Increasing Returns and Economic Prosperity: How Can Size Not Matter?*

Preliminary and Incomplete

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Abstract

Models that feature ideas naturally lead to scale effects, and this results in the counterfactual implication that larger countries should be richer than smaller ones. Perhaps small countries are not poor because they benefit from foreign ideas through trade. Quantitative trade models do imply that small countries gain more from trade than large countries, but the difference is too small to make a difference. There are two candidates to solve the puzzle: first, there are additional ways besides trade through which countries are integrated to the rest of the world, and second, countries are not fully integrated domestically. In this paper we explore these two ideas by building a quantitative model of trade and multinational production with frictions to the domestic movement of goods and ideas. The resulting model comes close to solving the puzzle, but not fully.

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1 Introduction

Models that feature ideas naturally lead to scale effects. As Romer (1990, 1993), Jones (2005) and Jones and Romer (2010) have emphasized, this is a direct result of the fact that ideas are non-rivalrous. In growth models such as Jones (1995) and Kortum (2007), for example, idea-based scale effects imply that larger countries exhibit higher productivity. This is clearly a counter-factual implication: small countries are not poor compared to larger countries (Rose, 2006).[1]

One possible fix is to allow for the fact that small countries trade more – perhaps small countries are not poor because they benefit from foreign ideas through trade. Quantitative trade models such as Eaton and Kortum (2002), Alvarez and Lucas (2007), and Waugh (2010) offer a simple way to explore this idea. In these models the gains from trade can be computed using aggregate trade flows and a couple of parameters that are relatively easy to calibrate. The finding is that small countries do gain more from trade than large countries, but the difference is small. Thus, even allowing for trade, quantitative models featuring ideas generate the counterfactual implication that small countries are poor. For example, if the stock of ideas is proportional to population, the Alvarez and Lucas (2007) model implies that Denmark's real GDP per capita should be 37% of the US level, whereas Denmark's actual relative real per-capita income is 91%. We refer to this as the "Danish Puzzle", but it is a puzzle common to all small countries.

There are two obvious candidates to solve this puzzle. First, there are additional ways in which countries are integrated to the rest of the world. Trade is clearly an important channel through which countries share ideas, but it is not the only one: multinational production and other forms of diffusion allow ideas originated in one country to be used directly in production in other countries (Ramondo and Rodríguez-Clare, 2010). Second, countries are not fully integrated units: the United States is not a single economy that hap-

[1] Models that feature diffusion of ideas and growth without any scale effects (Lucas and Moll, 2011, and Alvarez, Buera, and Lucas, 2011) assume that ideas are rival.

pens to be fifty times larger than Denmark, but rather a collection of separate economies.

In this paper we explore these two ideas through a model of trade and multinational production (MP) that builds on Kortum (2007), Eaton and Kortum (2002), and Ramondo and Rodríguez-Clare (2010), and add frictions to the domestic movement of goods and ideas that imply that countries are not fully integrated units. Allowing for trade and MP between countries while adding frictions to domestic trade and MP within countries weakens country-level scale effects. In the extreme, if the frictions to trade and MP *across* countries were equal to the frictions to trade and MP *within* countries then country-level scale effects would disappear. How far are we from that scenario?

We calibrate the model and explore whether openness and domestic frictions offer a resolution to the Danish Puzzle. Our main finding is that these two features do indeed help to solve the puzzle, but not fully. Returning to the case of Denmark, our calibrated model implies a relative real per-capita income of 78%, not quite reaching the one observed in the data. We also find that domestic frictions are quantitatively much more important than openness, although our calibration of domestic frictions is more tentative. We conclude by exploring the role of diffusion that takes place without being recorded in the data as multinational production.

2 The Model

We extend Ramondo and Rodriguez-Clare (2010)'s model of trade and MP to incorporate domestic trade and MP costs. The model is Ricardian with a continuum of tradable intermediate and non-tradable final goods, produced under constant returns to scale. We adopt the probabilistic representation of technologies as first introduced by Eaton and Kortum (2002). We embed the model into a general equilibrium framework similar to the one in Alvarez and Lucas (2007).

2.1 The Closed Economy

Consider first a closed economy formed by a set of identical towns, $m = 1, ..., M$, each with population $\bar{L}$. The total population is then $L = \bar{L}M$. We use subscript m to denote variables associated with town m and superscripts f and g to denote variables associated to final and intermediate goods, respectively. A representative agent in town m consumes a continuum of final goods indexed by $u \in [0, 1]$ in quantities $q_m^f(u)$. Preferences over final goods are CES with elasticity $\sigma^f > 0$.

