Dynamic gravity: endogenous country size and asset accumulation

María Pía Olivero and Yoto V. Yotov
Department of Economics, LeBow College of Business, Drexel University

Abstract. Numerous gravity applications have resorted to panel data econometric techniques over the past decade. However, with the theory of gravity being so far only static, these estimations lack solid structural dynamic foundations. As a consequence, a consensus on a unified dynamic gravity estimation approach is yet to be reached. In this paper, (i) we build the theoretical foundations for a dynamic gravity model, (ii) we provide guidance for gravity-type estimations with panel data and we consider applications, and (iii) we calibrate and simulate our model to compare its properties with those of the standard, static gravity setup. JEL classification: F10, F11

Gravité dynamique : le cas où la taille du pays et l'accumulation d'actifs sont endogènes. De nombreuses applications du modèle de gravité ont eu recours à des techniques économétriques de données de panel au cours de la dernière décennie. Cependant, la théorie de la gravité demeurant statique pour le moment, ces estimations manquent de fondements structurels dynamiques solides. En conséquence, on n'a pas fait consensus sur une approche unifiée à l'estimation de modèles de gravité dynamique. Dans ce mémoire, (i) on construit les fondements théoriques d'un modèle de gravité dynamique; (ii) on suggère uen façon de procéder pour l'estimation de modèles de gravité à l'aide de données de panel, et on examine certaines applications; et (iii) on calibre notre modèle et on le soumet à des simulations pour comparer ses propriétés avec celles obtenues au moyen du modèle statique standard.

We are grateful to James Anderson, Jeff Bergstrand, Andrew Cassey, Paul Jensen, Bang Jeon, Vibhas Madan, Costas Syropoulos, Pinar Uysal, and participants in the 2009 EEA meetings for helpful comments and productive feedback. In addition, we thank Werner Antweiler and three anonymous referees whose comments and constructive criticism improved the quality of the paper significantly. We are solely responsible for all errors in the manuscript.
Email: maria.olivero@drexel.edu; yotov@drexel.edu.

Canadian Journal of Economics / Revue canadienne d'Economique, Vol. 45, No. 1
February / février 2012. Printed in Canada / Imprimé au Canada

0008-4085 / 12 / 64–92 /

1. Introduction

Since its introduction to economics by Tinbergen (1962), the gravity equation has established itself as the most successful and celebrated empirical model in international trade. Until the late 1970s, Newton's law of gravity was applied to economic problems only intuitively to relate bilateral trade flows to GDP, distance, and other determinants of trade flows. Thirty years ago, Anderson (1979) set the structural foundations for a *static* economic gravity model and he noted that the use of pooled cross-section and time-series data requires building an intertemporal version of the model where part of the story should be the relationship between the trade balance and asset accumulation. More recently, Anderson and van Wincoop (2003) conclude their work pointing out the assumption of an endowment economy as a limitation of their analysis, and they suggest that trade barriers can affect trade through their impact on countries' production structures. We agree, and we believe that the intrinsically dynamic nature of trade flows, which are typically strongly autocorrelated over time, has at least two implications for the effects of trade barriers: First, trade barriers imposed at time $(t - 1)$ might still have an impact on trade volumes at time t. Second, these barriers also impact capital accumulation in $(t - 1)$, which changes country size and ultimately, trade flows in t. Therefore, it is very important to be able to draw testable implications from a structural *dynamic* gravity model. However, with a few recent developments in this direction,[1] to the best of our knowledge existing work on gravity is still only static.

What is it that a dynamic theory of gravity can explain that is not already captured by the static gravity setting? The following stories provide answers. In 1907 Australia extended temporary preferences to British sewing machines and, in response, the Singer Sewing Machine Company transferred its Australian business from its American to its British branch. Even after these preferences were removed, Britain remained the main source of Singer's exports to Australia (see Saul 1960). Another example is given by the breakdown of the pattern of multilateral settlements in the 1930s, when, as tariffs were raised, countries started

1 In a contemporaneous paper, Campbell (2010) also develops a model of dynamic gravity by introducing habit persistence in consumption and learning-by-doing in production. A few other papers introduce dynamic elements into international trade models. Cuñat and Maffezzoli (2007) use a model similar to ours, with the goal of reproducing the empirically observed increase in the trade share of output as a result of tariff reductions. They show that key to reproducing an increase in trade shares larger than in models with fixed factor endowments (even with a low elasticity of substitution) is the fact that, in their setting, a fall in tariffs leads to factor accumulation and therefore to diverging paths of relative factor endowments and to an increasing degree of specialization. Ruhl (2008) provides a dynamic trade model, where agents are subject to both permanent tariff changes and temporary business cycle shocks. Since in this model permanent tariff cuts induce entry of new exporters, the Armington elasticity increases relative to the elasticity estimate in models with only temporary productivity shocks, which helps to reconcile the large differences in the value of the elasticity used by the trade and the macroeconomic strands of the literature. However, neither Cuñat and Maffezzoli (2007) nor Ruhl (2008) derive a gravity equation from their structural models. Moreover, they do not study the implications of these models for gravity-type empirical estimations.

extending preferences to their overseas territories and to countries associated with them in a monetary area. As a result, many new European factories were set up in the sterling area. After the New Zealand government cut tariffs on automotive components (in 1997), Toyota, Nissan, Mitsubishi, and Honda all moved production from New Zealand to off shore locations (see Spearot 2008). Last, when, as part of the creation of Mercosur, in Uruguay the average tariff rate fell from 43% in 1985 to 14% in 1995, Uruguayan manufacturing firms switched to more capital-intensive technologies (see Casacuberta and Gandelman 2006).[2]

The common feature in all of the stories mentioned above is that trade barriers have an effect on the dynamic investment choices of firms and their output and productivity. Thus, the fact that the output of trading partners is exogenous in the standard gravity model seems counterintuitive in light of these anecdotes. Addressing this limitation of the gravity model by endogenizing the importer's and exporter's country size requires the introduction of investment decisions. Since these decisions are dynamic by nature, they make the model intrinsically dynamic, giving rise to three effects that we discuss in detail below: the *country size*, the *trade persistence*, and the *protection persistence* effects.

The empirical gravity literature could benefit from a dynamic theory of gravity as well. Until the 1990s most of this literature consisted of only cross-sectional estimations. Since then, numerous gravity applications have resorted to panel data econometric techniques in order to address questions that require a dynamic treatment, such as the effects of currency unions on bilateral trade. However, with the theory of gravity being so far only static, these estimations are still mostly ad hoc, they lack solid structural foundations and have therefore been criticized mainly on two grounds: first, because many of them do not account for persistence in trade flows; second, because of the lack of a consistent econometric treatment in a dynamic gravity setting of the multilateral resistance terms, introduced by Anderson and van Wincoop (2003) (hereafter AvW 2003).[3] A dynamic theory of gravity could simultaneously provide guidance on how to account for persistence in trade and trade protection and on the treatment of the multilateral resistance in a dynamic setting.

2 More examples can be found in Eichengreen and Irwin (1996), including one related to Japanese automotive firms establishing branch 'transplant' production plants in overseas markets in response to tariff cuts, even only temporary ones. Also, it has been documented that the trade liberalization period in Brazil from 1988 to 1990 resulted in substantial industrial productivity and investment growth (see Cavalcanti-Ferreira and Rossi 2003 for more details).

3 The standard procedure used to account for the multilateral resistances in a static setting is to use directional (for source and destination country) fixed effects (see Feenstra 2004). However, there is no consistent treatment of the multilateral resistances when panel data are involved: Rose (2000) does not account for multilateral resistances, but uses time dummies. Micco, Stein, and Ordonez (2003) use country-pair fixed effects as well as year dummies. Egger (2000) and Helpman, Melitz, and Rubinstein (2008) use directional fixed effects and time indicators. Anderson and Yotov (2010a) use time-varying directional fixed effects. Finally, Baltagi, Song, and Koh (2003) and Baltagi et al. (2007) suggest a full interaction effects design with fixed exporter, importer, and time effects and interaction terms to account for exporter-specific and importer-specific time-variant effects.

In sum, we believe that a structural dynamic gravity model will contribute to the theoretical as well as to the empirical trade literature. Accordingly, we set three main goals for this paper: first, to build the theoretical foundations of dynamic gravity; second, to provide a structural framework for gravity-type estimations with panel data; and, third, to study the general equilibrium effects of trade protection within a dynamic framework with endogenous country sizes.

We develop a structural dynamic gravity model in section 2 by extending on AvW (2003) to allow for endogenous production and capital accumulation in the spirit of the dynamic, stochastic, general equilibrium (DSGE), two-country models of the open economy macroeconomics literature. Our dynamic gravity equation nests its static counterpart from AvW (2003). It also introduces an additional term, which arises from the endogenous structure of production and accounts for the dynamic nature of trade flows.[4] We label this additional term the *dynamic* or *endogenous country size* effect. It encompasses two intuitive elements: The first one, which we refer to as the *trade persistence* effect, accounts for persistence in bilateral trade flows. The second one, which we refer to as the *protection persistence* effect, accounts for the fact that trade barriers may lead to an increase in domestic capital accumulation, which in turn leads to an increase in trade flows through its positive effect on output and country size.

The decomposition of the effects of trade barriers is an important feature of the dynamic gravity model because it reveals a possible case for trade policy intervention. On the one hand, trade barriers still have their standard negative *contemporaneous* effect on the volume of trade. On the other, however, through the endogenous structure of production, trade barriers may result in more capital accumulation, an increase in the size of the economies, and ultimately a positive impact on future trade flows.

Our model provides clear empirical implications for gravity-type estimations with panel data. We discuss those in section 3. Three main features stand out. First, persistence in trade flows should be accounted for by including lagged trade as a regressor in the gravity model. Not accounting for trade persistence may cause omitted variable biases when dynamic phenomena are analyzed. Second, our theory predicts that current and lagged values of any time-varying trade barriers have opposing effects on contemporaneous trade and should be accounted for accordingly. Finally, to properly control for the unobservable multilateral resistance terms, panel gravity estimates should be obtained with time-varying, directional fixed effects.

