# Trade, Domestic Frictions, and Scale Effects*

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**Abstract**

Because of scale effects, idea-based growth models have the counterfactual implication that larger countries should be much richer than smaller ones. New trade models share this same problematic feature: although small countries gain more from trade than large ones, this is not strong enough to offset the underlying scale effects. In fact, new trade models exhibit other counterfactual implications associated with scale effects – in particular, domestic trade shares and relative income levels increase too steeply with country size. We argue that these problems are largely a result of the standard assumption that countries are fully integrated domestically, as if they were a single dot in space. We depart from this assumption by treating countries as collections of symmetric regions that face positive costs to trade amongst themselves. The resulting model is largely consistent with the data. For example, for a small and rich country like Denmark, our calibrated model implies a real per-capita income of 85 percent the United States's, much closer to the data (94 percent) than the trade model with no domestic frictions (40 percent).

JEL Codes: F1; F2; O4. Key Words: International trade; Gains from trade; Gravity; Domestic geography; Scale effects; Multinational production.

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# 1 Introduction

Scale effects are so central a feature of innovation-led growth theory that, in Jones's (2005) words, "rejecting one is largely equivalent to rejecting the other." Because of scale effects, idea-based growth models such as Jones (1995) and Kortum (1997) imply that larger countries should be richer than smaller ones.[1] It is widely known, however, that this is not borne out in the data; to put it crudely, Belgium is not poorer than France and Great Britain is not poorer than the United States.[2]

New trade models such as Krugman (1980), Eaton and Kortum (2001, 2002) and Melitz (2003) are also idea-based models, and carry the same counterfactual implication that productivity strongly increases with country size. One might expect scale effects in such models to be offset by the fact that small countries tend to gain more from trade than large ones. It turns out, however, that although small countries do gain more from trade, these gains are not large enough to neutralize the underlying scale effects.[3] In fact, new trade models exhibit other counterfactual implications associated with scale effects – in particular, domestic trade shares and relative income levels increase too steeply with country size.

Our paper argues that these counterfactual scale effects are largely a result of the crude way in which geography has been treated in these growth and trade models. The usual assumption is that countries are fully integrated domestically, as if they were a single dot in space. We depart from this assumption in the simplest possible way by treating countries as a group of symmetric regions that face positive costs to trade amongst themselves. By including domestic trade costs, we capture the fact that countries are not fully integrated economies, and by assuming symmetry across regions within countries we ensure that the resulting country-level trade flows are still described by the standard gravity model of trade. A critical implication of our model is that domestic trade costs are positive and increase with country size, thereby weakening the underlying scale effects.

[1] First-generation endogenous growth models such as Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992) feature "strong" scale effects, whereby scale increases growth, whereas second-generation semi-endogenous growth models such as Jones (1995), Kortum (1997), Aghion and Howitt (1998, Ch. 12), Dinopoulos and Thompson (1998), Peretto (1998), and Young (1998), feature "weak" scale effects, whereby scale increases income levels rather than growth (see Jones, 2005, for a detailed discussion). Models that do not display any scale effects, such as Lucas (2009), Alvarez, Buera, and Lucas (2013), and Lucas and Moll (2013), depart from the standard assumption that ideas are non-rival by assuming that (1) knowledge can only be used in production when it is embodied in individuals with limited time endowments, and that (2) individuals face search frictions in learning about better ideas.

[2] See Rose (2006) for a systematic exploration of scale effects in the data.

[3] This is related to the finding in Waugh (2010) that the gains from trade are not very different between rich and poor countries.

We calibrate the strength of economies of scale by appealing to the growth and trade literatures, as well as cross-country estimates of scale effects, and we calibrate domestic trade costs so that the model is consistent with domestic trade data available for both the United States and Canada. We also estimate standard gravity equations to show that the positive relationship between calibrated domestic trade costs and size is supported by the data.

The calibrated model reveals that domestic trade costs greatly contribute to improve the model's fit with the data. For example, for a small and rich country like Denmark, our calibrated model implies a productivity level of 85 percent (relative to the United States), much closer to the data (94 percent) than the level implied by the trade model with no domestic trade costs (40 percent). Moreover, by offsetting scale effects, domestic trade costs not only help the model better match the observed productivity levels across countries; they also make the model better match observed import shares, relative income levels, and prices.

We are not the first to point out the importance of country size for trade flows and relative income levels in new trade models. Anderson and van Wincoop (2003) and Anderson and Yotov (2010) theoretically show that (for some special cases) home bias increases with country size, leading to lower import shares for larger countries, while Redding and Venables (2004) and Head and Mayer (2011) empirically show that relative income levels increase with a measure of "market potential," which is increasing in country size. Our contribution to this literature is twofold: first, we show that, relative to the data, these size effects are too strong in models without domestic trade costs, and second, we develop a trade model with domestic trade costs that better matches the observed relationship between country size and productivity, import shares, relative income levels, and prices.[4]

Our paper is related to Alvarez and Lucas (2007) and Waugh (2010), who calibrate an Eaton and Kortum (2002) model to match observed trade flows and cross-country income levels. Both of these calibrations assume that there are no domestic trade costs, but allow technology levels to vary across countries. In fact, in the calibrated models, strong scale effects are avoided by having technology levels that decrease rapidly with country size. Since it is hard to defend such systematic variation in the level of technologies, we calibrate the technology parameters to observed R&D intensities, which do not vary systematically with size in our sample of OECD countries.

In related work, Redding (2012) quantifies the gains from trade in a model with perfect

[4]Head and Mayer (2011) recognized the importance of domestic frictions and estimated gravity equations that include the domestic trade pair and a measure of internal distance (i.e., a transformation of country area) to proxy for domestic trade costs. They did not explore the role of domestic frictions for import shares and income levels.

labor mobility within countries composed of multiple asymmetric regions. In this paper we retain the assumption that regions are symmetric for three reasons: first, because Redding's analysis requires bilateral-trade data at the region level, which are available only for the United States and Canada; second, because under symmetry our model exhibits a standard gravity equation for country-level trade flows; and third, because at the national level the gains from trade do not seem to be affected substantially by this assumption.[5] This last point seems consistent with the results of Allen and Arkolakis (2013), who develop a model of trade and labor mobility for an economy with a continuum of regions arranged in a realistic geographic structure. In their calibration for the United States, they deal with the fact that trade data are available only at the state level by assuming that the multilateral resistance terms are the same among the continuum of regions belonging to a state, just as it would occur if those regions were symmetric. They use the model to show that inter-state trade flows are not significantly distorted by this symmetry assumption.

Finally, our paper is related to a literature exploring the theoretical and empirical relationship between country size, openness, and income. Ades and Glaeser (1999) and Alesina, Spolaore, and Wacziarg (2000) find a positive effect of country size and trade on income levels, with a negative interaction effect indicating that the positive scale effect is weakened by openness to trade. Frankel and Romer (1999) and Alcala and Ciccone (2004) also find that country size and trade openness (instrumented by geography) lead to higher income levels.

The rest of the paper is organized as follows. In Section 2 we present the baseline model of trade that incorporates domestic trade costs and derive some analytical results. Section 3 describes the calibration of the model. Section 4 presents the quantitative results focusing on the model's implications for TFP across countries taking domestic trade shares as given, while Section 5 presents the implications of the model for trade shares, prices, and relative income levels. In Section 6 we extend the baseline model to allow for multinational production as an additional channel for the gains from openness. Section 7 concludes.

[5]We explore the quantitative implications of our symmetry assumption by using the calibrated version of Redding's model to trade data—both between regions within and across countries—for Canada and the United States. We compute the gains from trade for a country in the model with and without symmetric regions, alternately. The results are reassuring: the difference between the gains from trade in the model with and without asymmetries are virtually identical (9.7 versus 9.5 percent for Canada, and 1.1 versus 0.9 percent for the United States, respectively). The details of this exercise are available upon request.

# 2 Baseline Model

We start with the simple version of the Ricardian trade model developed by Eaton and Kortum (2002 - EK) but applied to subnational economies that we call "regions" rather than countries. As we discuss below, equivalent formulations of the model could be derived from Krugman (1980) or Melitz (2003) instead of EK. After laying out the model at the level of regions, we present our assumptions on how to aggregate regions into countries. Since most data are for countries rather than regions, the country-level model is the one used later to think about the data.

There is a set of regions indexed by $m \in \{1, ..., M\}$ and a continuum of final goods in the interval $[0, 1]$. Preferences are CES with elasticity of substitution $\sigma$. Labor is the only factor of production, available in quantity $\widetilde{L}_m$ in region $m$, and immobile across regions.[6] Technologies are linear with good-specific productivities drawn from a Fréchet distribution with parameters $\theta$ and $\widetilde{T}_m$. There is perfect competition and iceberg trade costs $\widetilde{d}_{mk} \geq 1$ to export from $k$ to $m$, with $\widetilde{d}_{mm} = 1$. Bilateral trade flows between regions, $\widetilde{X}_{mk}$, statisfy the standard expression in the EK model,

$$\widetilde{X}_{mk} = \frac{\widetilde{T}_k \widetilde{w}_k^{-\theta} \widetilde{d}_{mk}^{-\theta}}{\sum_{k'} \widetilde{T}_{k'} \widetilde{w}_{k'}^{-\theta} \widetilde{d}_{mk'}^{-\theta}} \widetilde{X}_m, \tag{1}$$

where $\widetilde{w}_m$ is the wage in region $m$ and $\widetilde{X}_m \equiv \sum_k \widetilde{X}_{mk}$ is total expenditure in region $m$. In turn, price indices are

$$\widetilde{P}_m = \mu^{-1} \left( \sum_k \widetilde{T}_k \widetilde{w}_k^{-\theta} \widetilde{d}_{mk}^{-\theta} \right)^{-1/\theta} \tag{2}$$

where $\mu$ is a positive constant, given by $\mu \equiv \Gamma(\frac{1-\sigma}{\theta} + 1)^{1/(\sigma-1)}$.[7]

We depart from the standard practice of modeling countries as single economies, and instead think of countries as collections of regions. We index countries by $n \in \{1, ..., N\}$ and let $\Omega_n$ be the set of regions belonging to country $n$ and $M_n$ be the number of regions in that set. To be able to connect our model to country-level data, we make the following symmetry assumption:

**A1. [Symmetry]** *$\widetilde{L}_m = \widetilde{L}_{m'}$ and $\widetilde{T}_m = \widetilde{T}_{m'}$ for all $m, m' \in \Omega_n$, and $\widetilde{d}_{mk} = \widetilde{d}_{m'k'}$ for all $m, m' \in \Omega_n$ and $k, k' \in \Omega_i$.*

As we now explain, this assumption implies that, at the country-level, our model is

[6] As it is explained below, this assumption will not matter for our analysis.
[7] $\Gamma(.)$ is the Gamma function with $1 + \theta - \sigma > 0$.

isomorphic to the EK model with the only exception that the trade cost of a country with itself is a function of its size, $M_n$, and the trade cost among regions belonging to that country, $d_{nn} \equiv \widetilde{d}_{mm'}$ for $m \neq m'$ with $m, m' \in \Omega_n$. To proceed, we introduce notation to keep track of country-level variables. Let $L_n \equiv \sum_{m\in\Omega_n} \widetilde{L}_m$ and $T_n \equiv \sum_{m\in\Omega_n} \widetilde{T}_m$ denote the country-level labor endowment and technology parameters, respectively, and let $X_{ni} \equiv \sum_{m\in\Omega_n} \sum_{k\in\Omega_i} \widetilde{X}_{mk}$, $X_n \equiv \sum_i X_{ni}$, and $w_n = \widetilde{w}_m$ for $m \in \Omega_n$ denote country-level bilateral trade flows, total expenditure levels, and wage levels, respectively. For future reference, note that, thanks to A1, $\widetilde{L}_m = L_n/M_n \equiv \bar{L}_n$ and $\widetilde{T}_m = T_n/M_n \equiv \bar{T}_n$ for all $m \in \Omega_n$.

The following Proposition shows how to go from the region-level model to the country-level model that we can relate to the bilateral trade data (all proofs are in the Appendix):

**Proposition 1.** Country-level trade flows are

$$X_{ni} = \frac{T_i w_i^{-\theta} \tau_{ni}^{-\theta}}{\sum_j T_j w_j^{-\theta} \tau_{nj}^{-\theta}} X_n \tag{3}$$

and price indices at the country-level are

$$P_n = \mu^{-1} \left( \sum_j T_j w_j^{-\theta} \tau_{nj}^{-\theta} \right)^{-1/\theta} \tag{4}$$

where

$$\tau_{ni} \equiv \widetilde{d}_{mk} \text{ for } m \in \Omega_n \text{ and } k \in \Omega_i \text{ for } n \neq i, \tag{5}$$

and

$$\tau_{nn} \equiv \left( \frac{1}{M_n} + \frac{M_n - 1}{M_n} d_{nn}^{-\theta} \right)^{-1/\theta}. \tag{6}$$

If there were no domestic trade costs, i.e., $d_{nn} = 1$, then $\tau_{nn} = 1$ and the country-level model collapses to the standard EK model with trade costs given by (5). The key departure from this standard case, then, is caused by the presence of trade costs between regions belonging to the same country, $d_{nn} > 1$, which in our model leads to positive domestic trade costs given by (6). According to Proposition 1, these domestic trade costs are a weighted power mean with exponent $-\theta$ of the cost of intra-regional trade (which we assume is one) and the cost of trade between regions belonging to the same country ($d_{nn}$), with weights given by $1/M_n$ and $1 - 1/M_n$.

Equations (3) and (4) imply that trade shares are given by

$$\lambda_{ni} \equiv \frac{X_{ni}}{X_n} = \frac{T_i w_i^{-\theta} \tau_{ni}^{-\theta}}{(\mu P_n)^{-\theta}}. \tag{7}$$

Applied to the case of $n = i$, (7) leads to the following result for real wages in terms of technology levels, $T_n$, average domestic trade costs, $\tau_{nn}$, and (equilibrium) domestic trade shares, $\lambda_{nn}$,

$$\frac{w_n}{P_n} = \mu T_n^{1/\theta} \tau_{nn}^{-1} \lambda_{nn}^{-1/\theta}. \tag{8}$$

An immediate implication of this expression for real wages is that, even in the presence of domestic frictions, the gains from international trade (i.e., the change in the equilibrium real wage from autarky to the trade equilibrium) are the same as the ones in EK,

$$GT_n = \lambda_{nn}^{-1/\theta}. \tag{9}$$

Aggregate economies of scale arise in this model as soon as we acknowledge that the technology parameter $T_n$ is naturally increasing with population (see Eaton and Kortum, 2001). Formally, we make the following assumption:

**A2. [Technology Scales with Population]** $T_n = \phi_n L_n$ for all $n$.

We allow $\phi_n$ to vary with $n$ to reflect differences in "innovation intensity" across countries, but the important part of this assumption is that, conditional on $\phi_n$, technology levels are proportional to population. This result comes out naturally if we think of a "technology" as a productivity drawn from a Fréchet distribution and if we assume that the number of technologies is proportional to population.[8]

This is a good place to discuss how we could have derived equivalent formulations of the model based on Krugman (1980) or Melitz (2003). With Krugman (1980), all the results above would hold replacing $\theta$ by $\sigma - 1$ (with $\sigma$ the elasticity of substitution), and the assumption A2 would follow immediately from the free entry condition combined with the standard assumption that the fixed cost of production is not systematically related to country size. Equilibrium entry or variety produced in country $n$ would be $L_n/\sigma f_n$, where $f_n$ is the fixed cost of production in country $n$. Letting $T_n$ stand for entry or variety produced in country $n$, we would then have $T_n = L_n/\sigma f_n$. With Melitz (2003), we would need

[8]Formally, consider a region in country $n$, and let a "technology" be a productivity $\xi$ drawn from a Fréchet distribution with parameters $\theta$ and $\phi_n$, and assume that the number of technologies per good is equal to population, $\bar{L}_n$. It is then easy to show that the best technology for a good, $z \equiv \max \xi$, is distributed Fréchet with parameters $\theta$ and $\bar{T}_n = \phi_n \bar{L}_n$.

to assume that the productivity distribution is Pareto, as in Chaney (2008). If the Pareto shape parameter is $\theta$, then it is easy to show that $w_n/P_n \sim L_n^{1/\theta}\left(\bar{f}_n/\bar{L}_n\right)^{1/\theta-1/(\sigma-1)}\tau_{nn}^{-1}\lambda_{nn}^{-1/\theta}$, where $\bar{f}_n$ is the fixed cost of selling in any region of country $n$. Assuming either that $\theta \approx \sigma - 1$ or that $\bar{f}_n$ is proportional to $\bar{L}_n$, then $w_n/P_n \sim L_n^{1/\theta}\tau_{nn}^{-1}\lambda_{nn}^{-1/\theta}$, just as in (8) under A2.[9]

Under A2, (8) can now be written as

$$\frac{w_n}{P_n} = \mu\left(\phi_n L_n\right)^{1/\theta}\tau_{nn}^{-1}\lambda_{nn}^{-1/\theta}. \tag{10}$$

If there were no domestic frictions then $\tau_{nn} = 1$ and larger countries would exhibit higher real income levels with an elasticity given by $1/\theta$—conditional on $\lambda_{nn}$. This is because a larger population is linked to a higher stock of non-rival ideas (i.e., technologies), and more ideas imply a superior technology frontier. The strength of this effect is linked to the Fréchet parameter $\theta$: the lower is $\theta$, the higher is the dispersion of productivity draws from this distribution, and the more an increase in the stock of ideas improves the technology frontier. These are the aggregate economies of scale that play a critical role in semi-endogenous growth models (Kortum, 1997) and that underpin the gains from openness in EK-style models – see Eaton and Kortum (2002) and Arkolakis et al. (2008).

In the presence of domestic trade costs, economies of scale depend on how $\tau_{nn}$ is affected by size, $L_n$. To derive sharp results, we assume that all variation in country size comes from variation in the number of regions, $M_n$, with all regions being the same size and the domestic trade cost being the same across countries:

**A3. [Size Scales with the Number of Regions]** $L_n = M_n\bar{L}$ and $d_{nn} = d$ for all $n$.

We now arrive at our basic result for real wages:

**Proposition 2.** Under A1, A2 and A3, equilibrium real wages are given by

$$\frac{w_n}{P_n} = \mu \times \underbrace{\phi_n^{1/\theta}}_{\text{R\&D Intensity}} \times \underbrace{L_n^{1/\theta}}_{\text{Pure Scale Effect}} \times \underbrace{\left(\frac{1}{L_n/\bar{L}} + \frac{L_n/\bar{L} - 1}{L_n/\bar{L}}d^{-\theta}\right)^{1/\theta}}_{\text{Domestic Frictions}} \times \underbrace{\lambda_{nn}^{-1/\theta}}_{\text{Gains from Trade}}. \tag{11}$$

As (11) shows, there are four distinct terms that determine real wages across countries capturing, respectively, the effects of innovation intensity, pure scale effects, domestic

[9] The Appendix shows the derivations of these results.

frictions, and the gains from trade. Since $(\frac{1}{L_n}+\frac{L_n/\bar{L}-1}{L_n}d^{-\theta})^{1/\theta}$ is decreasing in size when $d>1$, the presence of domestic frictions weakens economies of scale. More specifically, the strength of economies of scale adjusted by the presence of domestic frictions—conditional on the gains from trade—is given by

$$\varepsilon \equiv \frac{d\ln\left[L_n^{1/\theta}\left(\frac{1}{L_n/\bar{L}}+\frac{L_n/\bar{L}-1}{L_n/\bar{L}}d^{-\theta}\right)^{1/\theta}\right]}{d\ln L_n}=\frac{1}{\theta}\left(\frac{d}{\tau_{nn}}\right)^{-\theta}.$$

If $d=1$ then $\tau_{nn}=1$ and $\varepsilon=1/\theta$; otherwise the term $(d/\tau_{nn})^{-\theta}$ is lower than one and offsets economies of scale, $\varepsilon<1/\theta$.