Final goods are produced with labor and a continuum of intermediate goods indexed by $v \in [0, 1]$. Intermediate goods used in quantities $q_m^g(v)$ are aggregated into a *composite intermediate good* via a CES production function with elasticity $\sigma^g > 0$. We henceforth assume $\sigma^g = \sigma^f = \sigma$. Denoting the total quantity produced of the composite intermediate good in town m as Q_m, we have

$$Q_m = \left(\int_0^1 q_m^g(v)^{(\sigma-1)/\sigma} dv \right)^{\sigma/(\sigma-1)}.$$

The composite intermediate good and labor are used to produce final goods via Cobb-Douglas technologies with varying productivities across goods and towns,

$$\widetilde{q}_m^f(u) = z_m^f(u) L_m^f(u)^\alpha Q_m^f(u)^{1-\alpha}. \tag{1}$$

Here $\widetilde{q}_m^f(u)$ denotes the quantity produced of final good u in town m – we use a "tilda" over q to differentiate production, $\widetilde{q}_m^f(u)$, from consumption, $q_m^f(u)$. The variables $L_m^f(u)$ and $Q_m^f(u)$ denote the quantity of labor and the composite intermediate good, respectively, used in the production of final good u in town m, and $z_m^f(u)$ is a productivity parameter for good u in town m. Similarly, intermediate goods in town m are produced according to

$$\widetilde{q}_m^g(v) = z_m^g(v) L_m^g(v)^\beta Q_m^g(v)^{1-\beta}. \tag{2}$$

Resource constraints (at the town level) are

$$\int_0^1 L_m^f(u)du + \int_0^1 L_m^g(v)dv = \bar{L},$$
$$\int_0^1 Q_m^f(u)du + \int_0^1 Q_m^g(v)dv = Q_m.$$

Here we have assumed that labor is immobile and the composite intermediate good is non-tradable across towns, but this is innocuous since towns are identical.

Final goods are non-tradable (even across towns within a country), but intermediate goods can be traded across towns with iceberg-type trade costs $d \geq 1$ (there is no trade cost if the good is sold in the same town where it is produced). The assumption that final goods are non-tradable implies that $\widetilde{q}_m^f(u) = q_m^f(u)$ while the possibility of trade in intermediate goods implies that we can have $\widetilde{q}_m^g(v) \neq q_m^g(v)$.

There are L technologies for each good (one technology per person), and each of these technologies is freely available to producers engaging in perfect competition. Each technology is characterized by a productivity parameter z and a "home town" m. If technology (z, m) is used to produce outside of its home town (i.e., in town $s \neq m$), then there is an iceberg-type efficiency loss $h^f \geq 1$ for final goods and $h^g \geq 1$ for intermediate goods, and the effective productivity is z/h^f and z/h^g, while if the technology is used to produce in its home town (i.e., in town m) then the effective productivity is z. With a slight abuse of terminology, we will say that if a technology is used for production outside of its home town then there is "multinational production" or MP. We assume that the cost of MP for intermediate goods is higher than the cost of trade, i.e., $h^g > d$.

For each good, the L technologies are uniformly assigned to the M towns as home towns – that is, for each good, the number of technologies (i.e., $\bar{L} = L/M$) for which a particular town is the home town is the same as the number of technologies for which any other town is the home town.[2] We assume that z is drawn from a Fréchet distribution

[2]Technically, the number of ideas should be a nonnegative integer. This would require that $\bar{L}$ be an integer. To simplify the analysis we henceforth ignore this integer constraint.

with parameters $\bar{T}$ and $\theta > \max\{1, \sigma - 1\}$, $F(z) = \exp\left(-\bar{T}z^{-\theta}\right)$, for $z > 0$.

2.1.1 Equilibrium Analysis

To describe the competitive equilibrium for this economy it is convenient to introduce the notion of an *input bundle for the production of final goods*, and an *input bundle for the production of intermediate goods*, both of which are produced via Cobb-Douglas production functions with labor and the composite intermediate good, and used to produce final and intermediate goods, as specified in (1) and (2), respectively. The unit cost of the input bundle for final goods is $c^f = Aw^\alpha (P^g)^{1-\alpha}$, and the unit cost of the input bundle for intermediate goods is $c^g = Bw^\beta (P^g)^{1-\beta}$, where w and P^g are the wage and the price of the composite intermediate good, respectively, and A and B are constants that depend on α and β, respectively. Letting $p_m^g(v)$ denote the price of intermediate good v, then $P^g = \left(\int_0^1 p_m^g(v)^{1-\sigma} dv\right)^{1/(1-\sigma)}$. Notice that since towns are identical, there is no need to differentiate aggregate variables (e.g., wages, price indices, unit costs) across towns.