In section 4, we confront the empirical implications of our model with the data by investigating the effects of Free Trade Agreements (FTAs) and of the Eurozone (EZ) on members' bilateral trade. Both topics have been the focus of a large

4 We label trade flows 'intrinsically dynamic' in the sense that they are autocorrelated over time, since together with the contemporaneous values, the lagged values of trade flows, trade barriers and multilateral resistances play a significant role in the determination of current trade flows.

body of empirical literature with mixed findings. In accordance with the latest developments in the empirical FTA literature (see, e.g., Baier and Bergstrand 2007; Anderson and Yotov 2011), we obtain large, positive, and significant long-run FTA effects on trade. In regard to the Eurozone impact, we do not find evidence for significant Euro effects on members' bilateral trade. These results are in contrast to findings from Micco, Stein, and Ordonez (2003), Baldwin, Skudelny, and Taglioni (2005), and Baldwin and Taglioni (2006), for example, who find positive and significant Euro effects, but in support of the estimates from De Souza (2002) and, more recently, Berger and Nitsch (2008) and Santos Silva and Tenreyro (2010). Overall, our empirical analysis indicates that not accounting for persistence in bilateral trade affects the estimates of the time-varying gravity estimates, but not the time-invariant coefficients. In addition, we show that the dynamic theory-founded specification with a time-varying, directional fixed effects treatment of the multilateral resistances is not dominated by any estimation alternative.

Since the dynamic general equilibrium nature of the model does not allow us to obtain a closed form solution needed to conduct a comparative statics analysis of the effects of trade policy, in section 5 we use the results of the structural empirical estimation to calibrate the model. We then simulate it numerically to study the effects of a unilateral increase in trade protection, and compare the performance of our model with that of the standard static, endowment economy gravity model. Our numerical simulations reveal that the standard static, partial equilibrium model without capital accumulation and endogenous country sizes overestimates the negative aggregate effects of a unilateral increase in trade protection on producers in all countries, but underestimates the negative aggregate effects on consumers. Most important, we find that when the elasticity of import demand is sufficiently large, trade protection may actually hurt producers even in the country that is imposing higher tariffs. This is due to rising producers' trade costs against all destinations, and it is not captured in partial equilibrium models. This finding is particularly interesting because (i) it is in contrast with the traditional theory of protectionism; and (ii) it suggests that trade policy should be applied in a discretionary fashion to different categories of commodities based on the elasticity of import demand in their category. In addition, we find that the effects of a change in bilateral trade costs that are channelled through the multilateral resistance terms are large and should be accounted for in the analysis and the interpretation of the results from gravity applications concerning the effects of the determinants of bilateral trade flows.

Following this introduction, the structure of the paper is as follows. Section 2 develops the theoretical model. Section 3 translates the structural dynamic model into an econometric specification. Section 4 presents the empirical application. Section 5 includes a numerical simulation analysis of the DSGE model. Section 6 concludes.

2. Theoretical model

To model dynamic gravity we 'merge' the static, endowment economy, gravity model from AvW (2003) with the two-country dynamic models in the macroeconomics literature (as in Backus, Kehoe, and Kydland 1992, 1994). As suggested by Anderson (1979), we incorporate dynamic elements in the gravity framework by introducing asset accumulation and making country size endogenous. Therefore, in this intertemporal version of the model, the relationship between asset accumulation and the trade balance becomes crucial to understanding the effects of trade policy.

Each region j in the world specializes in the production of only one good. Agents in each region work, invest, and consume. Total nominal output in region j at time t ($y_{j,t}$) is a function of employment ($L_{j,t}$) and the outstanding stock of capital ($K_{j,t}$) in that region according to the following constant returns to scale Cobb-Douglas production function:

$$y_{j,t} = p_{j,t} L_{j,t}^{(1-\alpha)} K_{j,t}^{\alpha} \qquad \alpha \in (0, 1). \tag{1}$$

Both capital and labour are country-specific. For simplicity and to abstract from the effects of trade barriers on labour markets, we assume that agents do not value leisure, so that labour supply is perfectly inelastic. With agents being endowed with a total of one unit of time, $L_{j,t} \equiv 1$, equation (1) can be restated as

$$y_{j,t} = p_{j,t} K_{j,t}^{\alpha} \qquad \alpha \in (0, 1). \tag{2}$$

The stock of capital follows a standard law of motion:

$$K_{j,t} = \Omega_{j,t} + (1 - \delta) K_{j,t-1}, \tag{3}$$

where Ω denotes the flow of investment and δ represents the depreciation rate.[5]

At every point in time consumers in region j choose aggregate consumption (C_j), aggregate investment (Ω_j), and the allocation of consumption and investment goods across i regions (c_{ij} and I_{ij}, respectively) to maximize the present discounted value of lifetime utility subject to a sequence of constraints given by equations (4)–(8):

$$\max_{\{C_{j,t}, \Omega_{j,t}, c_{ij,t}, I_{ij,t}\}} \quad \sum_{t=0}^{\infty} (1+\rho)^{-t} U(C_{j,t})$$
$$C_{j,t} = \left(\sum_i \beta_i^{\frac{(1-\sigma)}{\sigma}} c_{ij,t}^{\frac{(\sigma-1)}{\sigma}} \right)^{\frac{\sigma}{(\sigma-1)}} \tag{4}$$

5 Since physical capital is country specific and claims on it are not internationally traded, the rental rate on the capital stock is also country specific.

$$\Omega_{j,t} = \left(\sum_i \beta_i^{\frac{(1-\sigma)}{\sigma}} I_{ij,t}^{\frac{(\sigma-1)}{\sigma}} \right)^{\frac{\sigma}{(\sigma-1)}} \tag{5}$$

$$K_{j,t} = \Omega_{j,t} + (1-\delta)K_{j,t-1} \tag{6}$$

$$y_{j,t} = p_{j,t} K_{j,t}^{\alpha} \tag{7}$$

$$y_{j,t} = \sum_i p_{ij,t} c_{ij,t} + \sum_i p_{ij,t} I_{ij,t}. \tag{8}$$

Consumer preferences in each region j are identical, homothetic, and approximated by a CES utility function. Equation (4) defines the consumption aggregate (C_j) as a function of consumption from each region i (c_{ij}), where β_i is a positive distribution parameter and $\sigma > 1$ is the elasticity of substitution. Equation (5) presents a CES investment aggregator (Ω_j) that describes investment in each region j as a function of domestic components (I_{jj}) and imported components from all other regions $i \neq j$ (I_{ij}).[6] Equations (6) and (7) define the law of motion for the capital stock and the value of production, respectively. Finally, in a dynamic model, where capital accumulation allows households to engage in intertemporal consumption smoothing, lifetime utility is maximized subject to the budget constraint in equation (8), which states that aggregate spending in region j must equal the sum of spending on both consumption and investment goods across all regions. In this equation, $p_{ij} = p_i t_{ij}$ is the price of region i goods for region j consumers, where p_i denotes the exporter's factory-gate price, and t_{ij} labels bilateral trade costs for shipments from i to j.

Using x_{ij} to denote region j's total nominal spending on goods from region i, that is, $x_{ij} \equiv p_{ij}(c_{ij} + I_{ij})$, agents' optimization yields

$$x_{ij,t} = \left(\frac{\beta_i p_{i,t} t_{ij,t}}{P_{j,t}} \right)^{1-\sigma} y_{j,t}, \tag{9}$$

where $P_j = [\sum_i (\beta_i p_i t_{ij})^{1-\sigma}]^{\frac{1}{(1-\sigma)}}$ is the CES price index in region j, later identified as the inward multilateral resistance of j.

Impose market clearance, $y_{i,t} = \sum_j x_{ij,t}$ to solve for the endogenous scaled prices $\{\beta_i p_{i,t}\}$, and substitute in (9) to obtain the structural gravity model from AvW (2003):

$$x_{ij,t} = \frac{y_{i,t} y_{j,t}}{y_t^W} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}} \right)^{1-\sigma}, \tag{10}$$

6 We do not allow the distribution parameters β_i to differ between consumption and investment in equations (4) and (5) to avoid the inward multilateral resistances P_j to be different for consumption and investment goods. Notice that $P_j = [\sum_i (\beta_i p_i t_{ij})^{1-\sigma}]^{1/(1-\sigma)}$ is a function of these distribution parameters.

where $\Pi_{i,t}^{1-\sigma} = \sum_j (t_{ij,t}/P_{j,t})^{1-\sigma} y_{j,t}/y_t^W$ and $P_{j,t}^{1-\sigma} = \sum_i (t_{ij,t}/\Pi_{i,t})^{1-\sigma} y_{i,t}/y_t^W$ are the multilateral resistance (MR) terms (outward and inward, respectively), which consistently aggregate bilateral trade costs and decompose their incidence on the producers and the consumers in each region. Outward multilateral resistances (OMRs) are defined as if the sellers in each region shipped to a single world market, while inward multilateral resistances (IMRs) are defined as if the buyers in each region imported from a single world market (see AvW (2003) and Anderson and Yotov (2010a, b) for further discussion).

Next, we impose the model's endogenous structure of production in the destination region j and the law of motion for capital accumulation by working with $y_{j,t}$ in equation (10). This allows us to derive the dynamic gravity model and to discuss the additional effects of trade barriers on bilateral trade that arise from the dynamic nature of our model.

Combine (2) and (3) to obtain

$$\left(\frac{y_{j,t}}{p_{j,t}}\right)^{\frac{1}{\alpha}} = \Omega_{j,t} + (1-\delta)\left(\frac{y_{j,t-1}}{p_{j,t-1}}\right)^{\frac{1}{\alpha}} \tag{11}$$

$$\left(\frac{y_{j,t}}{p_{j,t}}\right)^{\frac{1}{\alpha}} = \phi\frac{y_{j,t}}{p_{j,t}} + (1-\delta)\left(\frac{y_{j,t-1}}{p_{j,t-1}}\right)^{\frac{1}{\alpha}}, \tag{12}$$

where $\phi \equiv \Omega_j/(y_j/p_j)$ is the investment share of real output, and $\phi = \delta\alpha/(\rho + \delta)$.[7]

Work with equations (10) and (12) to get a condition that relates current output in the destination region ($y_{j,t}$) to the lagged values of bilateral trade, trade costs, and multilateral resistances, world output and output in the country of origin:

$$y_{j,t} = \left[\phi y_{j,t} p_{j,t}^{\left(\frac{1}{\alpha}-1\right)} + (1-\delta)\left(\frac{p_{j,t}}{p_{j,t-1}}\right)^{\frac{1}{\alpha}} x_{ij,t-1}^{\frac{1}{\alpha}} \left(\frac{y_{t-1}^W}{y_{i,t-1}}\right)^{\frac{1}{\alpha}} \left(\frac{t_{ij,t-1}}{\Pi_{i,t-1}P_{j,t-1}}\right)^{\frac{(\sigma-1)}{\alpha}}\right]^{\alpha}. \tag{13}$$