We have so far focused on the implications of domestic frictions on real wages conditional on domestic trade shares. To learn more about the unconditional effects of country size in the presence of domestic frictions, we need to impose some additional restrictions. In particular, we assume that international trade costs are uniform and that countries are symmetric in terms of their innovation intensity. Formally,

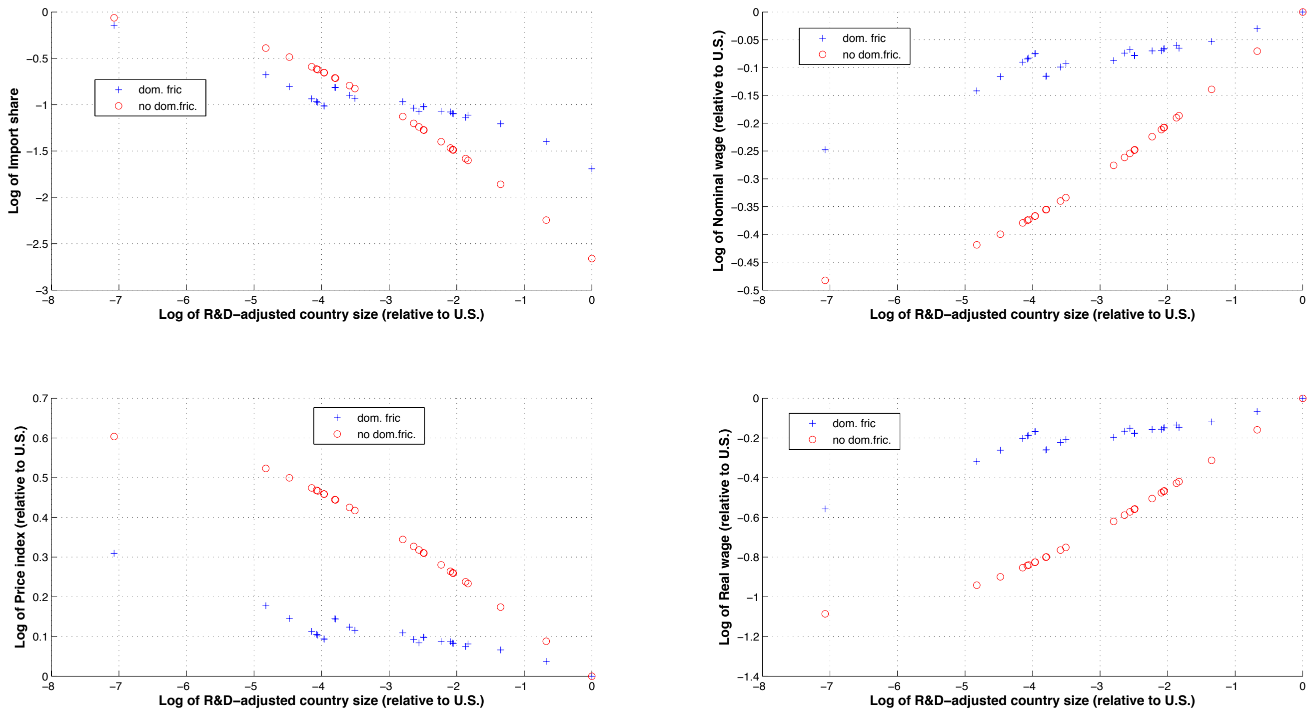
**A4. [Uniform Trade Costs and Innovation Intensity]** $\tau_{ni}=\tau$ for all $n\neq i$ and $\phi_i=\phi$ for all $i$.

Under this (admittedly strong) assumption, which we maintain only for the next Proposition, we can characterize how country size matters for import shares, wages and price levels:

**Proposition 3.** Assume A1, A2, A3 and A4. If $\tau>d$ then larger countries have lower import shares, higher wages, and lower price levels. If $\tau=d$ then larger countries have lower import shares, but wages and prices do not vary with country size.

As expected, import shares decline with country size and large countries gain less from trade, but aggregate economies of scale are strong enough so that the overall effect is for real wages to increase with size. The Proposition also establishes that real wages increase with country size both because of higher wages and because of lower prices. More importantly, these scale effects disappear when $\tau=d$. This suggests that scale effects should be strongest when there are no domestic frictions. This is illustrated in Figure 1. For $\theta=4$, we alternately fixed $d=1$ and $d=2.4$, and choose $\tau$ for each $d$ to match an average import share of 0.39 as observed in the data for our sample of 26 countries. For each case, the figure shows the implied import shares, nominal wages, real wages, and prices against country size. All four variables vary strongly with size in the model with no domestic frictions, but this dependence is severely weakened when domestic frictions are considered.

Figure 1: The Role of Domestic Frictions. Symmetry.




R&D-adjusted country size refers to $L_n$, where $L_n$ is a measure of equipped labor.

The strong relation between country size and import shares in the model with no domestic frictions in Figure 1 could be due to the restriction on trade costs imposed by A4. It might always be possible to replicate the effects of domestic frictions in a model without them if international trade costs were chosen appropriately. As we now show, the key is whether one allows for asymmetries in trade costs, and whether one deviates from A2 by allowing for a systematic pattern between innovation intensity ($T_i/L_i$) and country size ($L_i$). We explore this possibility by comparing the implications of three models that differ in terms of the assumptions on trade costs: symmetric trade costs with domestic frictions; asymmetric trade costs with asymmetries arising from importer-specific terms, as in Eaton and Kortum (2002); and asymmetric trade costs with asymmetries arising from exporter-specific terms, as in Waugh (2010). To proceed, let $\nu_{ni} = \nu_{in}$ for all $i \neq n$ be the symmetric component of trade costs and consider the following alternative assumptions for trade costs:

**A5. [Symmetric Trade Costs with Domestic Frictions]** $\tau_{ni}^{RRS} = \nu_{ni}$ for all $i \neq n$, and $\tau_{nn}^{RRS}$ as in (6).

**A5′. [Trade Costs with Asymmetries from Importer Effects]** $\tau_{ni}^{EK} = \kappa_n^{EK} \nu_{ni}$ for all $i \neq n$ and $\tau_{nn}^{EK} = 1$ for all $n$.

**A5″. [Trade Costs with Asymmetries from Exporter Effects]** $\tau_{ni}^{W} = \kappa_i^W \nu_{ni}$ for all $i \neq n$ and $\tau_{nn}^{W} = 1$ for all $n$.

We compare three models labeled RRS, EK, and W. All three models have the same parameter $\theta$ and the same country sizes, $L_i$, but they may differ in technology levels and trade costs. The RRS model has technology levels $T_i^{RRS}$ and trade costs satisfying A5. The EK model has the same technology levels as the RRS model, $T_i^{EK} = T_i^{RRS}$, and trade costs satisfying A5′ with $\kappa_n^{EK} = 1/\tau_{nn}^{RRS}$. The W model has technology levels $T_i^W = T_i^{RRS}\left(\tau_{ii}^{RRS}\right)^{-\theta}$ and trade costs satisfying A5″ with $\kappa_i^W = 1/\tau_{ii}^{RRS}$.

The following result follows directly from the expression for trade flows in (3) and price levels in (4):

**Proposition 4.** Under A1-A4, the RRS, EK, and W models generate the same equilibrium wages and trade flows. The equilibrium price levels are equal in the RRS and W models but differ in the EK model: $P_n^W = P_n^{RRS}$ and $P_n^{EK} = P_n^{RRS}/\tau_{nn}^{RRS}$.

According to this Proposition, if one adjusts the technology levels appropriately, the models with asymmetric trade costs as in Waugh (2010) and with symmetric trade costs with domestic frictions are equivalent in all respects. However, note that $T_i^W = T_i^{RRS}\left(\tau_{ii}^{RRS}\right)^{-\theta}$ implies that technology levels in the W model satisfy the following relationship:

$$\frac{T_i^W}{L_i} = \frac{\phi_i}{\bar{L}}\left(\frac{1}{L_i} + \frac{L_i/\bar{L} - 1}{L_i} d^{-\theta}\right). \tag{12}$$

If there is no systematic relationship between $\phi_i$ and $L_i$, Equation (12) implies that small countries will tend to exhibit higher values of $T_i^W/L_i$. As we explain in more detail at the end of Section 4, this is precisely what happens in the calibrated model in Waugh (2010).

Proposition 4 also implies that although wages and trade flows will be the same across all three models, prices in EK will be systematically high in small countries when compared with prices in the RRS and W models, since $P_n^{EK} = P_n^{RRS}/\tau_{nn}^{RRS}$ and $\tau_{nn}^{RRS}$ increases with size. This point is analogous to the one made by Waugh (2010), but applied here to large versus small as opposed to rich versus poor countries.[10]

[10] Is it possible to achieve a full equivalence between RRS and EK by deviating from $T_i^{EK} = T_i^{RRS}$? The answer is no, since the only way in which Equation (3) holds for the two models is by imposing $T_i^{EK} = T_i^{RRS}$ and $\kappa_n^{EK} = 1/\tau_{nn}^{RRS}$.

# 3 Calibration

We consider a set of 26 OECD countries for which all the variables needed are available. We restrict the sample to this set of countries to ensure that the main differences across countries are dominated by size, geography, and R&D, rather than other variables outside the model. We need to calibrate the parameters $\theta$ and $\bar{L}$ as well as $d_{nn}$, $M_n$, and $\phi_n$, for all $n$.

**Calibration of $\boldsymbol{\theta}$.** As in the standard trade model, the value of $\theta$ is critical for our exercise. We consider three approaches for the calibration of this parameter. First, we calibrate $\theta$ to match the growth rate of income per unit of equipped labor (or TFP) observed in the data. If $L_n$ grows at a constant rate $g_L > 0$ in all countries and $T_n = \phi_n L_n$, then $g_T = g_L$ and the model leads to a long-run income growth rate, common across countries, of

$$g = g_L/\theta. \tag{13}$$

Equation (13) simply follows from differentiating (10) with respect to time (with a constant $M_n$). Following Jones (2002), we set $g_L = 0.048$, the growth rate of research employment, and $g = 0.01$, the growth rate of TFP, among a group of rich OECD countries. Together with (13), these growth rates imply that $\theta = 4.8$.[11]

Our second approach is to calibrate the parameter $\theta$ by noting that our model is fully consistent with the Eaton and Kortum (2002) model of trade. Eaton and Kortum (2002) estimate $\theta$ in the range of $3$ to $12$, with a preferred estimate of $\theta = 8$. More recent estimates using different procedures range from $2.5$ to $5.5$.[12]

Finally, a third approach is to use the results in Alcala and Ciccone (2004), who show that controlling for a country's geography (land area), institutions, and trade openness, larger countries in terms of population have a higher real GDP per capita with an elasticity of $0.3$.[13] This elasticity can be interpreted in the context of (10). If geography is captured by $\tau_{nn}$, institutions by $\phi_n$, and trade openness is represented by the last term on the right-hand side of (10), the coefficient on $L_n$, $1/\theta$, can be equated to $0.3$, the value of the (partial) income-size elasticity in Alcala and Ciccone (2004). The implied $\theta$ equals $3.3$.

[11] Jones and Romer (2010) follow a similar procedure and conclude that the data supports $g/g_L = 1/4$, which implies $\theta = 4$.

[12] Bernard, Jensen, Eaton, and Kortum (2004) estimate $\theta = 4$; Simonovska and Waugh (2013) estimate $\theta$ between $2.5$ and $5$ with a preferred estimate of $4$; Arkolakis, Ramondo, Rodriguez-Clare, and Yeaple (2013) estimate $\theta$ between $4.5$ and $5.5$.

[13] This finding does not contradict Rose (2006)'s finding that small countries are not poor. While his result is unconditional, the one in Alcala and Ciccone (2004) is conditional on quality of institutions, geography, and trade.

Given these estimates, we choose $\theta = 4$ as our baseline value, and we show results for $\theta = 2.5$ and $\theta = 5.5$ in the robustness section. The implied (conditional) elasticity of the real wage with respect to size is then $1/\theta = 1/4$, in-between the one in Jones (2002) of $1/5$, and the one in Alcala and Ciccone (2004) of $1/3$. This elasticity may seem high relative to estimates of the income-size elasticity in the urban economics literature. For example, Combes, Duranton, Gobillon, Puga, and Roux (2012) find an elasticity of productivity with respect to density at the city level between $0.04$ to $0.1$. One should keep in mind, however, that these are reduced form elasticities, whereas our $1/4$ is a structural elasticity. Thus, the same reasons (i.e., internal frictions and trade openness) that make small countries richer than implied by the strong scale effects associated with an elasticity of $1/4$ should also lead to a lower observed effect of city-size on productivity in the cross-sectional data.

**Calibration of technology and size.** We calibrate $\phi_n$ assuming that it varies directly with the share of R&D employment observed in the data. We use data on R&D employment from the World Development Indicators averaged over the nineties. We measure $L_n$ as equipped labor to account for differences in physical and human capital per worker, as calculated by Klenow and Rodríguez-Clare (2005), an average over the nineties as well.[14] Note that the term $\phi_n L_n$ in (10) is a measure of R&D-adjusted equipped labor, or what we henceforth refer to as R&D-adjusted country size.

**Calibration of domestic frictions.** Our calibration of domestic frictions, $d_{nn}$, is based on the expression in (14) below. Let $\hat{X}_{nn} \equiv \sum_{m\in\Omega_n} \widetilde{X}_{mm}$ be total intra-regional trade in country $n$. From (1) and (3) we get

$$\frac{\hat{X}_{nn}}{X_{nn}} = \frac{\tau_{nn}^{-\theta}}{M_n}. \tag{14}$$

Given a measure of the share of domestic trade that takes place within regions in a country, $\hat{X}_{nn}/X_{nn}$, (14) can be used together with $M_n$ to infer $\tau_{nn}$, which can then be combined with (6) to get an estimate of $d_{nn}$.

We use data on domestic manufacturing trade flows for the United States from the Commodity Flow Survey (CFS), for 2002. We pair regions in the model with states in the data and hence set $M_{US} = 51$ (fifty states plus the District of Columbia). This immediately implies that $\bar{L} = L_{US}/51$. We measure $\hat{X}_{nn}$ as the sum across all states of the intra-state manufacturing shipments, and we measure $X_{nn}$ as total domestic manufacturing trade flows, both according to the CFS. This yields $\hat{X}_{nn}/X_{nn} = 0.41$ implying that $41$ percent of

[14] The correlation between R&D employment and equipped labor, for our sample of countries, is 0.22.

domestic U.S. trade flows are actually intra-state trade flows.[15] Together with $M_{US} = 51$, $\theta = 4$, and $\hat{X}_{nn}/X_{nn} = 0.41$, (14) and (6) imply that $d_{US,US} = 2.43$.[16]

The only other country for which we can perform this exercise is Canada, for which we have data on manufacturing domestic trade flows across and within the thirteen provinces, for 2002.[17] The ratio $\hat{X}_{nn}/X_{nn}$ computed with these data is $0.77$. The higher percentage of domestic trade that takes place within regions in Canada compared to the United States is a natural consequence of Canada being smaller, $M_{CAN} = 13 < M_{US} = 51$—in fact, this basically explains all the difference in $\hat{X}_{nn}/X_{nn}$ across the two countries. The implied $d_{CAN,CAN}$ is $2.53$, very similar to the number obtained for the United States.[18]

Our estimates for domestic frictions might seem high, but they are in line with the high trade costs that are commonly estimated in gravity models (see Anderson and Van Wincoop, 2004). First, with $\theta = 4$, as we are assuming here, we need high trade costs to explain the relatively little inter-state trade we observe in the data; a higher trade elasticity would lead to lower estimates for $d_{nn}$. In Section 4.1, we explore the sensitivity of our results to different values of the trade elasticity. Second, the high estimates are a direct consequence of the high values observed in the data for $\hat{X}_{nn}/X_{nn}$: $0.41$ for the United States and $0.77$ for Canada. For comparison, in a frictionless world ($d_{nn} = 1$), these shares would be $\hat{X}_{nn}/X_{nn} = 1/51 = 0.02$ and $\hat{X}_{nn}/X_{nn} = 1/13 = 0.077$ for the United States and Canada, respectively. Finally, if rather than using (6) and (14), we compute $d$ by applying the index of trade costs developed by Head and Ries (2001), and Head, Mayer, and Ries (2010) to the whole matrix of domestic trade, results are very similar. Assuming that $\widetilde{d}_{mk} = \widetilde{d}_{km}$ for $m, k \in \Omega_n$,

$$\widetilde{d}_{mk} \equiv \left( \frac{\widetilde{X}_{mk}}{\widetilde{X}_{kk}} \frac{\widetilde{X}_{km}}{\widetilde{X}_{mm}} \right)^{-\frac{1}{2\theta}}. \tag{15}$$

To aggregate the individual $\widetilde{d}_{mk}$'s into a single $d_{nn}$, we follow a procedure based on Agnosteva, Anderson and Yotov (2013):

$$d_{nn} = \sum_{m \in \Omega_n} \frac{\widetilde{L}_m}{L_n} \left( \sum_{k \neq m, k \in \Omega_n} \frac{\widetilde{L}_k}{L_n} \widetilde{d}_{mk}^{-\theta} \right)^{-1/\theta}, \tag{16}$$

where $L$'s refer to population. With $\theta = 4$, this procedure yields $d_{US,US} = 2.2$ and

[15] Table 7 in the online Appendix presents trade flows by state.

[16] The corresponding numbers for the year 2007 are $\hat{X}_{nn}/X_{nn} = 0.45$ and $d_{US,US} = 2.52$.

[17] The source is British Columbia Statistics, at $http : //www.bcstats.gov.bc.ca/data/bus_stat/trade.asp$. Other papers that used these data are McCallum (1995), Anderson and van Wincoop (2003), and more recently, Tombe and Winter (2012).

[18] For 2007, $\hat{X}_{nn}/X_{nn} = 0.79$ and $d_{CAN,CAN} = 2.52$.

$d_{CAN,CAN} = 2.1$, for 2002.[19] Still, we prefer to use the expression in (14) rather than (16) as the basis for our calibration because (14) is directly consistent with our model whereas (16) is not.

Other estimates in the literature point out to high domestic frictions within the United States. For instance, using the CFS at the most disaggregated level, Hillberry and Hummels (2008) find that shipments between establishments in the same zip code are three times larger than between establishments in different zip codes. One explanation for this finding is the existence of non-tradable goods even within the manufacturing sector. As recently emphasized by Holmes and Stevens (2010), there are many manufactured goods that are specialty local goods (e.g., custom-made goods that need face-to-face contact between buyers and sellers), and hence non-traded. If we assumed in our model that a share of manufactured goods were non-tradable, the required $d_{nn}$ would be lower, but the consequences for our quantitative exercise would be very similar to the ones from the baseline calibrated model.