The characterization of the equilibrium follows closely the analysis in Eaton and Kortum (2002) and Alvarez and Lucas (2007). Let $z_m^f(u)$ be the highest productivity among the set of technologies for final good u with home town m and let $z_m^g(v)$ be the highest productivity among the set of technologies for intermediate good v with home town m. Since each town is the home town for $\bar{L}$ technologies with scale parameter $\bar{T}$, by the properties of the Fréchet distribution, $z_m^f(u)$ and $z_m^g(v)$ are both distributed Fréchet with parameters $T \equiv \bar{L}\bar{T}$ and θ.

The unit cost of a final good u in town m produced with a technology with home town s is $h^f c^f / z_s^f(u)$ if $s \neq m$, and $c^f / z_m^f(u)$ if $s = m$. In a competitive equilibrium the price of the final good u in town m is simply the minimum unit cost at which this good can be obtained,

$$p_m^f(u) = \min(c^f / z_m^f(u), \min_{s \neq m}(h^f c^f / z_s^f(u)))$$

The unit cost of an intermediate good v in town m produced in town k with a technology with home town s is $dh^g c^g / z_s^g(v)$ if $m \neq k \neq s$, $dc^g / z_s^g(v)$ if $m \neq k = s$, $h^g c^g / z_s^g(v)$ if $m = k \neq s$, and $c^g / z_s^g(v)$ if $m = k = s$. Our assumption that $d < h^g$ implies that an intermediate good used in town m is either produced with the local technology, which entails unit cost $c^g / z_m^g(v)$, or it is imported from some other town s, which entails unit cost $dc^g / z_s^g(v)$.[3] Thus, the price of an intermediate good v in town m is

$$p_m^g(v) = \min\left(c^g / z_m^g(v), \min_{s \neq m}(dc^g / z_s^g(v))\right)$$

Note that since final goods are non-tradable and $d < h^g$ then there is MP but no trade in final goods and trade but no MP in intermediate goods.

Combining these results with the assumption that productivities are independently drawn from the Fréchet distribution and following standard procedures as in Eaton and Kortum (2002) and Alvarez and Lucas (2007), we can easily show that the price index for final and intermediate goods is given by

$$P^f = \gamma c^f \left(MT + (M-1)T \left(h^f\right)^{-\theta}\right)^{-1/\theta} \tag{3}$$

and

$$P^g = \gamma c^g \left(MT + (M-1)T d^{-\theta}\right)^{-1/\theta}, \tag{4}$$

respectively, where γ is a positive constant. Intuitively, the term $MT + (M-1)T \left(h^f\right)^{-\theta}$ can be understood as the number of technologies for each final good available in town m',

[3]To see this, note that $d, h^g \geq 1$ implies that if town m is using an intermediate good produced with a technology with home town s, then the only two options that could make sense are that the good is produced in m, i.e., $k = m$, or that it is produced in s, i.e., $k = s$. Thus, if $s \neq m$, there are two relevant options, local production with an outside technology at cost $h^g c^g / z_s^f(v)$, or importing the good at cost $dc^g / z_s^f(v)$. The assumption $d < h^g$ implies that if $s \neq m$ then producing the good in town s, i.e., $k = s$, is the best option.

where the $(M-1)T$ technologies with home towns $m \neq m'$ are "discounted" by $\left(h^f\right)^{-\theta}$. Similarly, the term $MT + (M-1)Td^{-\theta}$ is the number of technologies available for each intermediate good in town m', where the $(M-1)T$ technologies with home towns $m \neq m'$ are "discounted" by $d^{-\theta}$.