Plug (13) into (10) to get an expression for bilateral trade flows (x_{ij}) as a function of the same contemporaneous variables as in the static model, as well as the lagged values of bilateral trade, trade costs and multilateral resistances, and

7 To solve for ϕ we assume that the investment share of real output does not depart significantly from its steady-state value after a shock to trade barriers. Then, using the Euler equation for consumption $U'(C_{j,t}) = 1/(1+\rho)U'(C_{j,t+1})\left[(1-\delta) + \alpha K_{j,t+1}^{\alpha-1}\right]$ to solve for the steady-state value of capital, we obtain $K_j = (\rho+\delta)/\alpha^{1/(\alpha-1)}$. Knowing that $\Omega_j = \delta K_j$, we can solve for $\phi = \delta\alpha/(\rho + \delta)$.

world output and output in the origination region:

$$x_{ij,t} = \frac{y_{i,t}}{y_t^W}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}\left[\phi y_{j,t}p_{j,t}^{\left(\frac{1}{\alpha}-1\right)} + (1-\delta)\left(\frac{p_{j,t}}{p_{j,t-1}}\right)^{\frac{1}{\alpha}} x_{ij,t-1}^{\frac{1}{\alpha}}\left(\frac{y_{t-1}^W}{y_{i,t-1}}\right)^{\frac{1}{\alpha}} \times \left(\frac{t_{ij,t-1}}{\Pi_{i,t-1}P_{j,t-1}}\right)^{\frac{(\sigma-1)}{\alpha}}\right]^{\alpha}. \tag{14}$$

Equation (14) is the structural dynamic gravity equation. It is clear from equations (13) and (14) that the dynamic version of gravity transforms into its static counterpart for an endowment economy. As in the static model, our gravity equation predicts that bilateral trade flows are directly related to the GDP of each trading partner, and that trade barriers $t_{ij,t}$ have a negative impact on the volume of bilateral trade. We label this effect the *static* or *contemporaneous* effect of trade barriers.

The fact that we depart from the endowment economy and allow for an endogenous production structure is captured by the second term in square brackets in (14), which we label the *dynamic* or *endogenous country size* effect. This intertemporal effect consists of two intuitive components. The first is the lagged volume of trade ($x_{ij,t-1}$), which captures what we label the *trade persistence* effect. This effect accounts for the autocorrelation in bilateral trade flows and is related to the persistence imposed on the model by the process of capital accumulation and the fact that a fraction $(1-\delta)$ of the capital stock from period $(t-1)$ is still available for production in period t. The second component ($t_{ij,t-1}$) captures the dynamic effect of trade barriers on bilateral trade. We label this effect the *protection persistence* effect. With an increase in trade protection imposed at time $t-1$ by the importer j on region i, the price level in the country of destination increases, raising the value of the marginal product of capital in that region and inducing more capital accumulation. Thus, $K_{j,t}$ rises, output $y_{j,t}$ increases endogenously, and, all else equal, bilateral trade flows rise as a result. Therefore, in the context of a dynamic gravity equation, trade protection could ultimately have a positive impact on trade flows through its intertemporal effects on capital formation and production.

It is clear from this discussion that the *contemporaneous* and the *dynamic* effects of protection work in opposite directions. This decomposition of the static and the dynamic effects of protection on trade flows is an important feature of our model, and it reveals a possible case for trade policy intervention. On the one hand, trade barriers still have their standard negative contemporaneous effect on the volume of trade. On the other hand however, the resulting positive effect on the size of the economies may ultimately increase future trade flows.

Since obtaining a closed-form analytical solution for the general equilibrium dynamic gravity model is not feasible, in section 5 we numerically simulate the general equilibrium model to study the effects of trade protection and the differences in the response of the volume of trade flows between the dynamic and the static gravity settings. First, we discuss the empirical implications of our dynamic gravity theory, and we estimate some structural parameters needed to calibrate the model for the simulation analysis.

3. Empirical implications and analysis

We start this section by translating the structural dynamic gravity equation (14) into an econometric specification. To avoid potential indeterminacy of the nominal model, as we have not specified the monetary side of the economy, our first step is to re-express it in real terms. To do this, we set $p_{j,t} = 1, \forall t$, and equation (14) becomes

$$x_{ij,t} = \frac{y_{i,t}}{y_t^W}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}\left[\phi y_{j,t} + (1-\delta)x_{ij,t-1}^{\frac{1}{\alpha}}\left(\frac{y_{t-1}^W}{y_{i,t-1}}\right)^{\frac{1}{\alpha}}\left(\frac{t_{ij,t-1}}{\Pi_{i,t-1}P_{j,t-1}}\right)^{\frac{(\sigma-1)}{\alpha}}\right]^{\alpha}. \tag{15}$$

We choose to normalize p_j for two reasons: First, to prevent inflation in any given region from playing a role in the determination of trade flows (notice that p_j washes out from equation (14) after this normalization is performed). Otherwise, the empirical results would be sensitive to the choice of which country's inflation rate to use in equation (14). Second, taking an alternative approach, such as normalizing the price index P_i in any country i, would imply an essentially fixed inward resistance in one of the two countries in our two-country model general equilibrium simulation of section 4. This would prevent us from simulating the response of the inward multilateral resistances in both the importer and the exporter country to trade costs shocks.

Next, define size-adjusted trade $\tilde{x}_{ij,t} = x_{ij,t}/y_{i,t}y_{j,t}$ and rewrite (15) to get

$$\begin{aligned}\tilde{x}_{ij,t} = \frac{1}{y_t^W}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}&\left[\phi y_{j,t}^{1-\frac{1}{\alpha}} + (1-\delta)\left(\tilde{x}_{ij,t-1}y_{t-1}^W y_{j,t-1}\right)^{\frac{1}{\alpha}}\right.\\ &\left.\times\left(\frac{t_{ij,t-1}}{\Pi_{i,t-1}P_{j,t-1}}\right)^{\frac{\sigma-1}{\alpha}} y_{j,t}^{-\frac{1}{\alpha}}\right]^{\alpha}.\end{aligned} \tag{16}$$

Size-adjusted trade is the natural dependent variable choice: First, by using size-adjusted trade, we avoid complications associated with converting nominal trade to real trade values.[8] Second, bringing the exporter's GDP to the left-hand

8 It is a common practice in the gravity literature to use real GDP and real trade flows. The main problem with this is that it is usually US price index data that are used to deflate all trade values,

side of the estimation equation allows us, at least partially, to deal with GDP endogeneity.[9] Finally, as we show below, adjusting for country size proves to be a successful tool to attack the important issue of heteroscedasticity that, as shown by Santos Silva and Tenreyro (2006), renders gravity estimates inconsistent.

The dynamic version of the gravity equation is highly non-linear. Therefore, our next step is to log-linearize it around the deterministic steady state of the model to obtain[10]

$$\begin{aligned} \log(\tilde{x}_{ij,t}) = \beta_0 &+ (1-\delta)\log(\tilde{x}_{ij,t-1}) + (\xi\alpha - 1)\log(y_{j,t}) - \log(y_t^W) \\ &+ (1-\delta)\log(y_{t-1}^W) + (1-\delta)\log(y_{j,t-1}) + (1-\sigma)\log(t_{ij,t}) \\ &- (1-\sigma)(1-\delta)\log(t_{ij,t-1}) - \log(\tilde{\Pi}_{i,t}) \\ &+ (1-\delta)\log(\tilde{\Pi}_{i,t-1}) - \log(\tilde{P}_{j,t}) + (1-\delta)\log(\tilde{P}_{j,t-1}). \end{aligned} \tag{17}$$

Here, the constant term β_0 and the coefficient ξ are functions of the parameters in the model and the logarithms of the deterministic steady-state values of all explanatory variables, including the multilateral resistances.

Two additional steps complete the econometric specification. First, we follow Feenstra (2004) in using source and destination (directional) country fixed effects to account for the unobservable multilateral resistance terms in the last four terms of equation (17), which becomes

$$\begin{aligned} \log(\tilde{x}_{ij,t}) = \beta_0 &+ (1-\delta)\log(\tilde{x}_{ij,t-1}) + (1-\sigma)\log(t_{ij,t}) \\ &- (1-\sigma)(1-\delta)\log(t_{ij,t-1}) + \beta_{i,t} + \beta_{j,t}. \end{aligned} \tag{18}$$

The structural interpretation of the directional fixed effects is $\beta_{i,t} = -\log(\tilde{\Pi}_{i,t}) + (1-\delta)\log(\tilde{\Pi}_{i,t-1})$ and $\beta_{j,t} = -\log(\tilde{P}_{j,t}) + (1-\delta)\log(\tilde{P}_{j,t-1}) + (\xi\alpha - 1)\log(y_{j,t}) + (1-\delta)\log(y_{j,t-1})$. However, it should be noted that, in addition to the multilateral resistances and the importer's GDP variable, the fixed effects also absorb the current and lagged world output, which vary over time only.

Second, we provide structure behind the trade barriers, $t_{ij,t}$s. Following AvW (2003), we assume that, at each point in time, the unobservable $t_{ij,t}$s can be approximated by observable variables so that $\log(t_{ij,t}) = \sum_h \gamma_h z_{ij,t}(h)$, where the z's include the log of bilateral distance, contiguous borders, common language, colonial relationships, FTA membership, and so on. Furthermore, the dynamic structure allows us to distinguish between trade barriers that are time invariant

regardless of source or destination, and this leads to biased gravity estimates. For a good discussion on the appropriate use of nominal versus real trade and GDP values see Baldwin and Taglioni (2006).

9 We still need to worry about GDP endogeneity, as the exporter's GDP still appears on the right-hand side of our estimation equation. However, we address this by using standard econometric techniques. Furthermore, Frankel (1997) argues that the GDP bias in the gravity estimates is insignificant.

10 Details of the log-linearization procedure can be found in the technical appendix available from the CJE online archive at cje.economics.ca.