Since we do not have the required data to calibrate $d_{nn}$ separately for each country, we impose $d_{nn} = d = 2.43$ for all $n$, our most conservative estimate above. Of course, we are still allowing for differences in $\tau_{nn}$ across countries that come from differences in country size through $M_n$; this is precisely what weakens the economies of scale in the model with domestic frictions. In particular, we set $M_n$ for the remaining countries in our sample to $L_n/\bar{L}$ where $\bar{L} = L_{US}/M_{US}$. In this way, all regions in the world are measured in terms of the average population of a U.S. state.

Our results indicate that, for instance, a small country like Denmark with an implied $M_{DNK}$ of 1, has $\tau_{DNK,DNK}$ less than half the one for the United States. Conversely, a large country like Japan, with $M_{JPN} = 26$, has $\tau_{JPN,JPN}$ calibrated to be 70 percent the one of the United States. Column 3 in Table 1 shows the calibrated $\tau_{nn}$'s, relative to the U.S., for each country.

In Section 4.1, we explore how our results would be affected by different estimates of $d$ and the number of regions, $M_n$, for each country.

**Gravity estimates of domestic frictions.** We now explore another way to calibrate domestic frictions using the international bilateral trade data only. As shown in Proposition 4 in Section 2, a model with symmetric trade costs and domestic frictions has equivalent implications as a model without domestic frictions but asymmetric trade costs if the asymmetries are driven by exporter-specific effects (as in Waugh, 2010) and if technology indices are adjusted appropriately. This equivalence implies that, without additional re-

[19] Figure 5 in the online Appendix shows the distribution of these costs, for the years 2002 and 2007, for both countries.

strictions, the country-level data cannot be used to estimate domestic frictions separately from exporter-specific effects on trade costs. This is why we use region-level trade data for our baseline calibration of domestic frictions. However, it is plausible to argue that the exporter-specific component of trade costs are not too important for the sample of more advanced countries we consider. Under this assumption, we can still estimate domestic frictions using only international trade data, as we now show.

From (3), we get

$$\frac{X_{ni}}{X_{nn}} = \left(\frac{\tau_{ni}}{\tau_{nn}}\frac{w_i}{w_n}\right)^{-\theta}\frac{T_i}{T_n}. \tag{17}$$

Assume that for $n \neq i$ trade costs are symmetric and given by

$$\log \tau_{ni} = \delta_c + \delta_d \log dist_{ni} + \delta_b b_{ni} + \delta_l l_{ni} + \varepsilon_{ni}. \tag{18}$$

The variable $dist_{ni}$ is distance between $n$ and $i$ in kilometers, $b_{ni}$ ($l_{ni}$) is equal to one if $n$ and $i$ share a border (language), and zero otherwise, and $\varepsilon_{ni}$ reflects barriers to trade arising from all other country-pair specific factors (and orthogonal to the observable variables). Taking logs, (17) can then be written as

$$\log \frac{X_{ni}}{X_{nn}} = S_i - H_n - \theta\delta_d \log dist_{ni} - \theta\delta_b b_{ni} - \theta\delta_l l_{ni} - \theta\varepsilon_{ni}, \tag{19}$$

where

$$S_i \equiv \log T_i - \theta\delta_c - \theta \log w_i \tag{20}$$

and

$$H_n \equiv \log T_n - \theta \log \tau_{nn} - \theta \log w_n \tag{21}$$

gather source and destination country characteristics, respectively. Subtracting (21) from (20), for country $n$, and rearranging terms yields

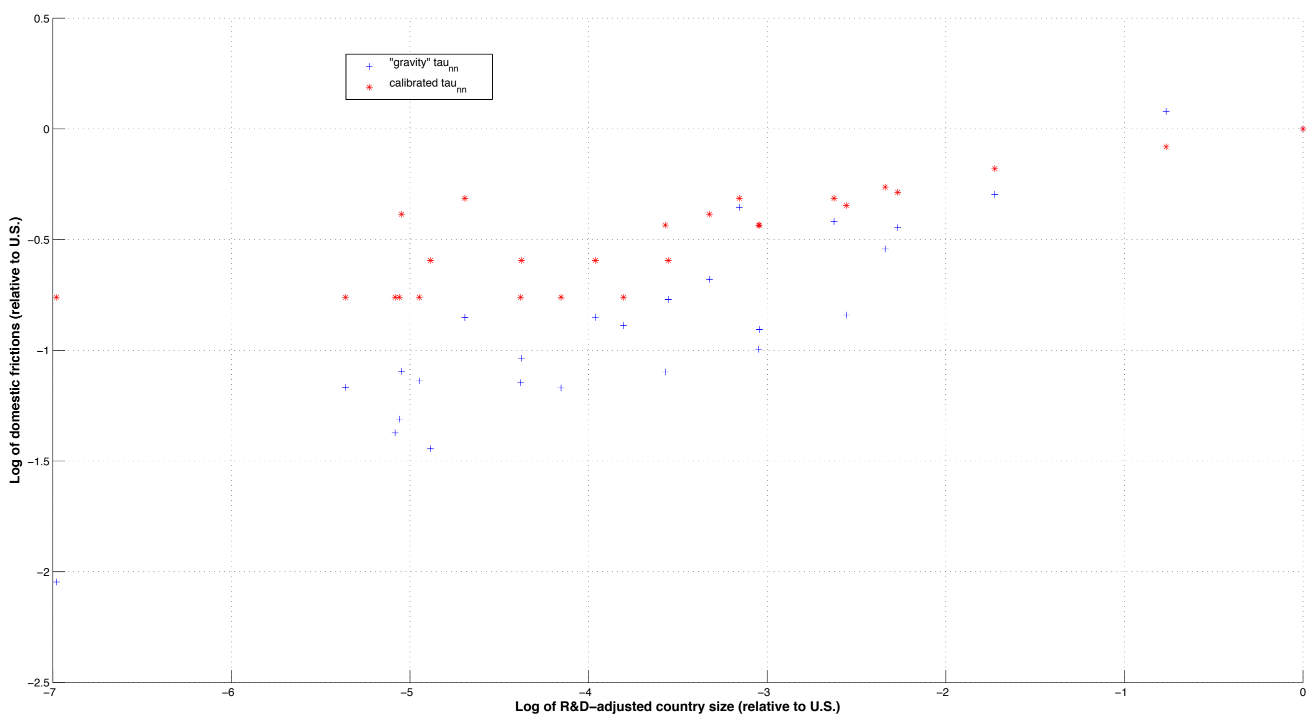
$$\log \hat{\tau}_{nn} = \frac{1}{\theta}(S_n - H_n). \tag{22}$$

We first estimate (19) by ordinary least squares (OLS). With 650 observations and robust standard errors, we get

$$\log \frac{X_{ni}}{X_{nn}} = \widehat{S}_i - \widehat{H}_n - 1.01^{***} \log dist_{ni} + 0.126 b_{ni} + 0.383^{***} l_{ni}, \tag{23}$$

with $^{***}$ denoting a level of significance of $p < 0.01$. For $\theta = 4$, we compute $\hat{\tau}_{nn}$ as indicated by (22) and plot it against our measure of country size in Figure 2. In this figure we also plot the calibrated measure of domestic frictions computed according to ( 6) with $d = 2.43$. We see that, just as the calibrated $\tau_{nn}$, the estimated $\hat{\tau}_{nn}$ exhibits a strong positive relationship with country size, implying a high positive correlation between $\hat{\tau}_{nn}$ and our calibrated $\tau_{nn}$ (in logs, the correlation is 0.88). Thus, assuming symmetric trade costs, the international trade data suggest the existence of domestic frictions that increase with size, as implied by our model.[20]

Figure 2: Gravity measures of domestic frictions




"Gravity" $\tau_{nn}$ is calculated using (22), while calibrated $\log \tau_{nn}$ is calculated using (6). R&D-adjusted country size refers to $\phi_n L_n$, where $\phi_n$ is the share of R&D employment observed in the data and $L_n$ is a measure of equipped labor.

As a final remark, note that if we allowed for both domestic frictions and trade cost asymmetries driven by exporter fixed effects as in Waugh (2010), or importer fixed effects as in Eaton and Kortum (2002), those country-specific components could not be distinguished from domestic frictions through a gravity equation such as (19). For example, allowing for exporter fixed effects would lead to $\log \hat{\tau}_{nn} + \log \kappa_n^W = \frac{1}{\theta}(S_n - H_n)$. By im-

[20]The elasticity of the estimated $\hat{\tau}_{nn}$ with respect to R&D-adjusted size is even higher than the corresponding elasticity for our calibrated $\tau_{nn}$ (0.29 versus 0.13). This implies that the effect of domestic frictions on offsetting scale effects would be even higher if we used the gravity estimated domestic frictions rather than our calibrated ones for the exercises in the next two sections.

posing structure on $\tau_{nn}$ and using domestic trade data, we could set $\hat{\tau}_{nn}$ equal to our calibrated $\tau_{nn}$ and use the procedure above to recover exporter or importer fixed effects.

# 4 The Role of Domestic Frictions: Real Wages

In this Section, our goal is to compute real wages implied by (10) and compare them with real wages in the data,in order to evaluate the role of openness and domestic frictions in reconciling the model with the data. In the data, real wage is computed as real GDP (PPP-adjusted) from the Penn World Tables (7.1) divided by our measure of equipped labor, $L_n$. The real wage calculated in this way is simply TFP; we henceforth refer indistinctly to real wage or TFP for country $n$. We consider averages over the period 1996-2001.

Using (10), the real wage for country $n$, relative to the U.S., can be written as

$$\frac{w_n/P_n}{w_{US}/P_{US}} = \underbrace{\left(\frac{\phi_n L_n}{\phi_{US} L_{US}}\right)^{1/\theta}}_{\text{country size}} \times \underbrace{\left(\frac{GT_n}{GT_{US}}\right)}_{\text{gains from trade}} \times \underbrace{\left(\frac{\tau_{nn}}{\tau_{US,US}}\right)^{-1}}_{\text{domestic frictions}}. \tag{24}$$

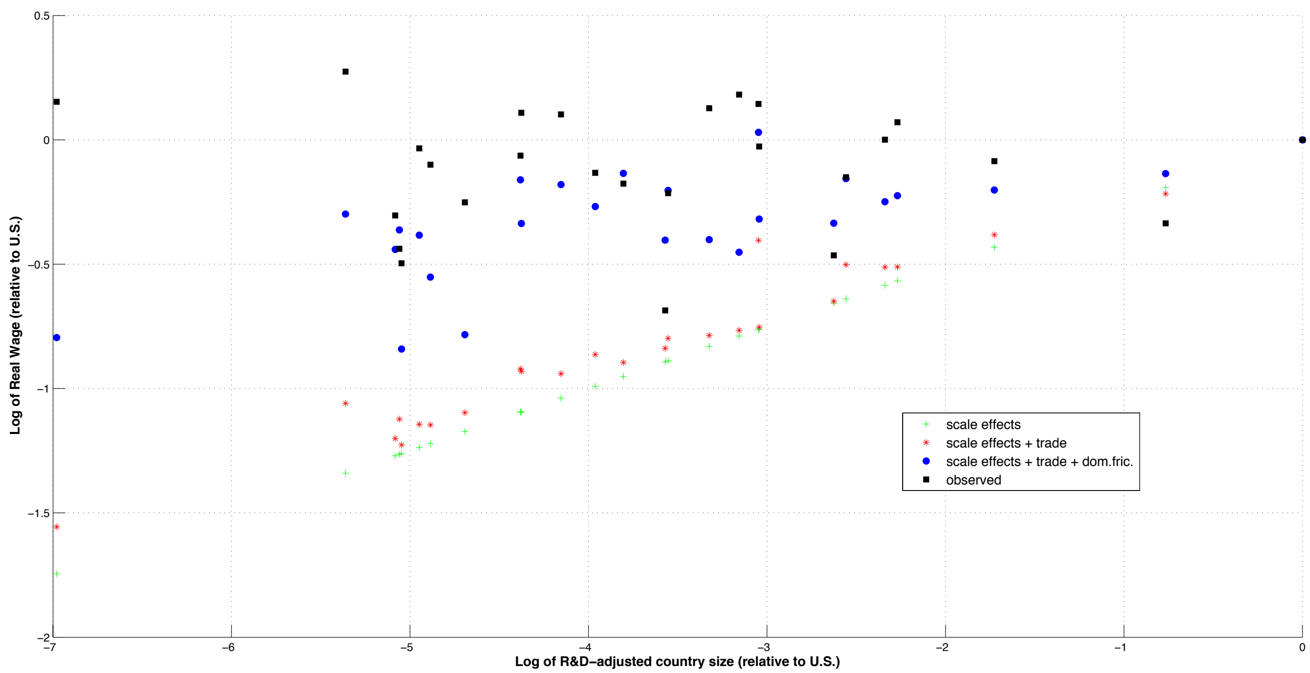
The role of scale effects is captured by the first term on the right-hand side of this expression, the role of openness to trade is captured by the second term, and the role of domestic frictions is captured by the third term.

The first and third terms are calibrated as explained in the previous Section. The second term are the gains from trade for each country $n$. As in Eaton and Kortum (2002) and Arkolakis, Costinot, and Rodriguez-Clare (2012), we use the data on trade flows to directly compute the gains from trade for each country $n$. We measure domestic expenditure on domestic goods ($X_{nn}$ in the model) as gross production minus total exports, and we measure total absorption ($X_n$ in the model) as $X_{nn}$ plus total imports from countries in our sample. We consider the manufacturing sector and we use data from STAN, averaged over 1996-2001.

Figure 3 shows the real wage implied by our model with scale effects, international trade, and domestic frictions (blue dots) as well as the real wage implied by the model with only scale effects (green dots) and with both scale effects and international trade but no domestic frictions (red dots). We also plot the real wages observed (black dots). Real wages are plotted against our measure of R&D-adjusted country size. Table 1 presents the numbers behind Figure 3.

It is clear from the figure that the model with only scale effects severely underesti-

Figure 3: Scale Effects, Trade Openness, and Domestic Frictions.




R&D-adjusted country size refers to $\phi_n L_n$, where $\phi_n$ is the share of R&D employment observed in the data and $L_n$ is a measure of equipped labor.

mates the real wage for the smallest countries (green versus black dots). According to that model, the real wage for a small country like Denmark would be only $33$ percent of the one in the United States, reflecting very strong scale effects. In contrast, the observed relative real wage of Denmark is $94$ percent. The implications are similar when we look at the six smallest countries in our sample: the model with only scale effects implies a relative real wage of $30$ percent, whereas in the data these countries have an average real wage almost equal to the one in the United States. We further compare this model with the data by calculating the elasticity of real wages with respect to size. An OLS regression (with a constant and robust standard errors) delivers a size-elasticity of the real wage in the model of $1/\theta = 0.25$, whereas the one in the data is not statistically different from zero (-0.006 with s.e. 0.03).

Now we add trade and domestic frictions to the model and calculate how much they help in matching the observed real wages for countries of different sizes. We start by considering the model with trade but no domestic frictions. As the red dots indicate in Figure 3, trade openness does not help much in bringing the model closer to the data. Focusing again on Denmark, the trade model with no domestic frictions implies a relative real wage for Denmark of $40$ percent, only a small improvement over the model with only scale effects. For the six smallest countries, the model implies a real wage of $34$ percent, higher than the $30$ percent generated by the model with no trade, but still very far from the data. The elasticity of the real wage with respect to country size for the model with trade but no domestic frictions is 0.22 (s.e. 0.007), much higher than the zero elasticity observed in the data.

It is important to clarify that, as expected, small countries do gain much more from trade than large countries. It is just that these gains are not large enough to have a substantial role in closing the gap between the model with only scale effects and the data. For example, Denmark has much larger gains from trade than the United States (23.9 versus 4.1 percent), but six-fold higher gains only increase the implied relative real wage of Denmark from 33 to 40 percent. Column 2 in Table 1 shows the results for the gains from trade (relative to the U.S.), by country.

Adding domestic frictions to the model helps to reconcile the model with the data (blue versus black dots in Figure 3). Coming back to the example of Denmark, the model with scale effects, trade and domestic frictions—the full model—implies a relative real wage of $85$ percent, much closer to the data, $94$ percent, than the real wage implied by the model with only scale effects, $33$ percent. The full model's implied relative wage for the six smallest countries in the sample is $73$ percent, closing the gap between the model with only scale effects and the data by $60$ percent. The elasticity of the real wage with respect to country size implied by the model is still significantly positive (0.098 with s.e. 0.018), but much closer to zero than in the model with only scale effects.

As the comparison between the green and blue dots with the black dots in Figure 3 reveals, the main contribution in getting the full model to better match the data comes from domestic frictions. Indeed, focusing again on Denmark, domestic frictions close almost two thirds of the gap between the real wage in the data and in the model with only scale effects, while openness to trade only closes a little more than ten percent. For the six smallest countries in our sample, domestic frictions close almost fifty percent of the gap, while trade openness closes around six percent.

More formally, we use

$$\Delta \equiv \sum_n \left[ (w_n/P_n)^{model} - (w_n/P_n)^{data} \right]^2, \tag{25}$$

as a measure of the fit of the model with the data. For the full model, $\Delta = 2.24$, while for the model with only scale effects $\Delta$ is almost four times higher (8.19). For the model with trade openness and no domestic frictions, we get $\Delta = 7.07$, while for the model with domestic frictions and no trade, we get $\Delta = 3.21$. This shows, once again, that most of the work of reconciling the model with the data is actually done by domestic frictions rather than trade openness. The improvement in fit is particularly high for the small countries in our sample, as Table 1 shows.[21]

Our results are related to those in Waugh (2010), who shows that his model without domestic frictions does well in matching real wages across countries. The main difference is that while we impose that $T_i/L_i$ is pinned down by R&D employment shares, Waugh (2010) estimates $T_i$ so that the model without domestic frictions matches the trade data.[22] As implied by Proposition 4 in Section 2, a model without domestic frictions can generate the same trade shares and real wages as a model with domestic frictions, but with $T_i/L_i$ ratios that are systematically lower for large countries. This is precisely what Waugh (2010) obtains in his model for our sample of countries: the estimated (average) $T/L$ ratios are 12 times bigger for the five smallest countries in our sample than for the five largest.[23] Moreover, for our sample of countries the elasticity of Waugh's estimated $T/L$

[21] In Table 8 in the online Appendix we show that the results are similar when we compute gains from trade in alternative ways. In particular, we compute the gains from trade taking into account trade with the whole world and not only trade with the countries in our sample, and using multiple sectors and tradable intermediate goods, as in Costinot and Rodríguez-Clare (2014). For Denmark, gains from trade relative to the United States increase from 1.19 in the baseline calibration (column 2 of Table 1) to 1.31 (Column 4 in Table 8) when we compute gains as in Costinot and Rodríguez-Clare (2014), but this still only increases the implied relative real wage of Denmark to 44 percent.

[22] The variable $L_i$ used in Waugh (2010) is equipped labor from Caselli (2005).

