow, factor-flow, and firm models of trade and their estimating equations, and the use of semiparametric and nonparametric methods to analyze treatment effects, selection, and the effects of endogenous continuous outcomes. It is foreseeable that many of those developments will have to be cast in the context of panel-data models, including ones for higher-order index structures.

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