(e.g., bilateral distance) and trade costs that vary over time (e.g., FTA membership). To make this distinction explicit, we use $t_{ij,t}$ to denote trade costs that vary over time and τ_{ij} to denote the time-invariant trade barriers. After adding an error term, equation (18) becomes

$$\begin{aligned}\log(\tilde{x}_{ij,t}) = \beta_0 &+ (1-\delta)\log(\tilde{x}_{ij,t-1}) + (1-\sigma)\log(t_{ij,t}) \\ &- (1-\sigma)(1-\delta)\log(t_{ij,t-1}) \\ &+ (1-\sigma)\delta\log(\tau_{ij}) + \beta_{i,t} + \beta_{j,t} + \epsilon_{ij,t}.\end{aligned} \tag{19}$$

Notice that the static gravity specification for the endowment economy from AvW (2003), $\log(\tilde{x}_{ij}) = (1-\sigma)\log(t_{ij}) + \beta_i + \beta_j$, is nested in our setting. Compared with its static counterpart, the dynamic gravity equation has several distinct features. First, it implies that lagged, size-adjusted trade values should be included as a regressor in the dynamic gravity specification. This is in accordance with the fact that trade relations are usually persistent. Not accounting for such persistence may cause omitted variable bias in the point estimates of the gravity coefficients. In an empirical study of the historical persistence of trade flows, Eichengreen and Irwin (1998) find such biases to be substantial and conclude that they 'will never run another gravity equation that excludes lagged trade flows' (56).

Second, while the output elasticity in a static gravity model is equal to one, the coefficient of importer's GDP on the right-hand-side in equation (17) implies that this is not necessarily the case in a dynamic setting. Furthermore, the importer fixed effects, $\beta_{j,t} = -\log(\tilde{P}_{j,t}) + (1-\delta)\log(\tilde{P}_{j,t-1}) + (\xi\alpha - 1)\log(y_{j,t}) + (1-\delta)\log(y_{j,t-1})$, which absorb the importer's GDP variable, are time varying, owing to the dynamic structure of the model. Similarly, the exporter fixed effects, $\beta_{i,t} = -\log(\tilde{\Pi}_{i,t}) + (1-\delta)\log(\tilde{\Pi}_{i,t-1})$, are also time varying, which has important implications for the structural interpretation and for the empirical significance of these terms.

Finally, the structural static model cannot differentiate between time-varying trade costs and barriers that are constant over time. More important, equation (18) suggests that current, size-adjusted bilateral trade is influenced by contemporaneous as well as by lagged time-varying trade barriers. This feature of the dynamic model is usually ignored in gravity estimations, but it is important because not accounting for the influence of these lagged variables may affect the coefficient estimates. As discussed earlier, the dynamic and the contemporaneous effects of trade protection on current trade work in opposite directions, which is captured by the opposing signs of the coefficients on $t_{ij,t}$ and $t_{ij,t-1}$ in (19).

4. Empirical implementation

To test the empirical significance of our theory and the above-mentioned features of the structural dynamic gravity model, we investigate the effects of Free Trade

Agreements (FTAs) and the Eurozone (EZ) on the volume of bilateral trade flows between member countries in a sample of 22 regions over the period 1970–2009.[11] We chose this particular sample because it has already been widely used in the EZ literature but it has produced mixed conclusions about the Euro effects on trade. For example, Micco, Stein, and Ordonez (2003), Baldwin, Skudelny, and Taglioni (2005) and Baldwin and Taglioni (2006), among others, find positive and significant Euro effects, while De Souza (2002) and, more recently, Berger and Nitsch (2008) and Santos Silva and Tenreyro (2010) do not find significant effects of the Euro on the volume of bilateral trade between members. Baldwin (2006) and De Nardis, De Santis, and Vicarelli (2007) provide surveys of the EZ gravity literature.

On the time dimension, we extend the data coverage to 2009, which is important compared with previous work that typically covers the period up to 2003, especially in light of studies predicting that the effects of currency unions should take a long time to phase in (see, e.g., Glick and Rose 2002). In addition, we also investigate the effects of FTAs, which often are included as a control variable in EZ estimations, but whose treatment and effects have been ignored by the Euro literature.[12] To do this, we employ the panel econometric techniques advocated by Baier and Bergstrand (2007), who treat the problem of FTA endogeneity. Applied to our setting, their methodology allows us to account for EZ endogeneity as well, an important issue met with little attention in the Euro literature thus far.

In addition to FTA and EZ endogeneity, estimating dynamic gravity requires us to address some important econometric challenges such as (i) the famous dynamic bias of Nickell (1981), (ii) heteroscedasticity of trade data, which not only leads to biased estimates but renders the non-linear gravity estimates inconsistent as well (see Santos Silva and Tenreyro 2006), and (iii) the fact that 'fixed-effects estimations, *such as ours,* are sometimes criticized when applied to data pooled over consecutive years on the grounds that dependent and independent variables cannot fully adjust in a single year's time' (Cheng and Wall 2004, 8, italics added). We address these challenges and introduce the dynamic features of our model by

11 The regions are (year of EZ membership, if applicable, in parentheses): Australia, Austria (1999), Belgium-Luxembourg (1999), Canada, Denmark, Finland (1999), France (1999), Germany (1999), Greece (2001), Iceland, Ireland (1999), Italy (1999), Japan, New Zealand, Netherlands (1999), Norway, Portugal (1999), Spain (1999), Sweden, Switzerland, United Kingdom, United States. Some advantages of this sample are (i) that the data are very reliable and readily available, and (ii) that there are actual trade flows between any two partners in each year. In fact, we needed to replace only 1.1% of missing exports (the theoretically correct gravity variable) with import values to get a complete balanced panel over the whole period. Thus, we do not need to worry about the biases caused by zero trade flows and/or the treatment of any missing values, both of which, as shown by Santos Silva and Tenreyro (2006), may lead to biased estimates.

12 Some recent developments in the FTA gravity literature include Magee (2003), Baier and Bergstrand (2004, 2007), and Anderson and Yotov (2011). Frankel (1997) provides a good summary of earlier findings.

gradually building on the following econometric specification, based on (19):

$$\begin{aligned} STRADE_{ij,t} = \beta_0 + \beta_1 STRADE_{ij,t-1} + \beta_2 FTA_{ij,t} + \beta_3 FTA_{ij,t-1} \\ + \beta_4 EZ_{ij,t} + \beta_5 EZ_{ij,t-1} + \beta_6 DIST_{ij} + \beta_7 CLNY_{ij} \\ + \beta_8 BRDR_{ij} + \beta_9 LANG_{ij} + \beta_{i,t} + \beta_{j,t} + \varepsilon_{ij,t}. \end{aligned} \quad (20)$$

Here, $STRADE_{ij,t} = \log(x_{ij,t}/y_{i,t}y_{j,t}) \quad \forall t$, and $\beta_1 = (1-\delta)$ is the coefficient on the logarithm of lagged, size-adjusted trade. To construct size-adjusted trade, we use data on bilateral trade flows from COMTRADE and on output from WDI, measured in constant US dollars. $\beta_2 = (1-\sigma)\gamma_1$ and $\beta_3 = -(1-\sigma)(1-\delta)\gamma_1$ estimate the effects of FTA membership and its lagged values, respectively. FTA data are from Rose (2004) and are updated to 2009 by the authors. $\beta_4 = (1-\sigma)\gamma_2$ and $\beta_5 = -(1-\sigma)(1-\delta)\gamma_2$ are the coefficients on the variables that capture EZ effects. $\beta_6 = (1-\sigma)\delta\gamma_3$, $\beta_7 = (1-\sigma)\delta\gamma_4$, $\beta_8 = (1-\sigma)\delta\gamma_5$, and $\beta_9 = (1-\sigma)\delta\gamma_6$ are the coefficients on bilateral distance (*DIST*), and the indicator variables capturing the presence of colonial relationships (*CLNY*), contiguity (*BRDR*), and common language (*LANG*) between two trading partners, respectively. Data on these variables are from Mayer and Zignago (2006).[13] As previously defined, $\beta_{i,t}$ and $\beta_{j,t}$ account for the multilateral resistance terms along with other observable and unobservable country-specific variables that may be time varying. Finally, to address the critique from Cheng and Wall (2004), we leave three years between our observations. Thus, period $t-1$ represents a 3-year lag and, accordingly, β_1 should be interpreted structurally as $(1-\delta)^3$.[14]

We start by estimating a 'static' version of (20). Estimation results in the first column of table 1 are obtained with time-varying, directional, country-specific fixed effects (to account for the multilateral resistances), but without including lags of the dependent variable and of the other time-varying regressors.[15]

13 A more comprehensive approach to account for all (observable and unobservable) time-invariant trade costs is to use bilateral fixed effects. As noted by Cheng and Wall (2004), this does not preclude estimation of the coefficients on the standard gravity variables, which can be recovered from a second stage OLS regression with the bilateral fixed effects estimates as dependent variable. Anderson and Yotov (2011) improve on this procedure by using variance weighted least squares to obtain unbiased gravity estimates from the bilateral fixed effects. Finally, Arellano-Bover (1995) / Blundell Bond's (1998) system-GMM estimator simultaneously accounts for the dynamic features of our model and allows for estimation of the coefficients of the standard gravity variables, which makes it particularly appropriate for our purposes.

14 This is consistent with the 3-year lags used in Trefler (2004), who also criticizes trade estimations pooled over consecutive years. Cheng and Wall (2004) and Baier and Bergstrand (2007) use 5-year lags, while Eichengreen and Irwin (1998) use 5- and 10-year lags. In the technical appendix, we experiment with various lags to check the robustness of our results. We find that estimates obtained with 3-year and 5-year lags are very similar, but we prefer the 3-year estimates as more efficient. Our yearly estimates produce suspiciously large δs, which reinforces the argument for allowing some time for adjustment in trade flows.

15 In the technical appendix, available at cje.economics.ca, we use alternative fixed effects specifications to show that the structural treatment of the multilateral resistance terms with time-varying, directional fixed effects specification is not dominated by any alternative.