[23] Germany and Iceland are not in Waugh (2010)'s sample.

ratios with respect to country size is -0.94 (s.e. 0.29).[24]

## 4.1 Robustness

### 4.1.1 Alternative values of $\theta$

To explore the effect of the value of $\theta$ on our results, let $O_n \equiv \lambda_{nn}^{-1}$, $D_n \equiv \tau_{nn}^{\theta}$ and rewrite (24) as

$$\frac{w_n/P_n}{w_{US}/P_{US}} = \left[\left(\frac{\phi_n L_n}{\phi_{US} L_{US}}\right)\left(\frac{D_n}{D_{US}}\right)^{-1}\left(\frac{O_n}{O_{US}}\right)\right]^{1/\theta}. \tag{26}$$

All the terms inside the bracket come directly, or indirectly, from the data and do not depend on the value of $\theta$.[25] Hence, this expression tells us how the relative real wage implied by the calibrated model changes with $\theta$ in the exponent. For countries with a lower real wage than the one for the United States, a higher $\theta$ increases the relative real wage towards one; the opposite is true for countries with a higher real wage than the one for the United States.

Table 2 shows how the gap between the calibrated and observed real wage varies with different values of $\theta$. For $\theta = 5.5$, Denmark's calibrated real wage, relative to the U.S., is even closer to the data, 0.89. In contrast, for $\theta = 2.5$, the calibrated model delivers a relative real wage for Denmark of $0.77$. Notice that, with only scale effects and no domestic frictions, for $\theta = 2.5$, the relative real wage implied for Denmark would be of only $0.17$, while for $\theta = 5.5$, it would reach $0.45$.

### 4.1.2 Alternative values of domestic frictions

Following the same procedure as for the fifty one states of the United States, we consider shipments between $100$ geographical units within the United States.[26] The ratio of $\widehat{X}_{nn}/X_{nn}$ is 0.35. With $M_{US} = 100$ and $\theta = 4$, using (6) and (14) delivers $d = 2.69$. Additionally, as mentioned above, using data on trade flows between 13 geographical units in

[24] The elasticity of $T/L$ with respect to country size computed for the the 77 countries considered in Waugh (2010) is still negative ($-0.3$), but not significantly different from zero (s.e. $0.3$).

[25] Notice that $D_n$ does not depend on $\theta$ because $d^{-\theta}$ is pinned down, through (14), by $\widehat{X}_{nn}/X_{nn}$ and $M_n$, both coming from the data for the United States.

[26] These units include 48 Consolidated Statistical Areas (CSA), 18 Metropolitan Statistical Areas (MSA), and 33 units represent the remaining portions of (some of) the states, for 2007, from the Commodity Flow Survey. For each of these $99$ geographical units, we compute the total purchases from the United States and subtract trade with the $99$ geographical units to get trade with the rest of the United States, which is considered the 100th geographical unit.

Canada implies $d = 2.53$, for 2002.[27]

We also explore the sensitivity of our results to incorporating data on population density and the number of towns with more than 250,000 habitants into our measure of $M_n$. For these two exercises, we again set $\tau_{nn}$ as implied by (6) with $d = 2.43$, as in the baseline calibration. First, we use data on population density so that more dense countries are allowed to have a higher $\bar{L}_n$.[28] We assume that $\overline{L}_n$ is proportional to population density defined as habitants per unit of land, $v_n \equiv L_n/A_n$, where $A_n$ is area of country $n$. Rather than fixing the size of all regions to the size of a U.S. region, we fix the *area* of all regions to the average *area* of U.S. states, $\bar{A}_{US} = A_{US}/51$. Then, $\bar{L}_n = \bar{A}_{US}v_n$, and again $M_n = L_n/\bar{L}_n$, so that low density countries have more regions given $L_n$. Second, we use data on the number of towns with more than 250,000 habitants for each country as a direct measure of $M_n$.[29]

The implied domestic frictions $\tau_{nn}$ (relative to U.S.) for each of the above-described calibrations are gathered in columns 1 to 5 of Table 3. Further, columns 6 to 10 in the same table present the implied real wage (relative to U.S.) for each calibration. The results for real wages do not change in any significant way as we consider these alternative calibrations. One exception (among the small countries) is Benelux, for which the calibration that adjusts for population density delivers a higher relative real wage than the one observed in the data.

# 5 The Role of Domestic Frictions: Import Shares, Nominal Wages, and Price Indices

In line with the theoretical findings in Section 2, we now assess the performance of the trade model with domestic frictions vis-$\grave{a}$-vis the trade model without domestic frictions, in terms of import shares, wages and prices. To proceed, it is necessary to estimate the whole matrix of international trade costs. We assume that trade costs are as in (18) in Section 3, for $n \neq l$; for $n = l$, trade costs take the values from our baseline calibration in the model with domestic frictions, and the value of one for the model with no frictions. By assuming that international trade costs depend only on geographic variables, we make

[27]Each of the calibrations of domestic frictions discussed above entails a different $M_n$ for the remaining countries in the sample. Specifically, as in the baseline calibration, we set $\overline{L}_r = M_r/L_r$ and $M_n = L_n/\overline{L}_r$, with $M_r$ and $L_r$ referring to the calibration using 100 U.S. geographical units or 13 Canadian provinces.

[28]Density is defined as population per square kilometer of land space. The data are from the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2007).

[29]Table 9 in the Appendix presents the implied number of regions for each calibration, for all countries in the sample.

sure that these costs are symmetric and do not capture features related to country size.

Our procedure is as follows:

1. Guess a value for $\delta$'s and compute $\tau_{ni}$ in (18), for $n \neq i$;

2. Given the trade costs in step 1 and the parameters calibrated in Section 3, compute the model's equilibrium (following the algorithm in Alvarez and Lucas, 2007) to get the $N \times N$ matrix of trade shares, $\lambda_{ni}$;

3. Calculate the sum of the square difference between the trade shares in the data and the model, for all pairs,
$$\Delta \equiv \sum_{i,n} (\lambda_{ni}^{model} - \lambda_{ni}^{data})^2; \tag{27}$$

4. Iterate on $\delta$'s until (27) is minimized.

The procedure is run twice: for $\tau_{nn}$ as calibrated in Section 3, and for $\tau_{nn} = 1$. The fit of both models in terms of $\Delta$ is virtually the same, 0.43. The question we ask is: using these estimates for international trade costs, what are the implications of the models with and without domestic frictions regarding import shares, nominal wages, prices and real wages?

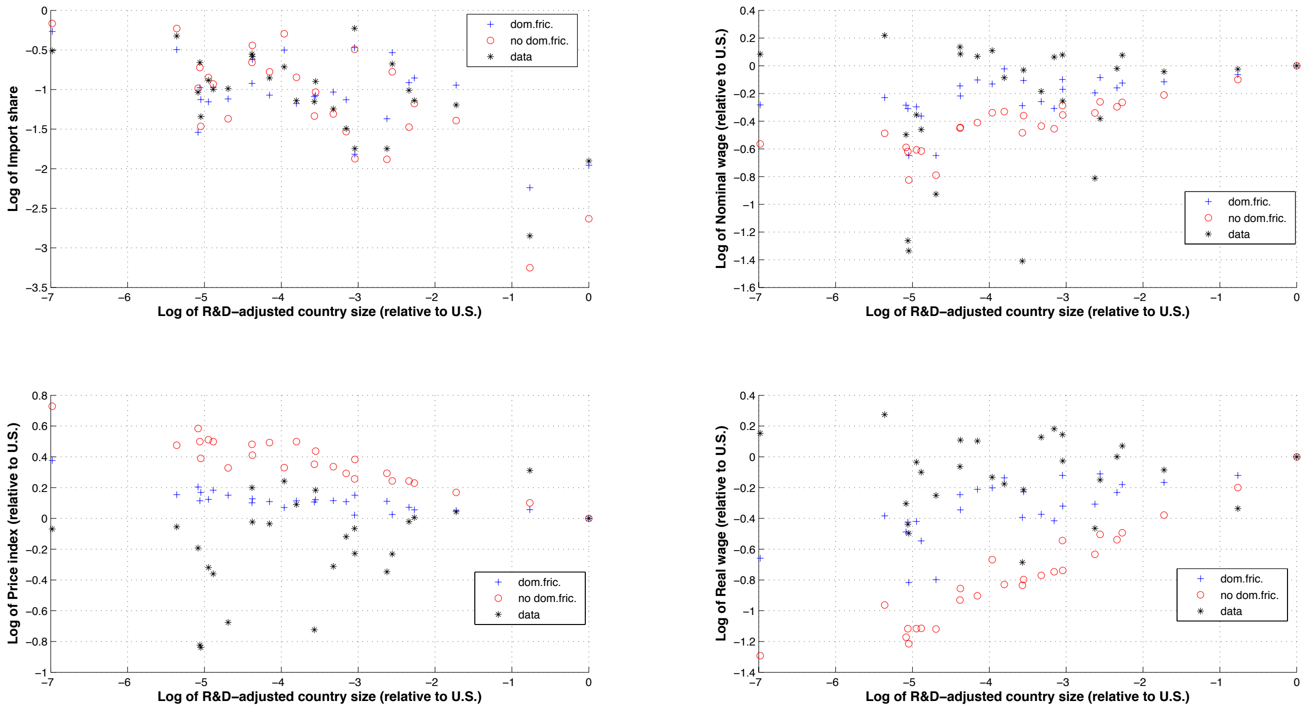
Figure 4 depicts the results, comparing data and models, across countries of different size.[30] In the data, the import share for country $n$ is calculated as $1 - \lambda_{nn}$, with $\lambda_{nn} \equiv X_{nn}/X_n$ computed as in Section 4. The nominal wage in the data is calculated as GDP at current prices from the World Development Indicators, divided by our measure of equipped labor. The price index is simply calculated as the nominal wage divided by the real wage computed as in Section 4. All variables are averages over 1996-2001.

The average import shares are matched well by both models, but the pattern they present across countries of different size resembles the one shown in our theoretical example in Figure 1: in the model with no frictions, import shares decrease too rapidly with country size. This is clear from the magnitude of the size elasticities presented in Table 4. The model without domestic frictions implies that import shares decline with size with an elasticity of $-0.35$ (s.e. 0.03), higher than the one in the data, which is $-0.23$ (s.e. 0.07). The model with domestic frictions does a little better in this regard: the implied elasticity is $-0.16$ (s.e. 0.06).[31]

[30]Table 4 presents summary statistics, and Table 10 in the Appendix shows the results by country.

[31]The calibrated model without domestic frictions in Alvarez and Lucas (2007) also matches fairly well

Figure 4: The Role of Domestic Frictions. Calibrated Models and Data.




R&D-adjusted country size refers to $\phi_l L_l$, where $\phi_l$ is the share of R&D employment observed in the data and $L_l$ is a measure of equipped labor.

Results for real wages are similar to the ones in Section 4, the only difference being that here we compute the gains from trade using the domestic trade shares implied by the model rather those observed in the data. As shown in Table 4, focusing on the six smallest countries in our sample, the model without domestic frictions implies a relative real wage that is too low compared to the one in the data: $0.37$ vs $1.02$. Introducing domestic frictions doubles the implied relative real wage to $0.71$. Similarly, the size elasticity of the real wage in the model without domestic frictions ($0.2$ with s.e. 0.01) is too high compared to the one in the data, which is not significantly different from zero. With domestic frictions there is still a positive elasticity ($0.1$ with s.e. 0.01), but it is halved relative to the model without domestic frictions.

The exercise in this section further shows that the behavior of real wages in the model

the relationship between size and import shares across countries. As we do in A2, Alvarez and Lucas (2007) allow technology levels to scale up with size, but rather than using equipped labor as a measure of size, they calibrate $L_n$ so that $w_n L_n$ in the model equals nominal GDP in the data. Letting $e_n$ be efficiency per unit of equipped labor in country $n$, their procedure is equivalent to calibrating $e_n$ such that $e_n(L_n/\lambda_n)^{1/\theta}$ matches observed TFP levels. For our sample of countries, their calibrated size ($e_n L_n$) has much less variation than the observed measure of equipped labor (s.d. of 0.05 versus 0.21), across countries, which implies that small countries have a much higher efficiency per unit of equipped labor than large ones.

with no domestic frictions is the result of nominal wages that rise – and prices that fall – too steeply with size. As shown in Table 4, the model with no domestic frictions implies size elasticities of the wage ($0.11$ with s.e. 0.015) and price index ($-0.10$ with s.e. 0.001) that are too high (in absolute value) relative to the ones in the data. Both elasticities are halved as we introduce domestic frictions. The main reason why the model with domestic frictions still overestimates the size elasticity of real wages is because of its implication that prices fall with size (elasticity of $-0.04$ with s.e. 0.001), whereas in the data the size elasticity of the price index is not significantly different from zero ($0.07$ with s.e. 0.04).

# 6 Multinational Production and Non-Tradable Goods

In the model of Section 2, international trade was the only channel through which countries could gain from openness. But, arguably, the activity of multinational firms could be even more important. We now incorporate multinational production as an extra channel for the gains from openness. To such end, we extend the model of Section 2 by allowing technologies to be used outside of the region where they originate; whenever this happens we say that there is multinational production (MP).

We follow Ramondo and Rodríguez-Clare (2013) and assume that a technology has a productivity $z_n$ in each country $n = 1, ..., N$. To introduce frictions to the "movement of ideas" within countries, analogously to the way we introduced domestic frictions for trade, we assume that each technology has a "home region" in each country. Using a technology originated in country $i$ for production outside of the technology's home region in country $i$ entails an iceberg-type efficiency loss, or "MP cost," of $h_{ii} \geq 1$. Moreover, using a technology originated in country $i$ in the technology's home region in country $l \neq i$ entails an MP cost of $\gamma_{li} \geq 1$. Finally, the total MP cost associated with using a technology from country $i$ outside of the technology's home region in country $l \neq i$ is $\gamma_{li} h_{ll}$.[32]

In sum, each technology is characterized by three elements: first, the country $i$ from which it originates; second, a vector that specifies the technology's productivity parameter in each country, $\boldsymbol{z} = (z_1, ..., z_N)$; and third, a vector that specifies the technology's home region in each country, $\boldsymbol{m} = (m_1, ..., m_N)$. The effective productivity of a technol-

[32] The assumption that technologies have a home region in each country is made to keep the treatment of domestic and foreign technologies consistent. We assume that technologies originated in country $i$ are "born" in a particular region and then face an MP cost $h_{ii}$ to be used in another region of country $i$. The analogous assumption for the use of technologies from $i$ in country $n \neq i$ is that they also have a region in country $n$ where they are "reincarnated" (their home region), and then face an MP cost $h_{nn}$ to be used in another region of country $n$.

ogy $(i, \boldsymbol{z}, \boldsymbol{m})$ is $z_i$ if used in region $m_i$, $z_i/h_{ii}$ if used in region $m \in \Omega_i$ with $m \neq m_i$, $z_l/\gamma_{li}$ if used in region $m_l$ for $l \neq i$, and $z_l/\gamma_{li}h_{ll}$ if used in region $m \in \Omega_l$ for $l \neq i$ and $m \neq m_l$.

We assume that productivity levels in $\boldsymbol{z}$, for technologies originating in country $i$, are independently drawn from the Fréchet distribution with parameters $\bar{T}_i$ and $\theta$, and we assume that $m_n$ is uniformly and independently drawn from the set $\Omega_n$.

In the model with MP, we introduce both tradable and non-tradable goods, since around half of MP flows in the data occur in non-tradable goods. We assume that tradable goods are intermediate goods while non-tradable goods are final goods. There is a continuum of final goods and a continuum of intermediate goods, both in the interval $[0, 1]$. Preferences over final goods are CES with elasticity of substitution $\sigma > 0$. Intermediate goods are used to produce a composite intermediate good with a CES aggregator with elasticity $\sigma > 0$. The composite intermediate together with labor are used, via a Cobb-Douglas production function, to produce final and intermediate goods with labor shares $\alpha$ and $\beta$, respectively.

We assume that MP is possible in both the final and intermediate goods, and that the MP costs are the same in both cases. Further, we assume that $1 \leq d_{nn} = h_{nn}$. Consider a particular intermediate good whose home region is $m_n$. The price of this good in other regions of country $n$ ($m \in \Omega_n$, $m \neq m_n$) is determined by $z/d_{nn}$ if traded and $z/h_{nn}$ if produced locally via MP. Our assumption that $d_{nn} = h_{nn}$ implies that there is indifference between these two options. We assume that the indifference is broken in favor of trade, which implies that there is no MP across regions within countries for intermediate goods. Summing up, there is "domestic" MP in final, but not intermediate, goods, whereas trade is feasible in intermediate, but not final, goods, within countries. Across countries, MP is feasible in both types of goods, while trade is only possible in intermediate goods.

Our object of interest in this Section, as in Section 4, is the equilibrium real wage in each country $n$, which we compare with the real wage in the data. A detailed derivation of the model's equilibrium with trade, MP, and domestic frictions, is relegated to the Appendix. Here, we present the main elements of the analysis.

In the model with trade, MP, and domestic frictions, analogously to the baseline model, equilibrium wages can be written as

$$\frac{w_n}{P_n} = \mu^M \times \underbrace{\phi_n^{\frac{1+\eta}{\theta}}}_{\text{R\&D Intensity}} \times \underbrace{L_n^{\frac{1+\eta}{\theta}}}_{\text{Pure Scale Effect}} \times \underbrace{\gamma_{nn}^{-1}\tau_{nn}^{-\eta}}_{\text{Domestic Frictions}} \times \underbrace{\lambda_{nn}^{-\frac{\eta}{\theta}}}_{\text{Gains Trade}} \times \underbrace{\pi_{nn}^{-\frac{1+\eta}{\theta}}}_{\text{Gains MP}}, \tag{28}$$

where $\mu^M$ is a positive constant (defined in the Appendix),

$$\eta \equiv \frac{1-\alpha}{\beta}, \tag{29}$$

and

$$\gamma_{nn} \equiv \left[\frac{1}{M_n} + \frac{M_n - 1}{M_n} h_{nn}^{-\theta}\right]^{-1/\theta}, \tag{30}$$

and $\pi_{nn}$ is the domestic MP share.[33] There are several points to be made about the result in (28). First, the pure scale effect now has elasticity $(1+\eta)/\theta$ rather than $1/\theta$. The reason is that there are scale effects operating in both the final and intermediate goods sectors. The scale effect elasticity in the final goods sector is $1/\theta$, as in the baseline model, but this elasticity is $\eta/\theta$ in the intermediate goods sector. The term $\eta$ captures the amplification of gains by the factor $1/\beta$ in the intermediate goods sector because of the input-output loop and the weakening of the overall effect due to intermediate goods being only used with share $1-\alpha$ in the production of final goods. Second, the real wage is now affected by frictions to domestic trade and to "domestic" MP. The impact of domestic trade frictions is $\tau_{nn}^{-\eta}$, while the impact of domestic MP frictions is $\gamma_{nn}^{-1}$. Third, the gains from trade are now captured by $\lambda_{nn}^{-\eta/\theta}$, rather than $\lambda_{nn}^{-1/\theta}$. Finally, the term $\pi_{nn}^{-(1+\eta)/\theta}$ captures the gains from MP (i.e., the change in the real wage from a situation with no MP to the observed equilibrium), for both final and intermediate goods. The gains from openness are just the product of the gains from trade and the gains from MP.