Using $c^f = Aw^{\alpha}(P^g)^{1-\alpha}$, and $c^g = Bw^{\beta}(P^g)^{1-\beta}$, and letting $\eta \equiv (1-\alpha)/\beta$, $H \equiv 1/M + ((M-1)/M)\left(h^f\right)^{-\theta}$, and $D \equiv 1/M + ((M-1)/M)d^{-\theta}$, the equilibrium real wage is then given by

$$\frac{w}{P^f} = \tilde{\gamma} T^{(1+\eta)/\theta} \left(MH\right)^{1/\theta} \left(MD\right)^{\eta/\theta}, \tag{5}$$

where $\tilde{\gamma} \equiv (\gamma^{1+\eta}AB^{\eta})^{-1}$. When towns are in isolation (i.e., $d, h \to \infty$), then $D = H = 1/M$, so the real wage is $\gamma T^{(1+\eta)/\theta}$. As d and h^f decrease towards 1, D and H increase and the real wage increases as towns get access to technologies from other towns either through trade (for the case of intermediate goods) or through MP (for the case of final goods). The term $(MH)^{1/\theta}$captures the gains from MP in final goods while the term $(MD)^{\eta/\theta}$ captures the gains from trade in intermediate goods. In the limit, when there are no trade or MP costs, i.e., $d = h^f = 1$, then $D = H = 1$ and the real wage is $\gamma(MT)^{(1+\eta)/\theta}$.

There are three implications of these results: first, larger countries will exhibit higher real income levels. This is due to the same aggregate economies of scale that play a critical role in semi-endogenous growth models (see Ramondo and Rodríguez-Clare, 2010). Formally, if $\bar{L}$ grows at a constant rate $g_L > 0$ then $g_T = g_L$ and the steady state growth rate of the real wage is $\frac{1+\eta}{\theta} g_L$. We will use this result below as one of our calibration strategies for θ. Second, higher trade and MP costs (reflected in lower D and H) diminish the strength of these economies of scale. This will play an important role below.

2.2 The World Economy

Now consider a set of countries indexed by $n \in \{1, ..., N\}$ with preferences and technologies as described above. As with the case of the closed economy above, each country is formed by set of identical towns, each with population $\bar{L}$. The number of towns in country n is M_n, so that the population size of country n is $L_n = \bar{L}M_n$.

Intermediate goods are tradable across towns within a country and across towns in different countries, but final goods are not. International trade is subject to iceberg-type costs: $d_{nl} \geq 1$ units of any good must be shipped from any town in country l for one unit to arrive in any town in country n. We assume that domestic trade is also subject to an iceberg-type cost: $d_{nn} \geq 1$ units of any good must be shipped from a town k in country n for one unit to arrive in a town s also in country n. Trade within a town is costless. We also assume that the triangular inequality holds: $d_{nl} \leq d_{nj}d_{jl}$ for all n, l, j.

Each technology has a country of origin, but it can be used also in other countries as well. As mentioned above, when a technology from country i is used for production in country $l \neq i$ we say that there is "multinational production" or simply MP. We adopt the convention that the subscript n denotes the destination country, subscript l denotes the country of production, and subscript i denotes the country where the technology originates.

There are L_i technologies for each good in country i. 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 town" in each country, $\boldsymbol{m} = (m_1, ..., m_N)$.

Using a technology originating in country i for production in country i but outside of the technology's home town (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 town in country $l \neq i$ entails an MP cost of $h^f_{li} \geq 1$ for final goods and $h^g_{li} \geq 1$ for intermediates. Finally, the total MP cost associated with using a technology from country i in country $l \neq i$ outside of the technology's home town in country l is $h^f_{li}h^f_{ii}$ for final goods and $h^g_{li}h^g_{ii}$ for intermediate goods. These assumptions imply that the effective productivity of a technology $(\boldsymbol{z}, \boldsymbol{m})$ originated in country i used in the technology's home town in country $l \neq i$ is z_l/h^f_{li} or z_l/h^g_{li} while if they are used in country $l \neq i$ but outside of the technology's home town then the effective productivity is $z_l/h^f_{li}h^f_{ll}$ or $z_l/h^g_{li}h^g_{ll}$ We assume that $d_{ii} \leq h^g_{ii}$, so in equilibrium technologies to produce intermediate goods will always be used in their home town.

We assume that technologies are uniformly assigned to home towns in each country, i.e., for each good and each country i, the number of technologies from i for which the home town in country l is town m is the same as the number of technologies from i for which the home town in country l is town m'.[4] To clarify: there are L_i technologies for each good in each country (not in each town), and the number of technologies from any country i for which a particular town in country n is the home town is L_i/M_n.

Finally, we assume that each productivity z_l for technologies originating in country i is independently drawn from the Fréchet distribution with parameters $\bar{T}_i$ and θ.