TABLE 1
Dynamic gravity estimates

	(1) STATIC	(2) TVDLT	(3) REDUCED	(4) IV	(5) SYSGMM	(6) STRCRL
$STRADE_{ij,t-1}$		0.881	0.593	0.634	0.713	0.606
		(0.011)**	(0.029)**	(0.037)**	(0.072)**	(0.011)**
$FTA_{ij,t}$	0.032	0.151	0.137	0.131	0.287	0.162
	(0.097)	(0.037)**	(0.039)**	(0.034)**	(0.047)**	(0.033)**
$FTA_{ij,t-1}$		−0.156	−0.007	−0.023	−0.065	−0.098
		(0.036)**	(0.038)	(0.034)	(0.036)*	(0.020)**
$EZ_{ij,t}$	0.336	0.046	−0.006	0.004	0.019	0.056
	(0.094)**	(0.046)	(0.047)	(0.039)	(0.046)	(0.036)
$EZ_{ij,t-1}$		0.005	0.001	0.008	0.014	−0.034
		(0.052)	(0.048)	(0.042)	(0.047)	(0.022)
$DIST_{ij}$	−1.118	−0.141			−0.281	
	(0.072)**	(0.016)**			(0.080)**	
$CLNY_{ij}$	0.558	0.032			0.147	
	(0.185)**	(0.026)			(0.071)*	
$BRDR_{ij}$	0.131	0.014			0.037	
	(0.114)	(0.018)			(0.035)	
$LANG_{ij}$	0.253	0.019			0.084	
	(0.112)*	(0.017)			(0.039)*	
$CONST$	−20.630	−2.818	−12.188	−16.844	−6.691	−8.460
	(0.864)**	(0.290)**	(0.863)**	(1.716)**	(1.526)**	(0.000)
N	5962	5499	5499	4567	5499	5499
R^2	0.828	0.966	0.973	0.977		0.966
RESET χ^2	19.98	0.40	0.26	0.19	0.37	1.74
Sargan χ^2				3.53	23.16	
Long-run FTA		−0.039	0.320	0.296	0.771	0.162
		(0.144)	(0.072)**	(0.070)**	(0.158)**	(0.033)**
Long-run EZ		0.444	−0.013	0.033	0.117	0.056
		(0.230)+	(0.093)	(0.082)	(0.139)	(0.036)
Annual δ		0.041	0.160	0.141	0.107	0.154
		(0.004)**	(0.014)**	(0.017)**	(0.030)**	(0.005)**

NOTES: Robust-clustered (by country pair) standard errors in parentheses. + $p < 0.1$, $^*p < .05$, $^{**}p < .01$. The dependent variable in each estimation is size-adjusted trade. Standard errors for the structural parameters are obtained with the Delta method. Estimates of the time-varying directional fixed effects, employed in each estimation, are omitted for brevity. Columns (3), (4), and (6) use country-pair fixed effects. Estimates of the latter are omitted for brevity.

Several findings stand out. First, the estimates on the standard gravity variables are mostly as expected.[16] Second, the estimates from column (1) imply that FTAs do not have a significant impact on bilateral trade, which is in contrast with the findings from Rose (2004), Baier and Bergstrand (2007) and Anderson and Yotov

16 Interestingly, we obtain a positive but economically small and not statistically significant estimate on the BRDR coefficient, implying that sharing a common border does not promote trade in our sample. Possible explanations include the clustering of European economies and the fact that contiguity and distance are confounded.

(2011) who all find large positive FTA trade volume effects. Finally, we estimate a suspiciously large, positive Euro effect on bilateral trade among members. Overall, the estimates from column (1) suggest that not accounting for the dynamic features of the model may have little impact on the effects of the time-invariant regressors, but may significantly affect the estimates of the time-varying covariates. Combined with the very high regression specification error test (RESET) χ_2^2 statistic of 19.98, reported in the middle of the table, these results cast doubt on the 'static' OLS specification.

Next, we introduce the lags of the dependent variable and the other time-varying variables as regressors in (20). Results, reported in column (2) of table 1, reveal several interesting properties. First, the introduction of the lagged covariates significantly improves the overall adequacy and explanatory power of the model, which is supported by the R^2 and RESET statistics. Second, all standard gravity variables, except distance, lose significance. A possible interpretation is that colonial ties, common language, and contiguity are important for establishing initial trade relationships and only distance matters after that. This finding may have potential implications for the instrumental variable (IV) gravity literature that has been struggling to find good instruments in various gravity-type policy estimations (see, e.g., Magee 2003 and Baier and Bergstrand 2004, 2007 for IV problems with FTA gravity estimations). Third, we obtain a very high lagged trade estimate. Keeping in mind that we use three-year lags, the estimate of 0.881 (std.err. 0.011) translates into a very low estimate of $\delta = 0.041$ (std.err. 0.004), reported in the bottom of the table. The upward bias in the lagged OLS dependent variable, known as the Nickell (1981) dynamic bias, is expected. It is due to the positive correlation between the lagged dependent variable and the unobservable country-pair fixed effects (FEs) that are part of the error term in (20). A straightforward solution to this endogeneity issue for longer time period panels such as ours is to include the country-pair FEs directly in (20) or to use first differences that will eliminate the bilateral fixed effects.[17]

Finally, the introduction of the lagged regressors does not improve the FTA and EZ estimates. As can be seen from the bottom panel of the table, the total FTA estimate of -0.039 (std.err. 0.144) is still not significant, while the total EZ estimate of 0.444 (std.err. 0.230) is even larger than before.[18] These results point to potential problems with the FTA and EZ covariates. Endogeneity is

17 The problem is more severe for panels with short time dimension. Anderson and Hsiao (1982) are the first to achieve consistency in a short time period setting by using appropriate lagged levels and differences of the dependent variable as instruments for the lagged dependent variable. Using larger sets of orthogonality conditions, Arellano-Bond (1991) and Arellano-Bover (1995) / Blundell Bond (1998) extend the Anderson-Hsiao (AH) estimator to the difference-GMM and the system-GMM estimators, respectively. Below, we report estimates obtained with the system-GMM estimator and we experiment with the AH estimator and the difference GMM estimator in the technical appendix at cje.economics.ca. See Roodman (2006) for a thorough discussion and implementation of the three alternatives in Stata.

18 These long-run estimates are obtained by dividing the sum of the current and lagged FTA (EZ) estimates by 'one minus the coefficient on lagged trade.' Standard errors are obtained with the Delta method.

an important one. The issue of FTA (and, analogously, EZ) endogeneity is not new to the trade literature (see Trefler 1993). However, primarily owing to the lack of reliable instruments, standard IV treatments in cross-sectional settings have not been successful in addressing the problem. Only recently, Baier and Bergstrand (2007) resorted to the panel data estimation techniques described in Wooldridge (2002) to show that FTA effects on trade can be consistently isolated in a theoretically founded gravity model by using country-pair fixed effects. Turns out, given the long time coverage of our sample, that the issues with all three of our endogenous regressors can be addressed by using country-pair fixed effects. This is what we do next.

Results obtained from estimating (20) with country-pair fixed effects, which, as noted earlier, absorb all time-invariant covariates, are reported in column (3) of table 1. Several findings deserve discussion. First, we find that, indeed, our previous FTA estimates have been biased, owing to the endogenous nature of FTAs. Once we account for endogeneity, we obtain a positive and significant contemporaneous FTA effect and a negative, as predicted by our theory, but not statistically significant lagged FTA effect. The latter implies that all lagged FTA effects on current trade are channelled through lagged trade. Together, the lagged and the contemporaneous FTA effects add up to a large, positive, and statistically significant long-run FTA estimate of 0.320 (std.err. 0.072), which is comparable to (but a bit lower than) the corresponding FTA estimates from Rose (2004), Baier and Bergstrand (2007), and Anderson and Yotov (2011).

Second, once the endogenous nature of the European Monetary Union (EMU) is accounted for, both the contemporaneous and the lagged EZ variables become insignificant, which translates into an economically small and statistically insignificant estimate of the total EZ effect of −0.013 (std.err. 0.093), reported in the bottom of the table. This points to the importance of addressing the issue of EZ endogeneity, which has been overlooked by the existing literature. Our results are in accordance with recent findings by Berger and Nitsch (2008) and Santos Silva and Tenreyro (2010). Even though each of the three papers uses different economic intuition and econometric methods,[19] the common conclusion of their studies and our work is that most of the Eurozone integration effects on bilateral trade volumes have already been exhausted before the EMU formation, owing to the tight and lasting economic connections among its members.

Third, the estimate of the coefficient of the lagged dependent variable (0.593, std.err. 0.029) implies a discount parameter $\delta = 0.160$ (st.err. 0.014), reported in the bottom of the table, that is significantly lower than the corresponding

19 Berger and Nitsch (2008) explain the lack of significant Euro effects with the gradual trend in European economic integration since 1948, which they capture econometrically by introducing a time trend to the gravity model. Santos Silva and Tenreyro (2010) use a dummy variable for the Euro-12 countries that explains away the effects of the Euro due to the fact that those countries were already strongly integrated well in advance of the introduction of the common currency. Our theory and econometric approach account for both the time trend (through the time varying fixed effects) and for the Euro-12 group of countries (through the country-pair fixed effects).

persistence parameters from related empirical trade studies but a bit higher than the standard δ estimates from the macroeconomics literature. Thus, our result decreases the gap between the macroeconomics and trade estimates of the same parameter, but, it does not eliminate it. Below, we discuss avenues for further improvement in reconciling the static trade gravity model with the DSGE literature.

OLS gravity estimates, like the ones from column (3), have been recently criticized on the grounds that they produce biased (and inconsistent) estimates in the presence of heteroscedasticity, which often plagues trade data. Santos Silva and Tenreyro (2006) make this point very clear and advocate the use of the poisson pseudo-maximum-likelihood (PPML) estimator that estimates static gravity in multiplicative form and simultaneously controls for heteroscedasticity and takes into account the information contained in the zero trade flows. Unfortunately, we cannot apply the PPML estimator directly, owing to the complex non-linear structure of our model (see equation (16)). However, on the bright side, as can be seen from table 1, our linearized dynamic specification passes the regression specification error test (RESET), the same test that rendered the OLS estimates in Santos Silva and Tenreyro (2006) inappropriate. The main reason for the good performance of our model, in regard to heteroscedasticity, is that we employ as dependent variable trade that is adjusted by the sizes of both trading partners. Comparisons between the estimates from column (3) and their counterparts obtained with trade in levels (available in the technical appendix) reveal that the latter are indeed subject to the Santos Silva and Tenreyro's critique.[20,21]

In the next specification, we use instrumental variables to account for residual endogeneity, if any, of the lagged trade variable. Our instruments include third (9-year) lags of the dependent variable as well as size adjusted trade values from 1970 and their squares. As can be seen from column (4) of table 1, the instruments pass the Sargan test of overidentifying restrictions (with $\chi_2^2 = 3.53$) and the IV estimates are not statistically different from the OLS numbers from column (3). In addition, a Durdin-Wu-Hausman test cannot reject the exogeneity of the

20 The finding that size-adjusted trade controls for heteroscedasticity is not specific to our sample. Tests with other, even sectoral-level, data sets reveal that in each case the severity of heteroscedasticity is significantly decreased, if not completely eliminated, once bilateral trade is adjusted by the market sizes of the trading partners. This should not come as a huge surprise, because what size adjustment does in regard to heteroscedasticity, is essentially to re-scale the variance of the disturbances to decrease (eliminate) its variability. Nonetheless, we believe that the PPML estimator should be favoured if allowed by a model's structure, owing to its consistent treatment of heteroscedasticity and for samples with many zeroes.