As the last term in (28) indicates, the gains from MP can be expressed as a function of observed flows, in the same way the gains from trade are. Data on the gross value of production for multinational affiliates from $i$ in $n$ are used as the empirical counterpart of bilateral MP flows in the model, which in turn are used to compute the MP shares, $\pi_{nn}$. The labor shares $\alpha$ and $\beta$ are set to 0.75 and 0.50, respectively, while the parameter $\theta$ is set to a value of $6$. The Appendix presents the description of the MP data and more details on the calibration of these three parameters. It is worth noting here that $(1+\eta)/\theta = 1/4$ so that the strength of scale effects is the same as in the baseline calibration. Our calibration of domestic frictions for trade in goods is equivalent to the procedure described for the baseline model. For $\theta = 6$, we get $d = 1.81$, and we assume that $d = h$. The remaining parameters in (28) are as in the baseline calibration.

Columns 2 to 7 in Table 5 show each term in the right-hand side of (28), relative to the United States. Given our assumption that $h = d$, $\gamma_{nn} = \tau_{nn}$; still, these frictions are different across countries due to differences in $M_n$). Together with $(1+\eta)/\theta = 1/4$ and the

[33] Formally, $\pi_{li} \equiv Y_{li}/Y_l$, where $Y_{li}$ is value of production in country $l$ with technologies originated in country $i$, and $Y_l \equiv \sum_i Y_{li}$.

(re)calibration of $d$ to satisfy (14), there is no difference in the role of domestic frictions here with respect to the model of Section 2. But the gains from trade are now $\lambda_{nn}^{-\eta/\theta}$, with $\eta/\theta = 1/12$, rather than $\lambda_{nn}^{-1/\theta}$ with $1/\theta = 1/4$, as in Section 2. Consequently, the gains from trade have a smaller role now, as shown in column 6 of Table 5, although the gains from openness also include the gains from MP. But as column 3 indicates, MP does not help much to increase real wages, relative to the United States, for small countries because the United States has large gains from MP. While only Japan has lower gains from trade than the United States (column 2), several countries have lower gains from MP than the United States.

The result from Section 4 still holds: the existence of domestic frictions, rather than openness, remains the dominant channel to bring the calibrated model closer to the data. For instance, for Denmark, adding MP does not help much quantitatively to bring the relative real wage in the calibrated model closer to the one observed in the data: the implied relative real wage is 0.76, against 0.94 in the data, and 0.85 in the baseline model. More generally, looking at the average for the six smallest countries in the sample, trade and MP openness together help to close around three percent of the gap between the standard model with only scale effects and the data on relative real wages, while domestic frictions close almost 50 percent of the gap.

As a final remark, suppose that there is no MP, but we add non tradable final goods to the baseline model of Section 2. This would require setting $\pi_{nn} = 1$ in (28), and taking a stand about the nature of non-tradable goods. If these goods were local at the region level, then $h_{nn} \rightarrow \infty$, and $\gamma_{nn} = (1/M_n)^{-1/\theta}$; if they were local at the country level, then $h_{nn} = 1$ and $\gamma_{nn} = 1$. The question is then: how much would the baseline results change by just adding non tradable goods? In the first case ($h_{nn} \rightarrow \infty$), our baseline results would be reinforced: a country like Denmark would reach a real wage (relative to U.S.) of 0.93, and domestic frictions would explain almost 90 percent of the gap between the data and the model with only scale effects. A lower bound would be obtained if, instead, non-tradable goods were national ($h_{nn} = 1$): for Denmark, the real wage would be half the United States's (versus 0.85 in our baseline calibration). Still, domestic frictions, as opposed to openness to trade, would have the largest role in bringing the model closer to the data.

# 7 Conclusion

Models in which growth is driven by innovation naturally lead to scale effects. This feature results in the counterfactual implication that larger countries should be much richer than smaller ones. These scale effects are also present in the standard gravity model of trade. In those models, trade and scale lead to TFP gains through exactly the same mechanism as in innovation-led growth models, namely an expansion in the set of available non-rival ideas. These trade models, as semi-endogenous growth models do, assume that any innovation produced in a given country is instantly available to all residents of that country. We depart from the standard assumption and build a trade model that incorporates costs to domestic trade. We calibrate the model and evaluate the role of domestic frictions in reconciling the data and the theory.

The calibrated model reveals that domestic frictions are key to explain the discrepancy between the standard trade model, as well as the standard semi-endogenous growth model, and the data. For a small and rich country like Denmark, our calibrated model implies a productivity level of 85 percent (relative to the United States), much closer to the data (94 percent) than the level implied by the trade model with no domestic frictions (40 percent). By weakening scale effects, domestic frictions not only help the model better match the observed productivity levels across countries; they also make the model better match observed import shares, relative income levels, and price indices.

An obvious limitation of our analysis is that we restricted our attention to differences across countries only coming from differences in R&D-adjusted size, gains from trade (and gains from MP), and domestic frictions. Some forces left out of the model can be potentially important to further reconcile the model and the data. One obvious possibility is that small countries benefit from "better institutions," which in the model would be reflected in higher technology levels ($\phi_n$) than those implied by the share of labor devoted to R&D. Using the number of patents per unit of equipped labor registered by country $n$'s residents, at home and abroad, rather than R&D employment shares, as a proxy for $\phi_n$, does not change our quantitative results. Similarly to R&D employment share, small countries do not have a systematically higher number of patents per capita. Furthermore, small countries are not systematically better in terms of schooling levels, corruption in government, bureaucratic quality, and rule of law; the data do not support the idea that smallness confers some productivity advantage through better institutions.[34]

Another possibility is that the gains from openness materialize in ways other than trade and MP. An obvious channel is international technology diffusion which allows local firms to use foreign technologies. Unfortunately, except for the small part that happens

[34] Schooling levels are average years of schooling from Barro and Lee (2000); corruption in government, rule of law, and bureaucratic quality, are indices ranging from zero (worst) to six (best), from Beck, Clarke, Groff, Keefer, and Walsh (2001). Patents per unit of R&D-adjusted equipped labor from country $i$ registered in all other countries in the sample (including itself) are from the World Intellectual Property Organization (WIPO), average over 2000-2005.

through licensing, technology diffusion does not leave a paper trail that can be used to *directly* measure the value of production done in a country by domestic firms using foreign technologies.[35] The big challenge of incorporating diffusion as an additional channel for the gains from openness is to discipline the amount of diffusion occurring across countries as it is not directly observable in the data. Our paper can be seen as a step in that direction since, after controlling for observable sources of gains from openness and domestic frictions, any difference in TFP between the data and the model could be attributed to non-observable diffusion. Our framework could be then taken a step further and used to discipline parameters related to diffusion. This is an important topic left for future research.

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Table 1: Baseline Calibration.

| | Size | GT | $\tau_{nn}^{-1}$ | Real Wage | | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1)x(2) | (1)x(3) | (1)x(2)x(3) | data |
| Australia | 0.47 | 1.01 | 1.54 | 0.47 | 0.72 | 0.73 | 0.97 |
| Austria | 0.33 | 1.18 | 1.81 | 0.39 | 0.61 | 0.71 | 1.11 |
| Benelux | 0.47 | 1.43 | 1.54 | 0.67 | 0.72 | 1.03 | 1.16 |
| Canada | 0.53 | 1.15 | 1.41 | 0.61 | 0.75 | 0.86 | 0.86 |
| Switzerland | 0.37 | 1.14 | 1.81 | 0.42 | 0.67 | 0.76 | 0.88 |
| Denmark | 0.33 | 1.19 | 2.14 | 0.40 | 0.72 | 0.85 | 0.94 |
| Spain | 0.44 | 1.05 | 1.47 | 0.46 | 0.64 | 0.67 | 1.14 |
| Finland | 0.39 | 1.06 | 2.14 | 0.41 | 0.83 | 0.87 | 0.84 |
| France | 0.57 | 1.06 | 1.33 | 0.60 | 0.76 | 0.80 | 1.07 |
| Great Britain | 0.56 | 1.08 | 1.30 | 0.60 | 0.72 | 0.78 | 1.00 |
| Germany | 0.65 | 1.05 | 1.20 | 0.68 | 0.78 | 0.82 | 0.92 |
| Greece | 0.29 | 1.08 | 1.81 | 0.32 | 0.53 | 0.58 | 0.90 |
| Hungary | 0.28 | 1.15 | 2.14 | 0.33 | 0.60 | 0.70 | 0.65 |
| Ireland | 0.26 | 1.32 | 2.14 | 0.35 | 0.56 | 0.74 | 1.32 |
| Iceland | 0.17 | 1.21 | 2.14 | 0.21 | 0.37 | 0.45 | 1.17 |
| Italy | 0.45 | 1.02 | 1.37 | 0.46 | 0.62 | 0.64 | 1.20 |
| Japan | 0.83 | 0.97 | 1.08 | 0.80 | 0.90 | 0.87 | 0.71 |
| Korea | 0.52 | 1.01 | 1.37 | 0.52 | 0.71 | 0.72 | 0.63 |
| Mexico | 0.31 | 1.08 | 1.37 | 0.33 | 0.42 | 0.46 | 0.78 |
| Norway | 0.35 | 1.10 | 2.14 | 0.39 | 0.76 | 0.84 | 1.11 |
| New Zealand | 0.28 | 1.07 | 2.14 | 0.30 | 0.60 | 0.64 | 0.74 |
| Poland | 0.41 | 1.06 | 1.54 | 0.43 | 0.63 | 0.67 | 0.50 |
| Portugal | 0.29 | 1.10 | 2.14 | 0.32 | 0.62 | 0.68 | 0.97 |
| Sweden | 0.41 | 1.09 | 1.87 | 0.45 | 0.75 | 0.82 | 0.81 |
| Turkey | 0.28 | 1.04 | 1.47 | 0.29 | 0.42 | 0.43 | 0.61 |
| United States | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Avg all | 0.43 | 1.10 | 1.67 | 0.47 | 0.67 | 0.73 | 0.92 |
| Avg 6 smallest | 0.30 | 1.16 | 2.14 | 0.34 | 0.64 | 0.73 | 1.02 |
| Avg 6 largest | 0.68 | 1.03 | 1.21 | 0.69 | 0.80 | 0.82 | 0.98 |

Column 1 refers to the first term (country size), column 2 to the second term (gains from trade), and column 3 to the third term (domestic frictions) on the right-hand side of (24). The real wage in the data is the real GDP (PPP-adjusted) per unit of equipped labor. All variables are calculated relative to the United States. The six smallest countries (with respect to R&D-adjusted size) are Iceland, Ireland, New Zealand, Finland, Norway, and Denmark, while the six largest countries are Italy, France, Great Britain, Germany, Japan, and the United States.

Table 2: Alternative Values for $\theta$.

| | $\theta = 2.5$ | | | | $\theta = 4$ | | | | $\theta = 5.5$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | GT | DF | RW | S | GT | DF | RW | S | GT | DF | RW |
| Australia | 0.30 | 1.01 | 2.00 | 0.60 | 0.47 | 1.01 | 1.54 | 0.73 | 0.58 | 1.01 | 1.37 | 0.79 |
| Austria | 0.17 | 1.30 | 2.59 | 0.58 | 0.33 | 1.18 | 1.81 | 0.71 | 0.45 | 1.13 | 1.54 | 0.78 |
| Benelux | 0.30 | 1.77 | 2.00 | 1.05 | 0.47 | 1.43 | 1.54 | 1.03 | 0.57 | 1.30 | 1.37 | 1.02 |
| Canada | 0.36 | 1.25 | 1.74 | 0.78 | 0.53 | 1.15 | 1.41 | 0.86 | 0.63 | 1.10 | 1.29 | 0.89 |
| Switzerland | 0.20 | 1.23 | 2.59 | 0.65 | 0.37 | 1.14 | 1.81 | 0.76 | 0.49 | 1.10 | 1.54 | 0.82 |
| Denmark | 0.17 | 1.32 | 3.38 | 0.77 | 0.33 | 1.19 | 2.14 | 0.85 | 0.45 | 1.13 | 1.74 | 0.89 |
| Spain | 0.26 | 1.07 | 1.85 | 0.53 | 0.44 | 1.05 | 1.47 | 0.67 | 0.55 | 1.03 | 1.32 | 0.75 |
| Finland | 0.22 | 1.09 | 3.38 | 0.81 | 0.39 | 1.06 | 2.14 | 0.87 | 0.50 | 1.04 | 1.74 | 0.91 |
| France | 0.40 | 1.09 | 1.58 | 0.70 | 0.57 | 1.06 | 1.33 | 0.80 | 0.66 | 1.04 | 1.23 | 0.85 |
| Great Britain | 0.39 | 1.12 | 1.52 | 0.67 | 0.56 | 1.08 | 1.30 | 0.78 | 0.65 | 1.05 | 1.21 | 0.83 |
| Germany | 0.50 | 1.08 | 1.33 | 0.72 | 0.65 | 1.05 | 1.20 | 0.82 | 0.73 | 1.04 | 1.14 | 0.86 |
| Greece | 0.14 | 1.13 | 2.59 | 0.41 | 0.29 | 1.08 | 1.81 | 0.58 | 0.41 | 1.06 | 1.54 | 0.67 |
| Hungary | 0.13 | 1.25 | 3.38 | 0.56 | 0.28 | 1.15 | 2.14 | 0.70 | 0.40 | 1.11 | 1.74 | 0.77 |
| Ireland | 0.12 | 1.57 | 3.38 | 0.62 | 0.26 | 1.32 | 2.14 | 0.74 | 0.38 | 1.23 | 1.74 | 0.81 |
| Iceland | 0.06 | 1.35 | 3.38 | 0.28 | 0.17 | 1.21 | 2.14 | 0.45 | 0.28 | 1.15 | 1.74 | 0.56 |
| Italy | 0.28 | 1.04 | 1.65 | 0.49 | 0.45 | 1.02 | 1.37 | 0.64 | 0.56 | 1.02 | 1.26 | 0.72 |
| Japan | 0.74 | 0.96 | 1.14 | 0.80 | 0.83 | 0.97 | 1.08 | 0.87 | 0.87 | 0.98 | 1.06 | 0.91 |
| Korea | 0.35 | 1.01 | 1.65 | 0.59 | 0.52 | 1.01 | 1.37 | 0.72 | 0.62 | 1.01 | 1.26 | 0.78 |
| Mexico | 0.15 | 1.13 | 1.65 | 0.29 | 0.31 | 1.08 | 1.37 | 0.46 | 0.43 | 1.06 | 1.26 | 0.57 |
| Norway | 0.19 | 1.17 | 3.38 | 0.75 | 0.35 | 1.10 | 2.14 | 0.84 | 0.47 | 1.07 | 1.74 | 0.88 |
| New Zealand | 0.13 | 1.12 | 3.38 | 0.49 | 0.28 | 1.07 | 2.14 | 0.64 | 0.40 | 1.05 | 1.74 | 0.73 |
| Poland | 0.24 | 1.09 | 2.00 | 0.52 | 0.41 | 1.06 | 1.54 | 0.67 | 0.52 | 1.04 | 1.37 | 0.75 |
| Portugal | 0.14 | 1.16 | 3.38 | 0.54 | 0.29 | 1.10 | 2.14 | 0.68 | 0.41 | 1.07 | 1.74 | 0.76 |
| Sweden | 0.24 | 1.16 | 2.59 | 0.72 | 0.41 | 1.09 | 1.81 | 0.82 | 0.52 | 1.07 | 1.54 | 0.86 |
| Turkey | 0.13 | 1.06 | 1.85 | 0.26 | 0.28 | 1.04 | 1.47 | 0.43 | 0.40 | 1.03 | 1.32 | 0.54 |
| United States | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Avg all | 0.28 | 1.17 | 2.32 | 0.62 | 0.43 | 1.10 | 1.67 | 0.73 | 0.54 | 1.07 | 1.44 | 0.80 |
| Avg 6 smallest | 0.15 | 1.27 | 3.38 | 0.62 | 0.30 | 1.16 | 2.14 | 0.73 | 0.41 | 1.11 | 1.74 | 0.79 |
| Avg 6 largest | 0.55 | 1.05 | 1.37 | 0.73 | 0.68 | 1.03 | 1.21 | 0.82 | 0.75 | 1.02 | 1.15 | 0.86 |

"S," "GT," and "DF", refer to size, gains from trade, and domestic frictions, respectively, and correspond to the first, second, and third terms, respectively, on the right-hand side of (24). "RW" refers to the real wage and correspond to the product of the three terms on the right-hand side of (24). All variables are calculated relative to the United States. The six smallest countries (with respect to R&D-adjusted size) are Iceland, Ireland, New Zealand, Finland, Norway, and Denmark, while the six largest countries are Italy, France, Great Britain, Germany, Japan, and the United States.