2.3 Equilibrium Analysis

In this section we derive expressions for equilibrium price indices and equilibrium trade and MP flows. The details of the analysis are relegated to the Appendix. The results of this section are used in the following section to express real wages and gains from openness in terms of variables that we observe in the data, namely trade and MP flows. The hurried reader can skip this section and go directly to the next one.

Prices. Let c^f_l and c^g_l denote the unit costs of the input bundle for final and intermediate goods in country l, respectively. Following a similar logic as in the equilibrium analysis

[4]One interpretation of this assumption is as follows. First, recall that, for each good, the number of technologies in a country is the same as the number of people. Thus, we can link each technology to a person. Second, imagine that each person has a randomly assigned "friend" in every country. We can then assume that a technology's home town in country l for the technology linked to person X in country i is the town where X's friend resides in country l.

of a closed economy, we can show that the price index of final goods is

$$\gamma^{\theta}\left(P_n^f\right)^{-\theta} = M_n T_n (c_n^f)^{-\theta} H_n + \sum_{i \neq n} M_i T_i (h_{ni} c_n^f)^{-\theta} H_n, \tag{6}$$

while the price index of intermediates is

$$\begin{aligned} \gamma^{\theta}\left(P_n^g\right)^{-\theta} &= M_n T_n (c_n^g)^{-\theta} D_n + \sum_{i \neq n, l = n} M_i T_i (h_{ni} c_n^g)^{-\theta} D_n \\ &+ \sum_{i \neq n, l = i} M_i T_i (d_{ni} c_i^g)^{-\theta} + \sum_{l \neq n, l \neq i} M_i T_i \left(d_{nl} h_{li} c_l^g\right)^{-\theta}, \end{aligned} \tag{7}$$

where $T_i \equiv \bar{L}\bar{T}_i$, $H_n \equiv 1/M_n + ((M_n - 1)/M_n)\left(h_{nn}^f\right)^{-\theta}$ and $D_n \equiv 1/M_n + ((M_n - 1)/M_n) d_{nn}^{-\theta}$. In the case of final goods, the first term on the RHS of (6) corresponds to technologies originating in country n while the second term corresponds to technologies originating in country $i \neq n$. In the case of intermediate goods, the first term on the RHS corresponds to technologies originating in country n, the second term corresponds to technologies originating in country $i \neq n$ but used to produce domestically in country n, the third term corresponds to technologies originating in country $i \neq n$ used to produce in country i and export to country n, and the final term corresponds to technologies from any country used to produce outside of country n and outside of the country where the technology originates.

Trade Flows. Examining the contribution of country l to the price index for intermediates in $n \neq l$ reveals the value of trade flows (exports) from country l to country n. This is given by

$$X_{nl} = \left(\gamma^{-1} P_n^g / c_l^g\right)^{\theta} d_{nl}^{-\theta} \left[\sum_{i \neq l} M_i T_i \left(h_{li}^g\right)^{-\theta} + M_l T_l\right] \eta w_n L_n. \tag{8}$$

where $X_n^g = \eta w_n L_n$ is the expenditure on intermediate goods in country n. In turn, domestic trade flows are

$$X_{nn} = \left(\gamma^{-1} P_n^g / c_n^g\right)^{\theta} D_n \left[\sum_{i \neq n} M_i T_i \left(h_{ni}^g\right)^{-\theta} + M_n T_n\right] \eta w_n L_n. \tag{9}$$

It is interesting to note that using (8) and the equivalent of (9) for X_{ll}, the gravity equation is

$$\frac{X_{nl}/w_n L_n}{X_{ll}/w_l L_l} = D_l^{-1} \times \left(d_{nl} \frac{P_l^g}{P_n^g}\right)^{-\theta}. \tag{10}$$

The term D_l^{-1} is a country specific effect greater than one. When $d_{ll} = 1$, $D_l = 1$ and (10) collapses to the gravity expression in Eaton and Kortum (2002).

MP Flows. Again, examining the price index for intermediate goods reveals that total MP in intermediate goods by country i in $l \neq i$ is

$$Y_{li}^g = M_i T_i \left(c_l^g h_{li}^g\right)^{-\theta} \left[D_l \frac{\eta w_l L_l}{\left(\gamma^{-1} P_l^g\right)^{-\theta}} + \sum_{n \neq l} d_{nl}^{-\theta} \frac{\eta w_n L_n}{\left(\gamma^{-1} P_n^g\right)^{-\theta}}\right], \tag{11}$$

while total production in country n with domestic technologies is

$$Y_{nn}^g = M_n T_n (c_n^g)^{-\theta} \left[D_n \frac{\eta w_n L_n}{\left(\gamma^{-1} P_n^g\right)^{-\theta}} + \sum_{j \neq n} d_{jn}^{-\theta} \frac{\eta w_j L_j}{\left(\gamma^{-1} P_j^g\right)^{-\theta}}\right]. \tag{12}$$