21 On a related note, Sun, Henderson, and Kumbhakar (2010) make good points, which are valid in our setting, about the potential biases due to log-linearization and approximation. As we already showed, our main specification does pass the Ramsey adequacy test but, in relation to the approximation biases discussed in Sun, Henderson, and Kumbhakar (2010), we would like to attribute part of this to the rich fixed effects structure of our model, which allows us to account for large series of omitted observable and unobservable variables. This is confirmed by a series of experiments from the technical appendix. Finally, even though our approach works well for our sample, we recognize the need for a more consistent econometric treatment of heteroscedasticity and the log-linearization and approximation biases in dynamic gravity.

lagged dependent variable. This suggests that the country-pair fixed effects have completely accounted for the Nickell dynamic bias. It is also worth noting that with an estimate of $\delta = 0.141$ (st.e. 0.017) this specification comes even closer to the discount parameter estimates from the macro literature.

In the next experiment we employ the Arellano-Bover (1995) / Blundell Bond's (1998) system-GMM estimator, which, by construction, not only accounts for the dynamic econometric concerns raised above, but, in addition, allows for direct estimation of the coefficients of the standard gravity variables (distance, contiguity, etc.) because it estimates the model as a system of equations in levels and instruments with differenced instruments. This makes it particularly appealing for gravity-type estimations.[22] The system-GMM estimates from column (5) are econometrically sound, as they pass the RESET test with $\chi^2(1) = 0.37$, the Sargan test of overidentifying restrictions with $\chi^2_{15} = 23.16$, and the Arellano-Bond test for autocorrelation in the disturbances by rejecting (as expected) the null hypothesis of no AR(1) errors with $z = -7.74$, but passing the test for second-order serial correlation AR(2) with $z = 1.11$. Furthermore, the system-GMM estimates are superior to the previous findings on three grounds. First, we estimate a positive and significant contemporaneous FTA effect and a negative and significant lagged FTA effect, exactly as predicted by our theory. Second, we obtain reasonable estimates on the standard gravity coefficients. In fact, the long-run transforms of the estimates on DIST, CLNY, BRDR, and LANG are not statistically different compared with their counterparts from the 'static' setting from column (1), which confirms our conjecture that the effects of the time-invariant covariates are not subject to panel biases. Third, the system-GMM estimator produces an estimate of $\delta = 0.107$ (st.err. 0.030), which is very much in accordance with our priors. Finally, once again, we do not find significant Euro effects.

Even though we obtain a positive and significant contemporaneous FTA effect (β_2) and a negative and significant lagged FTA effect (β_3), our theory imposes a specific functional relationship between the two estimates, $\beta_3 - \beta_2(1 - \delta) = 0$. This relationship does not seem to be strictly supported by the data, even though the difference $\beta_3 - \beta_2(1 - \delta) = -0.09$ (st.err. 0.038) is only marginally different than zero. In our final experiment, we take our theory literally and we estimate (20) by imposing the structural relationships between its parameters.[23] In particular, our theoretical specification implies that $\beta_1 = 1 - \delta$, the lagged FTA parameter is $\beta_3 = -\beta_1\beta_2$, and the lagged EZ parameter is $\beta_5 = -\beta_1\beta_4$. Results from the last column of table 1 are obtained with a non-linear estimator

22 We also experiment with the Anderson-Hsiao IV estimator, which estimates the model in differences, and with the Arellano-Bond (1991) difference-GMM estimator, which treats Anderson-Hsiao's econometric model as a system of equations, one for each t, and uses as instruments all possible lags of the endogenous variables along with the exogenous regressors. Both estimators produce results similar to the ones reported in table 1. These are reported in the technical appendix, which can be found at cje.economics.ca.

23 We are grateful to a referee for this suggestion and to Werner Antweiler for encouraging us to pursue it.

that imposes these restrictions. Several properties stand out. First, the estimate of the discount parameter δ, which this time we obtain directly and use to construct the estimate for $STRADE_{ij,t-1}$, is very precise and close to the corresponding reduced-form estimates from columns (3) and (4). Second, we find the estimate of the total FTA effects to be significantly lower than its system-GMM counterpart. Finally, we see that even when the structural relationships of our theory hold, the Euro has an economically small and statistically insignificant total effect on trade.

In sum, our empirical analysis and sensitivity experiments indicate that the dynamic theory-founded specification of the gravity model with a lagged dependent variable regressor, contemporaneous and lagged trade barriers, and time-varying, directional, fixed effects performs reasonably well. Our results suggest that omitting the dynamic considerations may affect the estimates of the time-varying variables, but we find no evidence for changes in the time-invariant gravity variables. In regard to the effects of free trade agreements and the Euro on bilateral trade, we find sizeable and significant FTA trade volume effects, but we do not find evidence of significant EZ effects. Finally, a series of experiments presented in the technical appendix support the robustness of our results and suggest that panel data gravity estimations should be obtained with time-varying, directional, country-specific fixed effects.

5. Simulation analysis

Our goal in this section is to investigate the effects of a unilateral increase in trade protection adopted by one of the trading partners and to study the differences between the dynamic and the static gravity setting in the response of bilateral trade flows, inward and outward multilateral resistances, and macroeconomic variables. We proceed in two steps. First, we calibrate the general equilibrium model using some of the results of the empirical estimations of section 4 as well as other parameters that are standard in the real business cycle literature. Then, we solve the model numerically and we compute the response to a one-time permanent shock to trade costs. Details on the calibration and the numerical method used to solve the model as well as the impulse response function plots for all endogenous variables in the system are included in the technical appendix.

The two key structural parameters that govern the evolution of the variables under investigation are the rate of capital depreciation, δ, which also captures persistence in bilateral trade, since it is the sole parameter in front of the lagged dependent variable in our econometric specification, and the elasticity of import demand, σ. While the qualitative results of our simulation analysis are not sensitive to alternative specifications of δ, experimenting with different values of σ allows us to gain additional insights on the behaviour of the variables of interest.

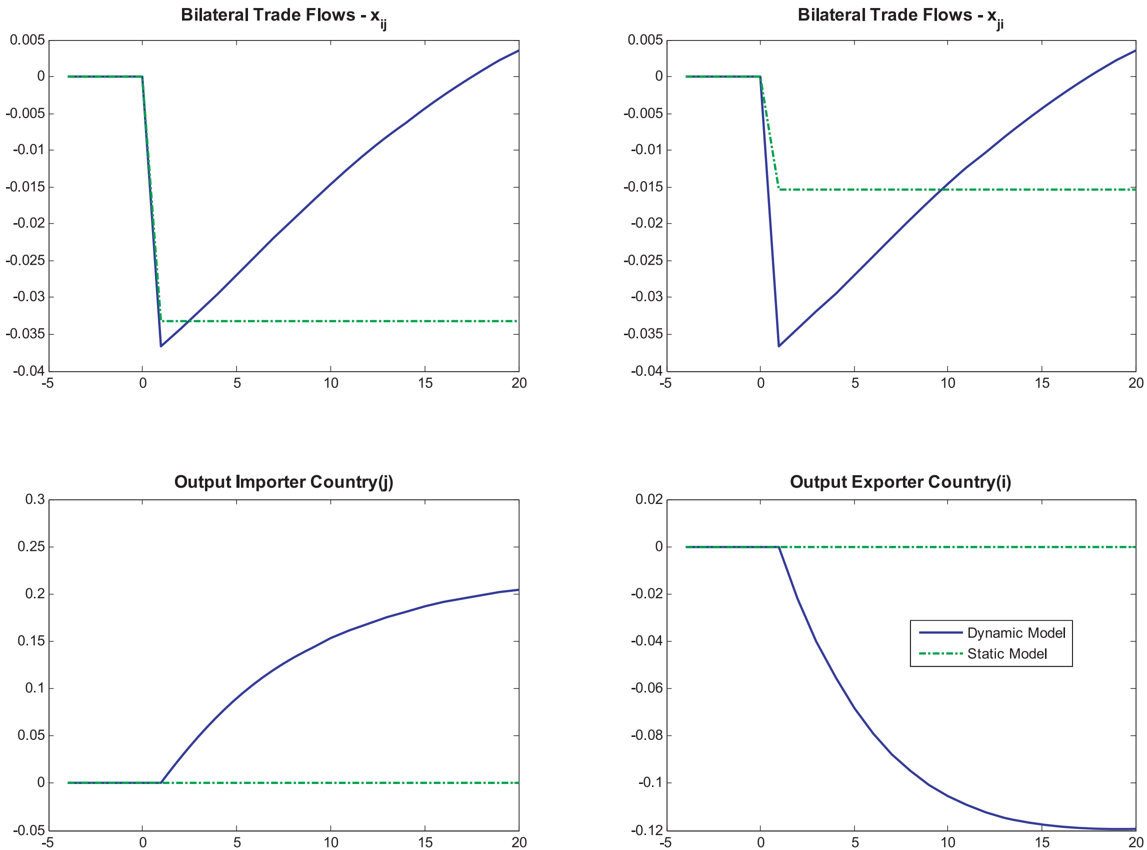

FIGURE 1 Impulse response functions to an increase in trade protection, $\sigma = 1.02$

The results in figure 1 show the impulse response functions for both our benchmark dynamic model with endogenous output and the static gravity model of AvW (2003) for bilateral trade flows and output. They are obtained for a 100% unilateral increase in trade costs (possibly caused by an increase in tariff rates or other non-tariff trade barriers) with a value of $\delta = 0.107$ (estimated in section 4, see column (5) of table 1) and a value of σ that approaches unity from above ($\sigma = 1.02$), which is standard in the open economy macroeconomics literature. In what follows, we discuss the behaviour of equilibrium allocations, focusing mostly on the subsystem of equilibrium conditions given by the gravity equation:

$$x_{ij,t} = \frac{y_{i,t}}{y_t^W}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}\left[\phi y_{j,t} + (1-\delta)x_{ij,t-1}^{\frac{1}{\alpha}}\left(\frac{y_{t-1}^W}{y_{i,t-1}}\right)^{\frac{1}{\alpha}}\left(\frac{t_{ij,t-1}}{\Pi_{i,t-1}P_{j,t-1}}\right)^{\frac{(\sigma-1)}{\alpha}}\right]^{\alpha};$$

the equation for the inward multilateral resistance

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{y_{i,t}}{y_t^W},$$

which consistently aggregates bilateral trade costs across all partners for the consumers in a given country j as if the country imported from a single world market, and the equation for the outward resistance

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{y_{j,t}}{y_t^W},$$

which consistently aggregates bilateral trade costs across all partners for the shippers in a given region i as if the region exported to a single world market.