Table 3: Alternative Calibrations for Domestic Frictions.

| | Domestic Frictions $\tau_{nn}$ | | | | | Real Wage | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | U.S. states (1) | U.S. CSA-SMA (2) | Can. prov. (3) | Pop. den. (4) | Cities $> 250$K (5) | U.S. states (6) | U.S. CSA-SMA (7) | Can. prov. (8) | Pop. den. (9) | Cities $> 250$K (10) | Data (11) |
| Australia | 0.65 | 0.65 | 0.69 | 0.98 | 0.76 | 0.73 | 0.72 | 0.69 | 0.48 | 0.62 | 0.97 |
| Austria | 0.55 | 0.54 | 0.55 | 0.47 | 0.53 | 0.71 | 0.73 | 0.71 | 0.84 | 0.74 | 1.11 |
| Benelux | 0.65 | 0.67 | 0.70 | 0.55 | 0.66 | 1.03 | 0.99 | 0.95 | 1.21 | 1.01 | 1.16 |
| Canada | 0.71 | 0.72 | 0.76 | 1.01 | 0.81 | 0.86 | 0.84 | 0.80 | 0.60 | 0.75 | 0.86 |
| Switzerland | 0.55 | 0.54 | 0.59 | 0.47 | 0.45 | 0.76 | 0.78 | 0.72 | 0.90 | 0.93 | 0.88 |
| Denmark | 0.47 | 0.49 | 0.55 | 0.47 | 0.45 | 0.85 | 0.82 | 0.72 | 0.85 | 0.88 | 0.94 |
| Spain | 0.68 | 0.69 | 0.73 | 0.61 | 0.83 | 0.67 | 0.66 | 0.62 | 0.75 | 0.55 | 1.14 |
| Finland | 0.47 | 0.49 | 0.50 | 0.55 | 0.53 | 0.87 | 0.84 | 0.81 | 0.74 | 0.77 | 0.84 |
| France | 0.75 | 0.77 | 0.81 | 0.61 | 0.71 | 0.80 | 0.77 | 0.74 | 0.99 | 0.85 | 1.07 |
| Great Britain | 0.77 | 0.78 | 0.82 | 0.55 | 0.84 | 0.78 | 0.77 | 0.73 | 1.09 | 0.71 | 1.00 |
| Germany | 0.84 | 0.84 | 0.88 | 0.55 | 0.90 | 0.82 | 0.81 | 0.78 | 1.24 | 0.76 | 0.92 |
| Greece | 0.55 | 0.54 | 0.55 | 0.47 | 0.53 | 0.58 | 0.59 | 0.58 | 0.68 | 0.60 | 0.90 |
| Hungary | 0.47 | 0.49 | 0.55 | 0.47 | 0.45 | 0.70 | 0.67 | 0.59 | 0.70 | 0.72 | 0.65 |
| Ireland | 0.47 | 0.41 | 0.42 | 0.47 | 0.45 | 0.74 | 0.84 | 0.82 | 0.74 | 0.77 | 1.32 |
| Iceland | 0.47 | 0.41 | 0.42 | 0.47 | n/a | 0.45 | 0.51 | 0.50 | 0.45 | n/a | 1.17 |
| Italy | 0.73 | 0.74 | 0.79 | 0.55 | 0.79 | 0.64 | 0.63 | 0.59 | 0.84 | 0.59 | 1.20 |
| Japan | 0.92 | 0.93 | 0.95 | 0.61 | 1.01 | 0.87 | 0.86 | 0.85 | 1.33 | 0.79 | 0.71 |
| Korea | 0.73 | 0.74 | 0.78 | 0.47 | 0.95 | 0.72 | 0.70 | 0.67 | 1.12 | 0.55 | 0.63 |
| Mexico | 0.73 | 0.74 | 0.79 | 0.77 | 0.99 | 0.46 | 0.45 | 0.43 | 0.43 | 0.34 | 0.78 |
| Norway | 0.47 | 0.49 | 0.55 | 0.61 | 0.53 | 0.84 | 0.80 | 0.71 | 0.64 | 0.73 | 1.11 |
| New Zealand | 0.47 | 0.49 | 0.50 | 0.55 | 0.59 | 0.64 | 0.62 | 0.60 | 0.55 | 0.51 | 0.74 |
| Poland | 0.65 | 0.67 | 0.72 | 0.55 | 0.80 | 0.67 | 0.64 | 0.60 | 0.78 | 0.54 | 0.50 |
| Portugal | 0.47 | 0.49 | 0.55 | 0.47 | 0.45 | 0.68 | 0.65 | 0.58 | 0.68 | 0.70 | 0.97 |
| Sweden | 0.55 | 0.54 | 0.59 | 0.61 | 0.59 | 0.82 | 0.84 | 0.76 | 0.74 | 0.77 | 0.81 |
| Turkey | 0.68 | 0.69 | 0.73 | 0.65 | 0.88 | 0.43 | 0.43 | 0.40 | 0.45 | 0.33 | 0.61 |
| United States | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Avg all | 0.63 | 0.64 | 0.67 | 0.60 | 0.70 | 0.73 | 0.73 | 0.69 | 0.80 | 0.70 | 0.92 |
| Avg smallest | 0.47 | 0.46 | 0.49 | 0.52 | 0.51 | 0.73 | 0.74 | 0.69 | 0.66 | 0.73 | 1.02 |
| Avg largest | 0.83 | 0.85 | 0.87 | 0.64 | 0.87 | 0.82 | 0.81 | 0.78 | 1.08 | 0.78 | 0.98 |

Columns 1 to 3 refer to the calibrations using U.S. states, U.S. sub-regional geographical units (CSA-MSA), and Canadian provinces, respectively. Column 4 refers to the calibration using population density in each country. Column 5 shows the results for the calibration using the number of towns with more than 250K habitants in the data. Columns 6 to 10 shows the real wage in (24) using the different calibrations in columns 1 to 5, respectively. All variables are relative to the United States. The six smallest countries (with respect to R&D-adjusted size) are Iceland, Ireland, New Zealand, Finland, Norway, and Denmark, while the six largest countries are Italy, France, Great Britain, Germany, Japan, and the United States.

Table 4: The Role of Domestic Frictions. Summary Statistics.

| | Average | | | Size elasticity |
|---|---|---|---|---|
| | full sample | 6 smallest countries | 6 largest countries | |
| Data | | | | |
| import share | 0.39 | 0.50 | 0.24 | -0.23 (0.07) |
| real wage | 0.92 | 1.02 | 0.98 | -0.006 (0 .03) |
| nominal wage | 0.83 | 1.01 | 1.01 | 0.07 (0.057) |
| price index | 1.25 | 1.02 | 0.97 | 0.07 (0.04) |
| Model with $d = 2.4$ | | | | |
| import share | 0.38 | 0.44 | 0.30 | -0.16 (0.06) |
| real wage | 0.73 | 0.71 | 0.84 | 0.10 (0.01) |
| nominal wage | 0.81 | 0.84 | 0.88 | 0.06 (0.015) |
| price index | 1.12 | 1.20 | 1.06 | -0.04 (0.009) |
| Model with $d = 1$ | | | | |
| import share | 0.38 | 0.57 | 0.19 | -0.35 (0.03) |
| real wage | 0.48 | 0.37 | 0.70 | 0.20 (0.01) |
| nominal wage | 0.67 | 0.63 | 0.81 | 0.11 (0.015) |
| price index | 1.46 | 1.73 | 1.19 | -0.10 (0.006) |

The real wage, nominal wage, and price index, for country $n$, are calculated relative to the United States. The size elasticity of each variable is from an OLS regressions with a constant and robust standard errors (in parenthesis). The six smallest countries (with respect to R&D-adjusted size) are Iceland, Ireland, New Zealand, Finland, Norway, and Denmark, while the six largest countries are Italy, France, Great Britain, Germany, Japan, and the United States.

Table 5: The Model with Multinational Production.

| | Size (1) | GT (2) | GMP (3) | GO (4) | Dom.Fric. (5) | Real Wage (1)x(2) | (1)x(3) | (1)x(4) | (1)x(4)x(5) | data |
|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 0.47 | 1.00 | 1.02 | 1.03 | 1.55 | 0.47 | 0.48 | 0.48 | 0.74 | 0.97 |
| Austria | 0.33 | 1.06 | 1.04 | 1.10 | 1.81 | 0.37 | 0.35 | 0.37 | 0.67 | 1.11 |
| Benelux | 0.47 | 1.13 | 1.09 | 1.22 | 1.55 | 0.59 | 0.51 | 0.57 | 0.88 | 1.16 |
| Canada | 0.53 | 1.05 | 1.07 | 1.12 | 1.41 | 0.58 | 0.56 | 0.59 | 0.84 | 0.86 |
| Switzerland | 0.37 | 1.04 | 1.06 | 1.11 | 1.81 | 0.40 | 0.39 | 0.41 | 0.74 | 0.88 |
| Denmark | 0.33 | 1.06 | 1.00 | 1.06 | 2.14 | 0.38 | 0.33 | 0.35 | 0.76 | 0.94 |
| Spain | 0.44 | 1.01 | 1.01 | 1.02 | 1.47 | 0.45 | 0.44 | 0.45 | 0.66 | 1.14 |
| Finland | 0.39 | 1.02 | 1.01 | 1.03 | 2.14 | 0.40 | 0.39 | 0.40 | 0.85 | 0.84 |
| France | 0.57 | 1.02 | 1.01 | 1.03 | 1.33 | 0.59 | 0.57 | 0.58 | 0.78 | 1.07 |
| Great Britain | 0.56 | 1.02 | 1.06 | 1.09 | 1.30 | 0.59 | 0.59 | 0.61 | 0.79 | 1.00 |
| Germany | 0.65 | 1.02 | 1.03 | 1.05 | 1.20 | 0.67 | 0.67 | 0.68 | 0.81 | 0.92 |
| Greece | 0.29 | 1.03 | 0.98 | 1.01 | 1.81 | 0.31 | 0.29 | 0.30 | 0.54 | 0.90 |
| Hungary | 0.28 | 1.05 | 1.12 | 1.17 | 2.14 | 0.31 | 0.32 | 0.33 | 0.71 | 0.65 |
| Ireland | 0.26 | 1.10 | 1.08 | 1.19 | 2.14 | 0.32 | 0.28 | 0.31 | 0.67 | 1.32 |
| Iceland | 0.17 | 1.06 | 0.97 | 1.04 | 2.14 | 0.20 | 0.17 | 0.18 | 0.39 | 1.17 |
| Italy | 0.45 | 1.01 | 0.99 | 1.00 | 1.37 | 0.46 | 0.45 | 0.45 | 0.62 | 1.20 |
| Japan | 0.83 | 0.99 | 0.97 | 0.96 | 1.08 | 0.81 | 0.80 | 0.80 | 0.86 | 0.71 |
| Korea | 0.52 | 1.00 | 0.98 | 0.98 | 1.37 | 0.52 | 0.51 | 0.51 | 0.69 | 0.63 |
| Mexico | 0.31 | 1.03 | 1.01 | 1.04 | 1.37 | 0.33 | 0.31 | 0.32 | 0.44 | 0.78 |
| Norway | 0.35 | 1.03 | 1.00 | 1.04 | 2.14 | 0.38 | 0.35 | 0.37 | 0.79 | 1.11 |
| New Zealand | 0.28 | 1.02 | 1.03 | 1.06 | 2.14 | 0.29 | 0.29 | 0.30 | 0.64 | 0.74 |
| Poland | 0.41 | 1.02 | 1.03 | 1.05 | 1.55 | 0.42 | 0.42 | 0.43 | 0.66 | 0.50 |
| Portugal | 0.29 | 1.03 | 1.08 | 1.12 | 2.14 | 0.31 | 0.31 | 0.32 | 0.70 | 0.97 |
| Sweden | 0.41 | 1.03 | 1.04 | 1.07 | 1.81 | 0.44 | 0.43 | 0.44 | 0.80 | 0.81 |
| Turkey | 0.28 | 1.01 | 0.98 | 0.99 | 1.47 | 0.29 | 0.28 | 0.28 | 0.41 | 0.61 |
| United States | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Avg all | 0.43 | 1.03 | 1.03 | 1.06 | 1.67 | 0.46 | 0.44 | 0.45 | 0.71 | 0.92 |
| Avg 6 smallest | 0.30 | 1.05 | 1.02 | 1.07 | 2.14 | 0.33 | 0.30 | 0.32 | 0.68 | 1.02 |
| Avg 6 largest | 0.68 | 1.01 | 1.01 | 1.02 | 1.21 | 0.69 | 0.68 | 0.69 | 0.81 | 0.98 |

Column 1 refers to the first term (size), column 2 to the third term (gains from trade), column 3 to the fourth term (gains from MP), and column 5 (domestic frictions) to the second term, respectively, on the right-hand side of (28). Column 4 are the gains from openness, $GO_n = GT_n \times GMP_n$. The real wage in the data is the real GDP (PPP-adjusted) per unit of equipped labor. All variables are calculated relative to the United States. The six smallest countries (with respect to R&D-adjusted size) are Iceland, Ireland, New Zealand, Finland, Norway, and Denmark, while the six largest countries are Italy, France, Great Britain, Germany, Japan, and the United States.

# A Proof of Proposition 1

Replacing (1) into $X_{ni} \equiv \sum_{m\in\Omega_n} \sum_{k\in\Omega_i} \widetilde{X}_{mk}$, we get

$$X_{nl} = \sum_{m\in\Omega_n} \sum_{k\in\Omega_l} \frac{\widetilde{T}_k \widetilde{w}_k^{-\theta} \widetilde{d}_{mk}^{-\theta}}{\sum_{k'} \widetilde{T}_{k'} \widetilde{w}_{k'}^{-\theta} \widetilde{d}_{mk'}^{-\theta}} \widetilde{X}_m.$$

Using A1, for $n \neq l$, we have

$$\begin{aligned}
X_{nl} &= \sum_{m\in\Omega_n} \sum_{k\in\Omega_l} \frac{\widetilde{T}_k \widetilde{w}_k^{-\theta} \widetilde{d}_{mk}^{-\theta}}{\sum_j \sum_{k'\in\Omega_j} \widetilde{T}_{k'} \widetilde{w}_{k'}^{-\theta} \widetilde{d}_{mk'}^{-\theta}} \frac{X_n}{M_n} \\
&= \sum_{m\in\Omega_n} \frac{T_l w_l^{-\theta} \tau_{nl}^{-\theta}}{\sum_{j\neq n} T_j w_j^{-\theta} \tau_{nj}^{-\theta} + (M_n - 1)\, \bar{T}_n w_n^{-\theta} d_{nn}^{-\theta} + \bar{T}_n w_n^{-\theta}} \frac{X_n}{M_n} \\
&= \sum_{m\in\Omega_n} \frac{M_l \bar{T}_l w_l^{-\theta} \tau_{nl}^{-\theta}}{\sum_{j\neq n} T_j w_j^{-\theta} \tau_{nj}^{-\theta} + M_n \bar{T}_n w_n^{-\theta} \left[\frac{1}{M_n} + \frac{M_n - 1}{M_n} d_{nn}^{-\theta}\right]} \frac{X_n}{M_n} \\
&= \frac{T_l w_l^{-\theta} \tau_{nl}^{-\theta}}{\sum_j T_j w_j^{-\theta} \tau_{nj}^{-\theta}} X_n.
\end{aligned}$$

Similarly, for $n = l$,

$$\begin{aligned}
X_{nl} &= \sum_{m\in\Omega_n} \sum_{k\in\Omega_l} \frac{\widetilde{T}_k \widetilde{w}_k^{-\theta} \widetilde{d}_{mk}^{-\theta}}{\sum_j \sum_{k'\in\Omega_j} \widetilde{T}_{k'} \widetilde{w}_{k'}^{-\theta} \widetilde{d}_{mk'}^{-\theta}} \frac{X_n}{M_n} \\
&= \sum_{m\in\Omega_n} \frac{(M_n - 1)\, \bar{T}_n w_n^{-\theta} d_{nn}^{-\theta} + \bar{T}_n w_n^{-\theta}}{\sum_{j\neq n} T_j w_j^{-\theta} \tau_{nj}^{-\theta} + (M_n - 1)\, \bar{T}_n w_n^{-\theta} d_{nn}^{-\theta} + \bar{T}_n w_n^{-\theta}} \frac{X_n}{M_n} \\
&= \frac{M_n \bar{T}_n w_n^{-\theta} \left[\frac{1}{M_n} + \frac{M_n - 1}{M_n} d_{nn}^{-\theta}\right]}{\sum_{j\neq n} T_j w_j^{-\theta} \tau_{nj}^{-\theta} + M_n \bar{T}_n w_n^{-\theta} \left[\frac{1}{M_n} + \frac{M_n - 1}{M_n} d_{nn}^{-\theta}\right]} X_n \\
&= \frac{T_n w_n^{-\theta} \tau_{nn}^{-\theta}}{\sum_j T_j w_j^{-\theta} \tau_{nj}^{-\theta}} X_n.
\end{aligned}$$

This establishes that

$$X_{nl} = \frac{T_l w_l^{-\theta} \tau_{nl}^{-\theta}}{\sum_j T_j w_j^{-\theta} \tau_{nj}^{-\theta}} X_n,$$

for all $n, l$, and $\tau_{nn}$ defined as in (6).

Turning to the price index, we know that for $m \in \Omega_n$, we have $P_n = \widetilde{P}_m$. Hence,

$$
\begin{aligned}
P_n &= \mu^{-1} \left( \sum_j \sum_{k \in \Omega_j} \widetilde{T}_k \widetilde{w}_k^{-\theta} \widetilde{d}_{mk}^{-\theta} \right)^{-1/\theta} \\
&= \mu^{-1} \left( \sum_{j \neq n} T_j w_j^{-\theta} \tau_{nj}^{-\theta} + (M_n - 1) \frac{T_n}{M_n} w_n^{-\theta} d_{nn}^{-\theta} + \frac{T_n}{M_n} w_n^{-\theta} \right)^{-1/\theta} \\
&= \mu^{-1} \left( \sum_j T_j w_j^{-\theta} \tau_{nj}^{-\theta} \right)^{-1/\theta}.
\end{aligned}
$$

# B Proof of Proposition 3

Equilibrium wages are determined by the system

$$
w_i L_i = \sum_n \frac{L_i w_i^{-\theta} \tau_{ni}^{-\theta}}{\sum_j L_j w_j^{-\theta} \tau_{nj}^{-\theta}} w_n L_n,
$$

with

$$
\tau_{nn}^{-\theta} = \frac{1}{M_n} + \frac{M_n - 1}{M_n} d^{-\theta}.
$$

Given A3, and letting $\Phi \equiv \sum_j M_j w_j^{-\theta} \tau^{-\theta}$,

$$
\begin{aligned}
w_i M_i &= \frac{w_i^{-\theta} \left(1 - d^{-\theta}\right) + w_i^{-\theta} M_i d^{-\theta}}{\Phi + w_i^{-\theta} \left[1 - d^{-\theta} + M_i \left(d^{-\theta} - \tau^{-\theta}\right)\right]} w_i M_i \\
&\quad + \sum_{n \neq i} \frac{M_i w_i^{-\theta} \tau^{-\theta}}{\Phi + w_n^{-\theta} \left[1 - d^{-\theta} + M_n \left(d^{-\theta} - \tau^{-\theta}\right)\right]} w_n M_n,
\end{aligned}
$$

and hence,

$$
\frac{w^{1+\theta}}{\Phi + w^{-\theta} \left(1 - d^{-\theta} + M \left(d^{-\theta} - \tau^{-\theta}\right)\right)} = \tau^{-\theta} \Gamma / \Phi, \tag{31}
$$

where $\Gamma \equiv \sum_n \frac{w_n M_n}{\Phi + w_n^{-\theta} \left[1 - d^{-\theta} + M_n \left(d^{-\theta} - \tau^{-\theta}\right)\right]}$. Since $\tau > d$, then $d^{-\theta} > \tau^{-\theta}$, so that the left-hand side is decreasing in $M$ and increasing in $w$. This implies that if $M_i > M_j$ then necessarily $w_i > w_j$: larger countries have higher wages. In contrast, if $\tau = d$, then the left-hand side is invariant to $M$ and hence $w$ must be common across countries.

To compare import shares across countries in a given equilibrium, note that domestic trade shares are given by

$$\lambda_{nn}=\frac{1+\left(M_n-1\right)d^{-\theta}}{\Phi w_n^{\theta}+1-d^{-\theta}+M_n\left(d^{-\theta}-\tau^{-\theta}\right)}.$$

Plugging (B) into (31) and rearranging yield

$$w_n^{1+\theta}\left(1-\frac{1-d^{-\theta}+M_n\left(d^{-\theta}-\tau^{-\theta}\right)}{1+\left(M_n-1\right)d^{-\theta}}\lambda_{nn}\right)=\tau^{-\theta}\Gamma. \tag{32}$$

Since $w_i>w_j$ when $M_i>M_j$,

$$\frac{1-d^{-\theta}+M_i(d^{-\theta}-\tau^{-\theta})}{1-d^{-\theta}+M_i d^{-\theta}}\lambda_{ii}>\frac{1-d^{-\theta}+M_j(d^{-\theta}-\tau^{-\theta})}{1-d^{-\theta}+M_j d^{-\theta}}\lambda_{jj}.$$

But since $\frac{1-d^{-\theta}+x(d^{-\theta}-\tau^{-\theta})}{1-d^{-\theta}+xd^{-\theta}}$ is decreasing in $x$, then $M_i>M_j$ also implies

$$\frac{1-d^{-\theta}+M_i(d^{-\theta}-\tau^{-\theta})}{1-d^{-\theta}+M_i d^{-\theta}}<\frac{1-d^{-\theta}+M_j(d^{-\theta}-\tau^{-\theta})}{1-d^{-\theta}+M_j d^{-\theta}},$$

and hence $\lambda_{ii}>\lambda_{jj}$.