As previously discussed, any change in trade costs will affect bilateral trade flows directly and indirectly. The indirect effects are derived from: (1) the endogenous change in the multilateral resistance terms, which is still present in the static setting; and (2) the endogenous change in country sizes. Therefore, endogenous changes in country size affect trade flows directly (as is evident from equation (14)) and indirectly, through their impact on multilateral resistances. Country-size effects are not present in the static setting.

In order to understand the ultimate impact of trade protection on bilateral trade flows, we first consider its impact on the multilateral resistance (MR) terms. The technical appendix shows the MR charts. Start with the outward multilateral resistances (OMRs). Our simulations indicate that in the exporter country i, which does not change its trade policy, the OMR (Π_i) will go up in both the static and the dynamic setting. The main explanation is the direct effect of the increase in bilateral trade costs (t_{ij}). More important, however, the standard static model seems to overestimate the effect of protection on Π_i. The exporter's OMR increases by less when output is endogenous. The reason is that, provided that the OMRs are inversely related to output shares (see Π_i definition on previous page), the proportional increase in the importer's output y_j, in the dynamic setting, is larger than the decrease in the exporter's production y_i as indicated in figure 1.

When we consider the importer's OMR (Π_j), simulation results indicate that it falls in both the static and the dynamic setting, the decrease being larger in the dynamic model. Once again, the difference between the two models comes from the endogenous country-size effect. The increase in the importer's output (which dominates the decrease in the exporter's output), directly results in a decrease in Π_j. The net effect of a unilateral increase in trade protection imposed by country j is a loss in terms of higher OMRs (i.e., the proportional increase in Π_i is larger than the reduction in Π_j). Worthy of note is that this net loss is smaller when country sizes are endogenous to trade policy.

Next, we turn to the inward multilateral resistances (IMRs). As expected, the importer's IMR, P_j, increases in both the static and the dynamic setting, by more in the latter. The reason is that endogenous output forces make the terms of trade (defined here as the relative price of imports to exports) fall by less in our model than in the standard setup. Therefore, we conclude that the standard model underestimates the increase in P_j. The exporter's IMR, P_i, falls in both the static and the dynamic model. The economic intuition behind the fall in the IMR for the consumers in i is that when export profitability for the shippers in i is decreased by the higher tariffs in j, this lowers the domestic prices in i.[24] Hence, consumers gain in this country. Moreover, the static setting overestimates the fall in IMR for the exporter; that is, P_i falls less in the dynamic setting where output in country i falls endogenously, working in the direction of raising prices in that country.

Our analysis reveals an important consequence of trade protection policy that is barely captured by the static model: the net effect on all consumers in the world is very small in the static model. However, when output is endogenous, the net effect on the consumers in the world is a clear loss in terms of higher prices. The intuition is that when output is endogenous, trade protection reallocates production to the less efficient producers and therefore results in higher prices.

We now analyze the changes in bilateral trade flows. As expected, exports from i to j fall in both the dynamic and the static model. The main reason is the increase in t_{ij}, which dominates the effects of an increasing OMR for the exporter (Π_i) and IMR for the importer (P_j). In addition, there are two differences between the dynamic and the static treatment. First, the initial impact is stronger in the dynamic model. The main explanation is that even though the output in region j increases by more than output in i falls, this increase is caused by an increase

24 To see this, consider the opposite case: a unilateral tariff decrease in j will give the producers in i the opportunity to export more abroad, this will bid up domestic prices, and hurt the consumers in i.

in investment, while the level of consumption of final goods in j falls, so that, all else equal, exports to this region fall.

It is important to note, as evident from the consumption charts, that the static model underestimates the drop in j's consumption. Our calibrations indicate that in the dynamic model with endogenous output effects C_j falls about seven times as much as in the static endowment economy model, which is in part explained by the fact that the drop in consumption is needed to finance the increase in investment in country j. This result has potential implications for welfare analysis.

Second, the initial fall in x_{ij} is followed by a gradual increase in the next 20 periods. This is due to the increase in income caused by the trade protection-induced increase in capital accumulation and output in country j. The adjustment effect is strong enough to overcome the initial larger fall in the exports from i to j in the dynamic model. Our analysis shows that the new steady state in the dynamic model is characterized by a volume of exports from i to j larger than in the static model that lacks the *endogenous country size* effect. This result provides a possible case for trade policy intervention.

Interestingly, even though the direct bilateral trade costs of exporting from j to i, the t_{ji}s, have not changed (we investigate only a unilateral increase in t_{ij}), we still observe a fall in x_{ji} for both the static and the dynamic setting. The reason is that any change in bilateral trade costs results in changes in all multilateral resistances, which in turn affect bilateral trade flows. The decrease in x_{ji} is larger in the dynamic setting. The reason is the increase in both the inward multilateral resistance for country i and the outward multilateral resistance for country j, which act together to lower j's exports. Even though the endogenous country-size effect pushes j's exports up, this effect is overcome by the net changes in the multilateral resistance terms. This finding reveals the importance of trade cost effects channelled through the multilateral resistance terms. The latter effects are ignored in almost all gravity applications concerned with the determinants of bilateral trade. However, our simulations show that they can be very large and should be taken into account.

Regarding the terms of trade, defined here as the price of imports relative to that of exports, our simulations show that the standard static model overestimates the appreciation that typically follows an increase in protectionism. In the static model, the only effect on the terms of trade from an increase in tariffs is a demand-side effect arising from a reduction in the demand for imported goods that causes terms of trade to improve. The effect on the terms of trade also explains that the increase in P_j is smaller in the standard, static endowment economy than in the dynamic, endogenous output economy.

Next, we describe the behaviour of the model for a larger value of the elasticity of import demand, $\sigma = 2$. The new simulations are reported in figure 2. These results reveal some interesting insights about the role of σ on the outcomes of a unilateral increase in trade protection. They also suggest some important qualitative, as well as quantitative, differences in the comparisons of the dynamic

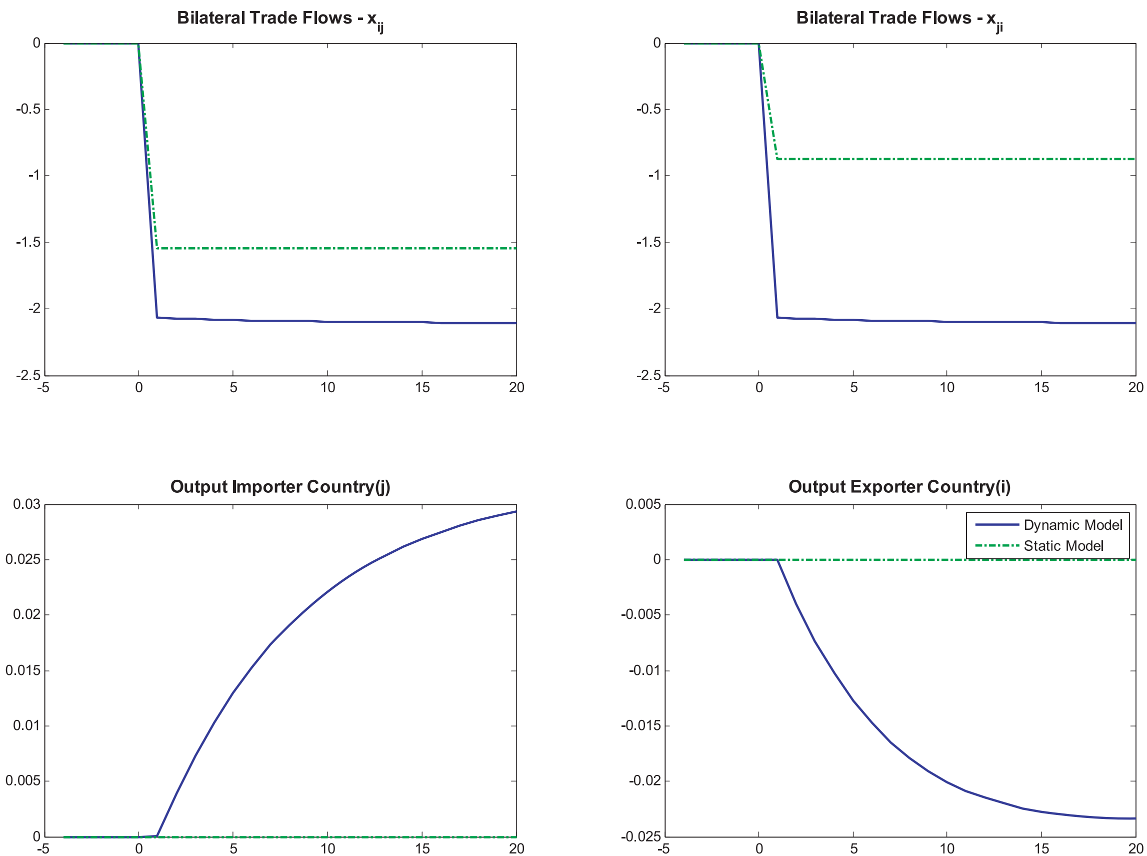

FIGURE 2 Impulse response functions to an increase in trade protection, $\sigma = 2$

and the static models. The new findings and insights are mainly due to the fact that a larger elasticity of import demand magnifies the trade cost effects, and makes the direct endogenous country-size effects relatively less important. This is the explanation for the larger magnitude in the response of all trade variables and the smaller magnitude in the response of all macro variables.

We discuss two of the qualitative implications obtained with the larger elasticity of import demand. The first one is that the net effect of a unilateral increase in trade protection on the consumers in the world is positive when the elasticity of import demand is large. Even though the consumers in the country with higher tariffs still suffer from higher prices, this effect on P_j is dominated by a larger fall in the IMR for the consumers in i (P_i). In the dynamic model the fall in the IMR for i is also larger in magnitude than the increase in the IMR for j. The economic intuition is that consumers in j are hurt less by the higher import prices when imports are closer substitutes to domestically produced goods.