For price indices, note that

$$(\mu P_n)^{-\theta}=\sum_j M_j w_j^{-\theta}\tau_{nj}^{-\theta}=\Phi+w_n^{-\theta}\left(1-d^{-\theta}+M_n\left(d^{-\theta}-\tau^{-\theta}\right)\right).$$

Hence, (31) implies that

$$w_n^{1+\theta}P_n^{\theta}=\frac{\mu^{-\theta}\tau^{-\theta}\Gamma}{\Phi}. \tag{33}$$

Again, since $w_i>w_j$ when $M_i>M_j$, then $P_i<P_j$. Combining the results for wages and price indices, real wages are also increasing in size. Moreover, if $\tau=d$, then the result that wages are the same across countries immediately follows from (33), which also implies that the price index is the same across countries.

# C Equivalence with Melitz (2003) Model

Assume that productivity draws in each region $z_m$ are from a Pareto distribution with shape parameter $\theta$ and lower bound $\widetilde{b}_m$. Replacing (1) into $X_{ni}\equiv\sum_{m\in\Omega_n}\sum_{k\in\Omega_i}\widetilde{X}_{mk}$, we get

$$X_{nl}=\sum_{m\in\Omega_n}\sum_{k\in\Omega_l}\frac{\widetilde{L}_k\widetilde{b}_k^{\theta}\widetilde{w}_k^{-\theta}\widetilde{d}_{mk}^{-\theta}}{\sum_{k'}\widetilde{L}_{k'}^{\theta}\widetilde{b}_{k'}\widetilde{w}_{k'}^{-\theta}\widetilde{d}_{mk'}^{-\theta}}\widetilde{X}_m.$$

The equivalent of A1 here would be $\widetilde{b}_m=\widetilde{b}_{m'}=b_n$ for all $m,m'\in\Omega_n$. Replacing, we get

$$X_{nl}=\frac{L_l b_l^{\theta}w_l^{-\theta}\tau_{nl}^{-\theta}}{\sum_j L_j b_j^{\theta}w_j^{-\theta}\tau_{nj}^{-\theta}}X_n,$$

for all $n,l$, and $\tau_{nn}$ defined as in (6). Analogously to the results in Melitz (2003)'s, the productivity cut-off for a region $m$ is given by:

$$\widetilde{z}_{km}^{*}=C_0\left(\frac{\widetilde{f}_m}{\widetilde{L}_m}\right)^{1/(\sigma-1)}\frac{\widetilde{w}_k\widetilde{d}_{mk}}{\widetilde{P}_m},$$

where $C_0$ is a constant. Turning to the price index, we get

$$\begin{aligned}P_n^{1-\sigma} &= \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\sum_j\sum_{k\in\Omega_j}\widetilde{L}_k\left(\widetilde{w}_k\widetilde{d}_{mk}\right)^{1-\sigma}\int_{\widetilde{z}_{km}^{*}}^{\infty}z^{\sigma-1}\widetilde{b}_k^{\theta}z^{-\theta-1}dz\\ &= C_1\sum_j\sum_{k\in\Omega_j}\widetilde{L}_k\widetilde{b}_k^{\theta}\left(\widetilde{w}_k\widetilde{d}_{mk}\right)^{1-\sigma}\left(\widetilde{z}_{mk}^{*}\right)^{\sigma-1-\theta}\\ &= C_1\sum_j\sum_{k\in\Omega_j}\widetilde{L}_k\widetilde{b}_k^{\theta}\left(\widetilde{w}_k\widetilde{d}_{mk}\right)^{1-\sigma}\left(\left(\frac{\widetilde{f}_m}{\widetilde{L}_m}\right)^{1/(\sigma-1)}\frac{\widetilde{w}_k\widetilde{d}_{mk}}{\widetilde{P}_m}\right)^{\sigma-1-\theta},\end{aligned}$$

where $C_1$ is a constant. Further, A1 in this case also implies that $\widetilde{f}_m=\bar{f}_n$. Hence, for $m\in\Omega_n$, $P_n=\widetilde{P}_m$. Replacing and after some algebra, we get

$$\begin{aligned}P_n^{-\theta} &= C_2\sum_{j\neq n}M_j\bar{L}_j b_j^{\theta}\left(w_j\tau_{nj}\right)^{-\theta}\left(\frac{\bar{f}_n}{\bar{L}_n}\right)^{1-\frac{\theta}{\sigma-1}}+C_2\bar{L}_n b_n^{\theta}w_n^{-\theta}\left(\frac{\bar{f}_n}{\bar{L}_n}\right)^{1-\frac{\theta}{\sigma-1}}\left(\left(M_n-1\right)d_{nn}^{-\theta}+1\right)\\ &= C_2\left(\frac{\bar{f}_n}{\bar{L}_n}\right)^{1-\frac{\theta}{\sigma-1}}\sum_j L_j b_j^{\theta}\left(w_j\tau_{nj}\right)^{-\theta},\end{aligned}$$

where $C_2$ is a constant. Thus,

$$\sum_j L_j b_j^{\theta}\left(w_j\tau_{nj}\right)^{-\theta}=C_2^{-1}P_n^{-\theta}\left(\frac{\bar{f}_n}{\bar{L}_n}\right)^{-[1-\theta/(\sigma-1)]},$$

and hence,

$$\lambda_{nn} = \frac{L_n b_n^{\theta} w_n^{-\theta} \tau_{nn}^{-\theta}}{C_2^{-1} P_n^{-\theta} \left(\frac{\bar{f}_n}{\bar{L}_n}\right)^{-\left(1-\frac{\theta}{\sigma-1}\right)}},$$

so that

$$\frac{w_n}{P_n} = C_2^{-1/\theta} L_n^{1/\theta} b_n \tau_{nn}^{-1} \lambda_{nn}^{-1/\theta} \left(\frac{\bar{f}_n}{\bar{L}_n}\right)^{1/\theta - 1/(\sigma-1)},$$

and

$$\begin{aligned}\frac{w_n}{P_n} &= C_2^{-1/\theta} M_n^{1/\theta} \bar{L}_n^{1/\theta} b_n \tau_{nn}^{-1} \lambda_{nn}^{-1/\theta} \left(\frac{\bar{f}_n}{\bar{L}_n}\right)^{1/\theta - 1/(\sigma-1)} \\ &= C_2^{-1/\theta} M_n^{1/\theta} \bar{L}_n^{1/(\sigma-1)} b_n \tau_{nn}^{-1} \lambda_{nn}^{-1/\theta} \bar{f}_n^{1/\theta - 1/(\sigma-1)}.\end{aligned}$$

Thus, if $\bar{f}_n$ does not vary with $\bar{L}_n$, the growth rate would be $g_L/(\sigma-1)$. To have the growth rate be $g_L/\theta$, we need to assume that $\bar{f}_n$ scales up with $\bar{L}_n$ proportionally, or $\theta \approx \sigma - 1$, in which case

$$\frac{w_n}{P_n} \sim L_n^{1/\theta} b_n \tau_{nn}^{-1} \lambda_{nn}^{-1/\theta}.$$

# D The Model with Multinational Production and Non-Tradable Goods

## D.1 Equilibrium Analysis

The following Proposition characterizes trade and MP flows for the model of trade and MP with domestic frictions presented in Section 6.

We introduce the following notation: $c_l^f \equiv A w_l^{\alpha} \left(P_l^g\right)^{1-\alpha}$, $c_l^g \equiv A w_l^{\beta} \left(P_l^g\right)^{1-\beta}$ and $Y_l^s \equiv \sum_i Y_{li}^s$, where $P_l^g$ is the price index of intermediate goods and where $Y_{li}^f$ and $Y_{li}^g$ denote the value of production of final and intermediate goods, respectively. It is easy to show that $Y_l^g = \eta w_l L_l$ while $Y_l^f = w_l L_l$.

**Proposition 5.** Country-level trade flows are

$$X_{nl} = \frac{\Gamma_l \left(\tau_{nl} c_l^g\right)^{-\theta}}{\sum_{l'} \Gamma_{l'} \left(\tau_{nl'} c_{l'}^g\right)^{-\theta}} X_n, \tag{34}$$

while country-level MP flows in intermediate and final goods are

$$Y_{li}^s = \frac{T_i \gamma_{li}^{-\theta}}{\Gamma_l} Y_l^s \text{ and } Y_{ll}^s = \frac{T_l}{\Gamma_l} Y_l^s \text{ for } s = g, f, \tag{35}$$

and price indices at the country-level are

$$P_n^g = \mu^{-1} \left( \sum_l \Gamma_l \left( c_l^g \right)^{-\theta} \tau_{nl}^{-\theta} \right)^{-1/\theta}, \tag{36}$$

and

$$P_n^f = \mu^{-1} c_n^f \left( \gamma_{nn}^{-\theta} \Gamma_n \right)^{-1/\theta}, \tag{37}$$

where

$$\gamma_{ll} \equiv \left( \frac{1}{M_l} + \frac{M_l - 1}{M_l} h_{ll}^{-\theta} \right)^{-1/\theta}. \tag{38}$$

*Proof:* The proof follows closely the proof of Proposition 1. First, note that no intermediate goods will be produced with technologies outside of their home region. This is because of our assumption that $h_{nn} = d_{nn}$, with the indifference broken in favor of trade rather than MP. Now, for $k \in \Omega_l$, we have an analogous result as in (1)m except that now, instead of $\widetilde{T}_k$, we have $\sum_{i \neq l} \frac{M_i \bar{T}_i}{M_l} \gamma_{il}^{-\theta} + \widetilde{T}_k$. Country-level trade flows are then

$$X_{nl} = \frac{\left( \sum_{i \neq l} T_i \gamma_{ll}^{-\theta} + T_l \right) w_l^{-\theta} \tau_{nl}^{-\theta}}{\sum_j \left( \sum_{i \neq j} T_i \gamma_{ji}^{-\theta} + T_j \right) w_j^{-\theta} \tau_{nj}^{-\theta}} X_i = \frac{\Gamma_l w_l^{-\theta} \tau_{nl}^{-\theta}}{\sum_j \Gamma_j w_j^{-\theta} \tau_{nj}^{-\theta}} X_i.$$

MP shares are simply given by the contribution of each source to $\Gamma_l$, hence

$$Y_{li}^s / Y_l^s = T_i \gamma_{li}^{-\theta} / \Gamma_l \text{ and } Y_{ll}^s / Y_l^s = T_l / \Gamma_l \text{ for } s = f, g.$$

The price index for intermediate goods is simply $\gamma^{-1} \left( \sum_j \Gamma_j w_j^{-\theta} \tau_{nj}^{-\theta} \right)^{-1/\theta}$, while for final goods we have

$$\begin{aligned} \left( \mu P_n^f \right)^{-\theta} &= \sum_{i \neq n} \frac{M_i \bar{T}_i}{M_n} \gamma_{ni}^{-\theta} \left( 1 + (M_n - 1) h_{nn}^{-\theta} \right) + (M_n - 1) \bar{T}_n h_{nn}^{-\theta} + \bar{T}_n \\ &= \sum_{i \neq n} T_i \gamma_{ni}^{-\theta} \gamma_{nn}^{-\theta} + T_n \gamma_{nn}^{-\theta} = \gamma_{nn}^{-\theta} \Gamma_n. \end{aligned}$$

□

The results for trade flows are very similar to those of Proposition 1, except that now technology levels are augmented because of the possibility of using technologies from other countries, appropriately discounted by the efficiency costs: $\Gamma_l \equiv \sum_{i \neq l} T_i \gamma_{li}^{-\theta} + T_l$. Note that if MP costs go to infinity, then $\Gamma_l \to T_l$, as in the model with no MP of Section 2.

We now derive an expression for real wages. First, from (34) and (36), we get

$$\frac{c_n^g}{P_n^g} = \mu \Gamma_n^{1/\theta} \tau_{nn}^{-1} \lambda_{nn}^{-1/\theta}.$$

Using (35),

$$\frac{c_n^g}{P_n^g} = \mu T_n^{1/\theta} \tau_{nn}^{-1} \lambda_{nn}^{-1/\theta} \left(\frac{Y_{nn}^g}{Y_n^g}\right)^{-1/\theta}.$$

Using $c_n^g = B w_n^\beta \left(P_n^g\right)^{1-\beta}$,

$$\frac{w_n}{P_n^g} = B^{-1/\beta} \mu^{1/\beta} T_n^{1/\beta\theta} \tau_{nn}^{-1/\beta} \lambda_{nn}^{-1/\beta\theta} \left(\frac{Y_{nn}^g}{Y_n^g}\right)^{-1/\beta\theta}. \tag{39}$$

From (37) and (35), we get

$$P_n^f = c_n^f \mu^{-1} \gamma_{nn} T_n^{-1/\theta} \left(\frac{Y_{nn}^f}{Y_n^f}\right)^{1/\theta}.$$

Using $c_n^f = A w_n^\alpha \left(P_n^g\right)^{1-\alpha}$ and (39) yield

$$P_n^f = A B^\eta w_n \mu^{-(1+\eta)} T_n^{-\frac{1+\eta}{\theta}} \gamma_{nn} \tau_{nn}^\eta \lambda_{nn}^{\eta/\theta} \left(\frac{Y_{nn}^g}{Y_n^g}\right)^{\eta/\theta} \left(\frac{Y_{nn}^f}{Y_n^f}\right)^{1/\theta}.$$

Further rearranging yields

$$\frac{w_n}{P_n^f} = A^{-1} B^{-\eta} \mu^{(1+\eta)} T_n^{\frac{1+\eta}{\theta}} \gamma_{nn}^{-1} \tau_{nn}^{-\eta} \lambda_{nn}^{-\eta/\theta} \left(\frac{Y_{nn}^g}{Y_n^g}\right)^{-\eta/\theta} \left(\frac{Y_{nn}^f}{Y_n^f}\right)^{-1/\theta}.$$

Using $Y_{nn}^g / Y_n^g = Y_{nn}^f / Y_n^f = T_l / \Gamma_l = \pi_{ll}$ and $T_n = \phi_n L_n$, and setting $\mu^M \equiv A^{-1} B^{-\eta} \mu^{(1+\eta)}$ yields (28).

## D.2 Data on Multinational Production.

Data on the gross value of production for multinational affiliates from $i$ in $n$ is from Ramondo, Rodríguez-Clare and Tintelnot (2013). We use this variable as the counterpart of bilateral MP flows in the model, $Y_{ni} \equiv Y_{ni}^f + Y_{ni}^g$.

Out of 650 possible country pairs, data are available for 581 observations. We impute missing values by estimating the following OLS regression

$$\log \frac{Y_{ni}}{w_n L_n} = \beta_d \log dist_{ni} + \beta_c b_{ni} + \beta_l l_{ni} + O_i + D_n + e_{ni},$$

where $Y_{ni}$ is gross production of affiliates from $i$ in $n$, $w_n L_n$ is GDP in country $n$, $dist_{ni}$ is geographical distance between $i$ and $n$, $b_{ni}$ ($l_{ni}$) is a dummy equal to one if $i$ and $n$ share a border (language), and zero otherwise, and $O_i$ and $D_n$ are two sets of country fixed effects, for source and destination country, respectively. All variables are averages over the period 1996-2001. The variable GDP is in current dollars, from the World Development Indicators, and the variables for distance, common border, and common language are from the *Centre d'Etudes Prospectives et Informations Internationales* (CEPII).

## D.3 Calibration with Multinational Production.

When non-tradable goods and MP are included into the model, we need to calibrate the labor shares in final and intermediate goods, $\alpha$ and $\beta$, respectively, as well as recalibrate the value of $\theta$.

We set the labor share in the intermediate goods' sector, $\beta$, to $0.50$, and the labor share in the final sector, $\alpha$, to $0.75$, as calibrated by Alvarez and Lucas (2007). This implies that $\eta \equiv (1-\alpha)/\beta = 0.5$.

We consider the same three different approaches for the calibration of the parameter $\theta$ as in the baseline model. When we calibrate $\theta$ to match the growth rate observed in the data, now (13) is replaced by $g = g_L(1+\eta)/\theta$, by differentiating (28) with respect to time. With $g_L = 0.048$, $g = 0.01$, and $\eta = 0.5$, $\theta = 7.2$. When we use the results in Alcala and Ciccone (2004), and (28), the role of institutions is captured by $\phi_n$, geography is captured by both $H_n$ and $D_n$, trade and MP openness are embedded in the last two terms on the right-hand side of (28), and the coefficient on $L_n$, $(1+\eta)/\theta$, can be equated to $0.3$, the value of the income-size elasticity in Alcala and Ciccone (2004). With $\eta = 0.5$, $\theta = 5$.

To compromise between the different approaches, we choose $\theta = 6$ which implies an elasticity of the real wage with respect to size of $1/4$.

# E Online Appendix

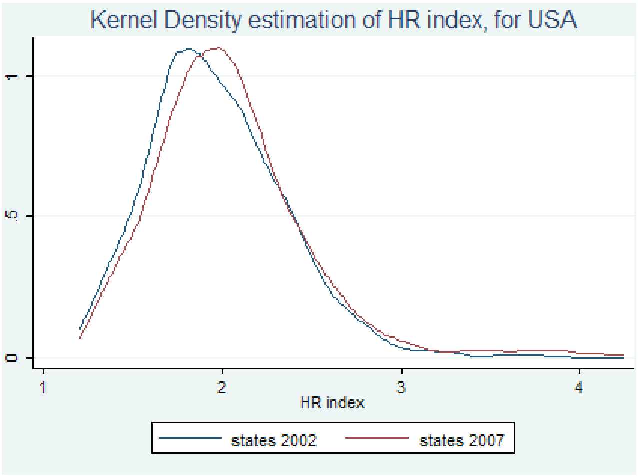
Table 6: Data Summary.

| | | Domestic MP final (1) | Domestic MP intermediate (2) | Domestic trade (3) | RGDP per capita (4) | CGDP per capita (5) | R&D emp. (6) | Equipped labor (7) | Pop. density (8) |
|---|---|---|---|---|---|---|---|---|---|
| Australia | AUS | 0.83 | 0.69 | 0.83 | 0.97 | 0.78 | 0.0068 | 7,915,148 | 2 |
| Austria | AUT | 0.80 | 0.58 | 0.44 | 1.12 | 1.09 | 0.0049 | 2,922,776 | 97 |
| Benelux | BNX | 0.70 | 0.47 | 0.20 | 1.16 | 1.08 | 0.0058 | 9,302,906 | 335 |
| Canada | CAN | 0.74 | 0.52 | 0.49 | 0.86 | 0.68 | 0.0063 | 13,986,022 | 3 |
| Switzerland | CHE | 0.76 | 0.55 | 0.51 | 0.88 | 1.12 | 0.0060 | 3,599,524 | 188 |
| Denmark | DNK | 0.91 | 0.77 | 0.42 | 0.94 | 1.15 | 0.0063 | 2,248,802 | 124 |
| Spain | ESP | 0.86 | 0.77 | 0.71 | 1.14 | 0.83 | 0.0038 | 10,760,358 | 81 |
| Finland | FIN | 0.85 | 0.79 | 0.68 | 0.84 | 0.92 | 0.0123 | 2,055,834 | 15 |
| France | FRA | 0.87 | 0.74 | 0.68 | 1.07 | 1.08 | 0.0059 | 20,075,700 | 108 |
| Great Britain | GBR | 0.77 | 0.51 | 0.64 | 1.00 | 0.98 | 0.0053 | 20,831,198 | 243 |
| Germany | GER | 0.81 | 0.67 | 0.70 | 0.92 | 0.96 | 0.0060 | 33,733,488 | 230 |
| Greece | GRC | 0.95 | 0.86 | 0.63 | 0.90 | 0.63 | 0.0030 | 2,901,406 | 83 |
| Hungary | HUN | 0.58 | 0.50 | 0.48 | 0.65 | 0.28 | 0.0029 | 2,465,370 | 114 |
| Ireland | IRL | 0.65 | 0.57 | 0.28 | 1.32 | 1.25 | 0.0051 | 1,043,106 | 65 |
| Iceland | ISL | 0.97 | 0.93 | 0.40 | 1.17 | 1.09 | 0.0096 | 110,390 | 3 |
| Italy | ITA | 0.90 | 0.85 | 0.78 | 1.20 | 1.07 | 0.0029 | 16,726,932 | 192 |
| Japan | JPN | 0.97 | 0.94 | 0.94 | 0.72 | 0.98 | 0.0080 | 66,310,712 | 336 |
| Korea | KOR | 0.95 | 0.95 | 0.83 | 0.63 | 0.44 | 0.0051 | 16,042,646 | 501 |
| Mexico | MEX | 0.84 | 0.78 | 0.63 | 0.78 | 0.40 | 0.0006 | 16,604,352 | 57 |
| Norway | NOR | 0.90 | 0.74 | 0.57 | 1.11 | 1.07 | 0.0081 | 2,206,808 | 12 |
| New Zealand | NZL | 0.82 | 0.63 | 0.64 | 0.74 | 0.61 | 0.0048 | 1,478,592 | 14 |
| Poland | POL | 0.81 | 0.67 | 0.68 | 0.50 | 0.24 | 0.0032 | 10,074,188 | 122 |
| Portugal | PRT | 0.70 | 0.48 | 0.59 | 0.97 | 0.70 | 0.0033 | 2,477,534 | 112 |
| Sweden | SWE | 0.78 | 0.64 | 0.59 | 0.81 | 0.97 | 0.0083 | 3,901,070 | 20 |
| Turkey | TUR | 0.94 | 0.89 | 0.74 | 0.61 | 0.26 | 0.0007 | 10,825,234 | 97 |
| United States | USA | 0.90 | 0.78 | 0.85 | 1.00 | 1.00 | 0.0087 | 130,099,480 | 30 |

Domestic MP in the final good sector in column 1 is calculated as a share of GDP. Domestic MP in the intermediate good sector in column 2 is calculated as a share of gross production in manufacturing. Domestic trade in manufacturing in column 3 is calculated as a share of absorption in manufacturing. Real GDP (RGDP) per capita in column 4 is PPP- adjusted real GDP divided by equipped labor (in column 7). Current GDP (CGDP) per capita in column 5 is GDP in current U.S. dollars divided by equipped labor (column 7). R&D employment in column 6 is calculated as a share of total employment. Population density in column 8 is the number of habitants per square kilometer. Real GDP and current GDP per capita are relative to the United States. Variables are averages over 1996-2001.

Figure 5: Head and Ries Index for Domestic Trade Costs.

(a) U.S. States




(b) Canadian Provinces

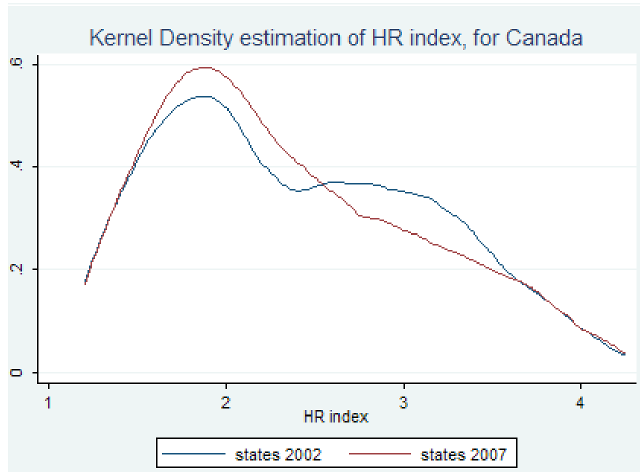


Table 7: Shipments within the United States, by state of destination.

| Destination state | All states | Same state | All other states | Own to others |
|---|---|---|---|---|
| Alabama | 124308 | 40388 | 83920 | 0.48 |
| Arizona | 118892 | 49047 | 69845 | 0.70 |
| Arkansas | 78105 | 22089 | 56016 | 0.39 |
| California | 894487 | 557566 | 336921 | 1.65 |
| Colorado | 104508 | 42796 | 61712 | 0.69 |
| Connecticut | 75329 | 20388 | 54941 | 0.37 |
| Delaware | 30719 | 4758 | 25961 | 0.18 |
| District of Columbia | 14154 | 588 | 13566 | 0.04 |
| Florida | 404644 | 194873 | 209771 | 0.93 |
| Georgia | 295406 | 98418 | 196988 | 0.50 |
| Idaho | 27887 | 9385 | 18502 | 0.51 |
| Illinois | 416154 | 164946 | 251208 | 0.66 |
| Indiana | 244031 | 82868 | 161163 | 0.51 |
| Iowa | 88753 | 29432 | 59321 | 0.49 |
| Kansas | 87391 | 25965 | 61426 | 0.42 |
| Kentucky | 159694 | 41730 | 117964 | 0.35 |
| Louisiana | 159495 | 76181 | 83314 | 0.91 |
| Maine | 29237 | 10411 | 18826 | 0.55 |
| Maryland | 151521 | 46222 | 105299 | 0.43 |
| Massachusetts | 159884 | 58214 | 101670 | 0.57 |
| Michigan | 406942 | 189489 | 217453 | 0.87 |
| Minnesota | 161310 | 69135 | 92175 | 0.75 |
| Mississippi | 77779 | 22058 | 55721 | 0.39 |
| Missouri | 177887 | 56661 | 121226 | 0.46 |
| Montana | 23295 | 7033 | 16262 | 0.43 |
| Nebraska | 52477 | 20741 | 31736 | 0.65 |
| Nevada | 69013 | 11957 | 57056 | 0.21 |
| New Hampshire | 32191 | 5263 | 26928 | 0.19 |
| New Jersey | 266867 | 77807 | 189060 | 0.41 |
| New Mexico | 34118 | 7277 | 26841 | 0.27 |
| New York | 372472 | 123744 | 248728 | 0.49 |
| North Carolina | 257179 | 115794 | 141385 | 0.82 |
| North Dakota | 24047 | 8384 | 15663 | 0.53 |
| Ohio | 413206 | 169127 | 244079 | 0.69 |
| Oklahoma | 82848 | 25450 | 57398 | 0.44 |
| Oregon | 94427 | 41290 | 53137 | 0.78 |
| Pennsylvania | 328278 | 117750 | 210528 | 0.56 |
| Rhode Island | 18147 | 3408 | 14739 | 0.23 |
| South Carolina | 128514 | 40927 | 87587 | 0.47 |
| South Dakota | 20137 | 7195 | 12942 | 0.56 |
| Tennessee | 200245 | 58344 | 141901 | 0.41 |
| Texas | 719284 | 365644 | 353640 | 1.03 |
| Utah | 62354 | 25803 | 36551 | 0.71 |
| Vermont | 17751 | 4188 | 13563 | 0.31 |
| Virginia | 198879 | 70575 | 128304 | 0.55 |
| Washington | 223300 | 122189 | 101111 | 1.21 |
| West Virginia | 36747 | 9446 | 27301 | 0.34 |
| Wisconsin | 182785 | 74401 | 108384 | 0.69 |
| Wyoming | 15548 | 4568 | 10980 | 0.42 |

Commodity Flow Survey. 2002. In millions of U$ dollars.

Table 8: Alternative Measures of the Gains from Trade.

| | Size | Gains from Trade | | | Real Wage | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1)x(2) | (1)x(3) | (1)x(4) |
| Australia | 0.47 | 1.008 | 1.006 | 1.069 | 0.47 | 0.47 | 0.50 |
| Austria | 0.33 | 1.177 | 1.176 | 1.381 | 0.39 | 0.39 | 0.46 |
| Benelux | 0.47 | 1.430 | 1.519 | 1.357 | 0.67 | 0.71 | 0.63 |
| Canada | 0.53 | 1.147 | 1.145 | 1.202 | 0.61 | 0.60 | 0.63 |
| Switzerland | 0.37 | 1.136 | 1.132 | n/a | 0.42 | 0.42 | n/a |
| Denmark | 0.33 | 1.190 | 1.193 | 1.306 | 0.40 | 0.40 | 0.44 |
| Spain | 0.44 | 1.045 | 1.039 | 1.092 | 0.46 | 0.45 | 0.48 |
| Finland | 0.39 | 1.057 | 1.055 | 1.110 | 0.41 | 0.41 | 0.43 |
| France | 0.57 | 1.058 | 1.055 | 1.082 | 0.60 | 0.60 | 0.61 |
| Great Britain | 0.56 | 1.076 | 1.079 | 1.122 | 0.60 | 0.60 | 0.63 |
| Germany | 0.65 | 1.051 | 1.051 | 1.120 | 0.68 | 0.68 | 0.73 |
| Greece | 0.29 | 1.078 | 1.076 | 1.142 | 0.32 | 0.32 | 0.34 |
| Hungary | 0.28 | 1.152 | 1.169 | 1.417 | 0.33 | 0.33 | 0.40 |
| Ireland | 0.26 | 1.324 | 1.347 | 1.266 | 0.35 | 0.35 | 0.33 |
| Iceland | 0.17 | 1.208 | 1.209 | n/a | 0.21 | 0.21 | n/a |
| Italy | 0.45 | 1.023 | 1.018 | 1.075 | 0.46 | 0.46 | 0.49 |
| Japan | 0.83 | 0.975 | 0.969 | 0.966 | 0.80 | 0.80 | 0.80 |
| Korea | 0.52 | 1.008 | 1.008 | 1.039 | 0.52 | 0.52 | 0.54 |
| Mexico | 0.31 | 1.079 | 1.068 | 1.093 | 0.33 | 0.33 | 0.34 |
| Norway | 0.35 | 1.103 | 1.101 | n/a | 0.39 | 0.39 | n/a |
| New Zealand | 0.28 | 1.072 | 1.075 | n/a | 0.30 | 0.30 | n/a |
| Poland | 0.41 | 1.056 | 1.055 | 1.235 | 0.43 | 0.43 | 0.51 |
| Portugal | 0.29 | 1.098 | 1.087 | 1.255 | 0.32 | 0.32 | 0.36 |
| Sweden | 0.41 | 1.095 | 1.087 | 1.148 | 0.45 | 0.45 | 0.47 |
| Turkey | 0.28 | 1.036 | 1.036 | 1.108 | 0.29 | 0.29 | 0.31 |
| United States | 1.00 | 1.000 | 1.000 | 1.000 | 1.00 | 1.00 | 1.00 |
| Avg all | 0.43 | 1.10 | 1.11 | 1.16 | 0.47 | 0.47 | 0.52 |
| Avg smallest | 0.30 | 1.16 | 1.16 | 1.23 | 0.34 | 0.34 | 0.40 |
| Avg largest | 0.68 | 1.03 | 1.03 | 1.06 | 0.69 | 0.69 | 0.71 |

"Size" and "Gains from Trade" correspond to the first and second terms, respectively, on the right-hand side of (24). The gains from trade are calculated: in column (2) with total imports from the countries in the sample, as in the baseline calibration; in column (3) with imports from all countries; and in column (4) taking into account different industries within manufacturing, as in Costinot and Rodriguez-Clare (2013). All variables are calculated relative to the United States. The six smallest countries (with respect to R&D-adjusted size) are Iceland, Ireland, New Zealand, Finland, Norway, and Denmark, while the six largest countries are Italy, France, Great Britain, Germany, Japan, and the United States.

Table 9: Number of Regions in Alternative Calibrations.

| | Number of Regions $M_n$ | | | | |
|---|---|---|---|---|---|
| | U.S. states | U.S. CSA-MSA | Canadian prov. | Pop. density | Cities > 250K hab. |
| | (1) | (2) | (3) | (4) | (5) |
| Australia | 4 | 7 | 8 | 42 | 10 |
| Austria | 2 | 3 | 3 | 1 | 2 |
| Benelux | 4 | 8 | 9 | 2 | 5 |
| Canada | 6 | 11 | 13 | 54 | 14 |
| Switzerland | 2 | 3 | 4 | 1 | 1 |
| Denmark | 1 | 2 | 3 | 1 | 1 |
| Spain | 5 | 9 | 11 | 3 | 16 |
| Finland | 1 | 2 | 2 | 2 | 2 |
| France | 8 | 16 | 19 | 3 | 7 |
| Great Britain | 9 | 17 | 20 | 2 | 18 |
| Germany | 14 | 26 | 32 | 2 | 27 |
| Greece | 2 | 3 | 3 | 1 | 2 |
| Hungary | 1 | 2 | 3 | 1 | 1 |
| Ireland | 1 | 1 | 1 | 1 | 1 |
| Iceland | 1 | 1 | 1 | 1 | 0 |
| Italy | 7 | 13 | 16 | 2 | 12 |
| Japan | 26 | 51 | 62 | 3 | 89 |
| Korea | 7 | 13 | 15 | 1 | 42 |
| Mexico | 7 | 13 | 16 | 9 | 63 |
| Norway | 1 | 2 | 3 | 3 | 2 |
| New Zealand | 1 | 2 | 2 | 2 | 3 |
| Poland | 4 | 8 | 10 | 2 | 13 |
| Portugal | 1 | 2 | 3 | 1 | 1 |
| Sweden | 2 | 3 | 4 | 3 | 3 |
| Turkey | 5 | 9 | 11 | 4 | 23 |
| United States | 51 | 100 | 121 | 51 | 74 |

Columns 1 to 3 refer to the calibrated number of regions calculated using $M_{n,r} = L_n/\overline{L}_r$ where $\overline{L}_r = L_r/M_r$, with $r$ indicating data coming from U.S. states, U.S. sub-regional geographical units (CSA-MSA), and Canadian provinces, respectively. Column 4 shows the number of regions calculated using population density in each country. Column 5 shows the number of towns with more than 250K habitants in the data.

Table 10: The Role of Domestic Frictions, by country.

| | import share | | | nominal wage | | | price index | | | real wage | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | data | DF | no DF | data | DF | no DF | data | DF | no DF | data | DF | no DF |
| Australia | 0.17 | 0.16 | 0.15 | 0.78 | 0.84 | 0.70 | 1.26 | 1.16 | 1.47 | 0.97 | 0.73 | 0.48 |
| Austria | 0.56 | 0.54 | 0.64 | 1.09 | 0.80 | 0.64 | 1.02 | 1.14 | 1.51 | 1.12 | 0.71 | 0.42 |
| Benelux | 0.80 | 0.62 | 0.61 | 1.08 | 0.91 | 0.75 | 1.07 | 1.02 | 1.29 | 1.16 | 0.89 | 0.58 |
| Canada | 0.51 | 0.59 | 0.46 | 0.68 | 0.92 | 0.77 | 1.26 | 1.03 | 1.28 | 0.86 | 0.90 | 0.60 |
| Switzerland | 0.49 | 0.61 | 0.74 | 1.12 | 0.88 | 0.71 | 0.79 | 1.07 | 1.39 | 0.88 | 0.82 | 0.51 |
| Denmark | 0.58 | 0.40 | 0.52 | 1.15 | 0.86 | 0.64 | 0.82 | 1.11 | 1.62 | 0.94 | 0.78 | 0.39 |
| Spain | 0.29 | 0.36 | 0.27 | 0.83 | 0.77 | 0.65 | 1.37 | 1.12 | 1.40 | 1.14 | 0.69 | 0.46 |
| Finland | 0.32 | 0.31 | 0.43 | 0.92 | 0.98 | 0.72 | 0.91 | 1.12 | 1.65 | 0.84 | 0.87 | 0.44 |
| France | 0.32 | 0.43 | 0.31 | 1.08 | 0.88 | 0.77 | 0.99 | 1.06 | 1.26 | 1.07 | 0.84 | 0.61 |
| Great Britain | 0.36 | 0.40 | 0.23 | 0.98 | 0.85 | 0.74 | 1.02 | 1.08 | 1.27 | 1.00 | 0.79 | 0.58 |
| Germany | 0.30 | 0.39 | 0.25 | 0.96 | 0.89 | 0.81 | 0.96 | 1.05 | 1.18 | 0.92 | 0.85 | 0.68 |
| Greece | 0.37 | 0.38 | 0.39 | 0.63 | 0.70 | 0.54 | 1.43 | 1.20 | 1.65 | 0.90 | 0.58 | 0.33 |
| Hungary | 0.52 | 0.38 | 0.49 | 0.28 | 0.73 | 0.54 | 2.28 | 1.12 | 1.65 | 0.65 | 0.65 | 0.33 |
| Ireland | 0.72 | 0.61 | 0.79 | 1.25 | 0.79 | 0.61 | 1.06 | 1.17 | 1.61 | 1.32 | 0.68 | 0.38 |
| Iceland | 0.60 | 0.77 | 0.85 | 1.09 | 0.75 | 0.57 | 1.07 | 1.46 | 2.07 | 1.17 | 0.52 | 0.27 |
| Italy | 0.22 | 0.32 | 0.22 | 1.07 | 0.74 | 0.63 | 1.13 | 1.11 | 1.34 | 1.20 | 0.66 | 0.47 |
| Japan | 0.06 | 0.11 | 0.04 | 0.98 | 0.94 | 0.91 | 0.73 | 1.06 | 1.11 | 0.72 | 0.89 | 0.82 |
| Korea | 0.17 | 0.25 | 0.15 | 0.44 | 0.82 | 0.71 | 1.41 | 1.12 | 1.34 | 0.63 | 0.74 | 0.53 |
| Mexico | 0.37 | 0.33 | 0.25 | 0.40 | 0.52 | 0.45 | 1.96 | 1.16 | 1.39 | 0.78 | 0.45 | 0.33 |
| Norway | 0.43 | 0.34 | 0.46 | 1.07 | 0.90 | 0.66 | 1.04 | 1.11 | 1.64 | 1.11 | 0.81 | 0.41 |
| New Zealand | 0.36 | 0.21 | 0.37 | 0.61 | 0.75 | 0.56 | 1.21 | 1.23 | 1.79 | 0.74 | 0.61 | 0.31 |
| Poland | 0.32 | 0.34 | 0.26 | 0.24 | 0.75 | 0.62 | 2.06 | 1.11 | 1.42 | 0.50 | 0.67 | 0.43 |
| Portugal | 0.41 | 0.32 | 0.43 | 0.70 | 0.74 | 0.55 | 1.38 | 1.13 | 1.67 | 0.97 | 0.66 | 0.33 |
| Sweden | 0.41 | 0.34 | 0.36 | 0.97 | 0.90 | 0.70 | 0.83 | 1.13 | 1.55 | 0.81 | 0.80 | 0.45 |
| Turkey | 0.26 | 0.32 | 0.23 | 0.26 | 0.52 | 0.44 | 2.31 | 1.18 | 1.48 | 0.61 | 0.44 | 0.30 |
| United States | 0.15 | 0.14 | 0.07 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

"DF" refers to the calibrated model with $d = 2.4$, and "no DF" to the model with $d = 1$. Nominal wages, real wages, and price indices are relative to the United States.