The second, and more interesting, implication of using a larger elasticity is on the producers' side. In particular, our results indicate that producers in the country that raises its tariff rate will actually end up being worse off. The explanation is that, even though the higher tariffs imposed by country j do not directly affect the exporting costs faced by the producers in j, the higher tariffs result (through the GE forces of the model) in higher outward multilateral resistance or shipping costs faced by these exporters. Moreover, this effect is magnified by a larger elasticity of import demand. Overall, this analysis implies that the effects of any unilateral increase in trade protection depend crucially on the elasticity of import demand, and that trade policy should be applied in a discretionary fashion to different categories of commodities (or industries) based on their import demand elasticity.

6. Conclusions

In this paper we build a dynamic model as a new theoretical foundation of gravity, an alternative to those foundations already provided by Anderson (1979) and Anderson and van Wincoop (2003) in a static setting. We then use our structural framework to provide clear empirical implications for gravity-type estimations with panel data. We fill an important gap in the literature, since so far the theory of gravity is only static, while trade flows data are intrinsically dynamic (in the sense that they are autocorrelated over time, since the lagged values of trade flows, trade barriers, and multilateral resistances all play a significant role in explaining contemporaneous trade). We also study the general equilibrium effects of trade protection in a dynamic model with asset accumulation and where country sizes are endogenous.

The structural dynamic gravity equation that we derive nests its static counterpart from AvW (2003) and introduces two additional intuitive elements that capture persistence in both trade flows and trade protection. Our model has two main implications for gravity estimations in a dynamic setting. First, persistence in both trade flows and trade barriers should be controlled for and, second, multilateral resistance terms should be accounted for by time-varying directional (source and destination) fixed effects. An application to the effects of FTAs and the Eurozone on bilateral trade reveals that our dynamic theory-founded econometric specification (with a lagged dependent variable and time-varying directional fixed effects) is superior to alternative fixed effect treatments of the multilateral resistances, even when the latter also account for trade persistence.

General equilibrium numerical simulations of our model reveal that the standard static, partial equilibrium model without capital accumulation and endogenous country sizes overestimates the negative aggregate effects of a unilateral increase in trade protection on producers in all countries, but underestimates the negative aggregate effects on consumers. Most important, we find that when the elasticity of import demand is sufficiently large, trade protection may actually hurt producers in the country that is imposing higher tariffs. In addition, our simulations of the structural model show that the effects of a change in bilateral trade costs that are channelled through the multilateral resistance terms are large and should be accounted for in the analysis and the interpretation of the results from gravity applications concerning the effects of the determinants of bilateral trade flows.

We also lay the foundation for several ideas for future work. First, in the current paper we assume that labour is country-specific. An interesting area for further research is to model the world labour market. This will allow us to study labour migration issues. Second, since our model already incorporates dynamic elements related to optimal asset accumulation decisions, it would also be interesting to extend it by modelling one global capital market. This will allow us to explore issues related to international capital flows, FDI in particular. Building a gravity model that simultaneously accounts for the movement of goods, labour, and capital is a tempting and very ambitious task worthy of future efforts.

Another potentially important contribution is to extend our theoretical setting to accommodate a dynamic gravity model disaggregated by type of good. On the one hand, this will shed more light on the effects of the elasticity of import demand and its implications for trade policy. In addition, a disaggregated dynamic gravity model will allow for estimation of the capital depreciation parameters, the δs, at both the country- and the sectoral level. Obtaining such estimates from a dynamic theory-founded gravity equation may be of interest to researchers in various fields.

Finally, we believe that further general equilibrium simulations that allow for asymmetries in country size, technological advancement, and trade costs may generate interesting insights about the behaviour of trade flows and the welfare effects of protection on world producers and consumers.

References

Anderson, J.E. (1979) 'A theoretical foundation for the gravity equation,' *American Economic Review* 69, 106–16

Anderson, J.E., and E. van Wincoop (2003) 'Gravity with gravitas: a solution to the border puzzle,' *American Economic Review* 93, 170–92

Anderson, J.E., and Y.V. Yotov (2010a) 'The changing incidence of geography,' *American Economic Review* 100, 2157–86

— (2010b) 'Specialization: pro- and anti-globalizing, 1990–2002,' NBER Working Paper No. 16301

— (2011) 'Terms of trade and global efficiency effects of free trade agreements, 1990–2002,' NBER Working Paper No. 17003

Anderson, T.W., and C. Hsiao (1982) 'Formulation and estimation of dynamic models using panel data,' *Journal of Econometrics* 18, 47–82

Arellano, M., and S. Bond (1991) 'Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations,' *Review of Economic Studies* 58, 277–97

Arellano, M., and O. Bover (1995) 'Another look at the instrumental variables estimation of error components models,' *Journal of Econometrics* 68, 29–51

Backus, D., P. Kehoe, and F. Kydland (1992) 'International real business cycles,' *Journal of Political Economy* 100, 745–75

— (1994) 'Dynamics of the trade balance and the terms of trade: the J-curve,' *American Economic Review* 84, 84–103

Baier, S.L., and J. Bergstrand (2004) 'Economic determinants of free trade agreements,' *Journal of International Economics* 64, 29–63

— (2007) 'Do free trade agreements actually increase members' trade?,' *Journal of International Economics* 71, 72–95

Baldwin, R. (2006) 'In or out: does it matter? An evidence-based analysis of the euro's trade effects,' CEPR report

Baldwin, R., and D. Taglioni (2006) 'Gravity for dummies and dummies for gravity equations,' NBER Working Paper No. 12516

Baldwin, R., F. Skudelny, and D. Taglioni (2005) 'Trade effects of the euro – evidence from sectoral data,' Working Paper Series 446, European Central Bank, Frankfurt

Baltagi, B.H., S.H. Song, and W. Koh (2003) 'Testing panel data regression models with spatial error correlation,' *Journal of Econometrics* 117, 123–50

Baltagi, B.H., S.H. Song, B.C. Jung, and W. Koh (2007) 'Testing for serial correlation, spatial autocorrelation and random effects using panel data,' *Journal of Econometrics* 140, 5–51

Berger, H., and V. Nitsch (2008) 'Zooming out: the trade effect of the euro in historical perspective,' *Journal of International Money and Finance* 27, 1244–60

Blundell, R., and S. Bond (1998) 'Initial conditions and moment restrictions in dynamic panel data models,' *Journal of Econometrics* 87, 115–43

Campbell, D. (2010) 'History, culture and trade: a dynamic gravity approach,' working paper, University of California at Davis

Casacuberta, C., and N. Gandelman (2006) 'Protection, openness and factor adjustment: evidence from the manufacturing sector in Uruguay,' World Bank Policy Research Working Paper No. 3891

Cavalcanti Ferreira, P., and J. Rossi (2003) "New evidence from Brazil on trade liberalization and productivity growth,' *International Economic Review* 44, 1383–405

Cheng, I.-Hui, and H.J. Wall (2002) 'Controlling for heterogeneity in gravity models of trade,' Federal Reserve Bank of St. Louis Working Paper Vol. 1999-01C

— (2004) 'Controlling for heterogeneity in gravity models of trade,' Federal Reserve Bank of St. Louis Working Paper, vol. 1999-010C

Cuñat, A., M. Maffezzolli (2007) 'Can comparative advantage explain the growth of US trade?' *Economic Journal* 117, 583–602

De Nardis, S., R. De Santis, and C. Vicarelli (2007) 'The euro's effect on trade in a dynamic setting,' ISAE Working Paper 80
De Souza, L.V. (2002) 'Trade effects of monetary integration in large, mature economies: a primer on the European monetary union,' Kiel Working Paper 1137, Kiel Institute for the World Economy
Egger, P. (2000) 'A note on the proper econometric specification of the gravity equation,' *Economic Letters* 66, 25–31
Eichengreen, B., and D. Irwin (1996) 'The role of history in bilateral trade flows,' NBER Working Paper No. 5565
— (1998) NBER chapters in *The Regionalization of the World Economy*, ed. Jeffrey Frankel (Chicago: University of Chicago Press)
Feenstra, R. (2004) *Advanced International Trade* (Princeton: Princeton University Press)
Frankel, J.A. (1997) *Regional Trading Blocs in the World Economic System* (Washington, DC: Institute for International Economics)
Glick, R., and A.K. Rose (2002) 'Does a currency union affect trade? The time-series evidence,' *European Economic Review* 46, 1125–51
Helpman, E., M.J. Melitz, and Y. Rubinstein (2008) 'Estimating trade flows: trading partners and trading volumes,' *Quarterly Journal of Economics* 123, 441–87
Mayer, T., and S. Zignago (2006) 'Notes on CEPII's distances measures,' CEPII working paper
Magee, Chris. (2003) 'Endogenous preferential trade agreements: an empirical analysis,' in *Contributions to Economic Analysis and Policy*, Vol. 2 (Berkeley, CA: Berkeley Electronic Press)
Micco, A., E. Stein, and G. Ordonez (2003) 'The currency union effect on trade: early evidence from EMU,' *Economic Policy* 18, 317–56
Nickell, S.J. (1981) 'Biases in dynamic models with fixed effects,' *Econometrica* 49, 1417–26
Roodman, D. (2006) 'How to do xtabond2: an introduction to "difference" and "system" GMM in Stata,' Working Paper 103, Center for Global Development, Washington, DC
Rose, A. (2000) 'One money, one market: the effect of common currencies on trade,' *Economic Policy* 15, 7–46
— (2004) 'Do WTO members have more liberal trade policy?' *Journal of International Economics* 63, 209–35
Ruhl, K. (2008) 'The international elasticity puzzle,' working paper, Stern School of Business, New York University
Santos Silva, J., and S. Tenreyro (2006) 'The log of gravity,' *Review of Economics and Statistics* 88, 641–58
— (2010) 'Currency unions in prospect and retrospect,' *Annual Review of Economics* 2, 51–74
Saul, S. (1960) *Studies in British Overseas Trade, 1870–1914* (Liverpool: Liverpool University Press)
Spearot, A. (2008) 'Trade liberalization, acquisition composition, and productivity: the case of New Zealand,' working paper, University of California, Santa Cruz
Sun, K., D. Henderson, and S.C. Kumbhakar (2011) 'Biases in approximating log production,' *Journal of Applied Econometrics* 26, 708–14
Tinbergen, J. (1962) *Shaping the World Economy* (New York: Twentieth Century Fund)
Trefler, D. (1993) 'Trade liberalization and the Theory of Endogenous Protection: an econometric study of U.S. import policy,' *Journal of Political Economy* 101, 138–60
— (2004) The long and the short of the Canada-U.S. Free Trade Agreement,' *American Economic Review* 94, 870–95
Wooldridge, J.M. (2002) *Econometric Analysis of Cross Section and Panel Data* (Cambridge, MA: MIT Press)