For final goods, total MP by country i in $n \neq i$ is

$$Y_{ni}^f = M_i T_i \left(\frac{c_n^f h_{ni}^f}{\gamma^{-1} P_n^f}\right)^{-\theta} H_n w_n L_n, \tag{13}$$

while total production in n with domestic technologies is

$$Y_{nn}^f = M_n T_n \left(\frac{c_n^f}{\gamma^{-1} P_n^f}\right)^{-\theta} H_n w_n L_n. \tag{14}$$

When $D_{nn} = H_{nn} = 1$, Y_{ni}^g and Y_{ni}^f collapse to the expressions in Ramondo and Rodríguez-Clare (2010), except that now MP flows in both sectors are multiplied by an extra L_i. This reflects the assumption that in our model countries are a collection of towns, and not just a dot in space.

2.4 Gains from trade, MP, and openness

We define the gains from openness as the change in the real wage from a situation where countries are in isolation to a situation with trade and MP. To compute these gains, we need to derive equilibrium real wages. We cannot solve the model to obtain real wages explicitly as a function of the exogenous variables, but we do not need to do that. Instead, we proceed as in Ramondo and Rodriguez-Clare (2010) to express real wages as a function of endogenous trade and MP flows, and then compute gains from openness as a function of these flows. Since we observe these flows in the data, this is sufficient to obtain a formula for gains that we can use for quantitative analysis.

Using the results in the previous section for price indices and trade and MP flows we can get an expression for the real wage in each country n as a function of trade and MP flows (see Appendix for details):

Lemma 1. The real wage in country n is given by

$$\frac{w_n}{P_n^f} = \widetilde{\gamma} \left(M_n T_n\right)^{(1+\eta)/\theta} H_n^{1/\theta} D_n^{\eta/\theta} \left(\frac{Y_{nn}^f}{w_n L_n}\right)^{-1/\theta} \left(\frac{Y_{nn}^g}{\eta w_n L_n}\right)^{-\eta/\theta} \left(\frac{X_{nn}}{\eta w_n L_n}\right)^{-\eta/\theta}. \tag{15}$$

Using this result, we can easily calculate the gains from openness as a function of trade and MP flows.[5]

Proposition 1. The gains from openness are given by

$$GO_n = \left(\frac{Y_{nn}^f}{w_n L_n}\right)^{-1/\theta} \left(\frac{Y_{nn}^g}{\eta w_n L_n}\right)^{-\eta/\theta} \left(\frac{X_{nn}}{\eta w_n L_n}\right)^{-\eta/\theta}. \tag{16}$$

[5]The gains from openness in the following proposition are the same as those in Ramondo and Rodríguez-Clare (2010) for the special case in which MP does not generate trade in inputs and productivity draws are uncorrelated across countries.

It is worth noting that the steady state growth rate for the open economy is the same as for the closed economy, given by differentiating (15) with respect to time. Growth is driven by the same forces that generate the gains from openness in the static model, namely the aggregate economies of scale associated with the fact that a larger population is linked to a higher stock of non-rival ideas.

3 Quantitative Analysis

We consider a set of nineteen OECD countries: Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, Great Britain, Germany, Greece, Italy, Japan, Netherlands, Norway, New Zealand, Portugal, Sweden and United States. This is the same set of countries as in Eaton and Kortum (2002).

For these countries, we compute real wages in the data as real (PPP) GDP from the Penn World Tables (6.3) divided by is a measure of equipped labor from Klenow and Rodríguez-Clare (2005) that controls both for physical and human capital. The latter is also our measure of L_n. We want to compare real wages in the data with those implied by the model.

3.1 Calibration of key parameters

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

The value of θ is critical for our exercise. We consider three approaches for this calibration. First, we calibrate θ to match the model's implication for the growth rate with that in the data. If $\bar{L}$ grows at a constant rate of $g_L > 0$ in all countries, then the model leads to a common long-run growth rate of

$$g = \frac{1+\eta}{\theta} g_L. \tag{17}$$

This follows by differentiating (5) with respect to time and then noting that $T = \bar{L}\bar{T}$ implies that $g_T = g_L$.[6] Following Jones (2002), we set g_L equal to the growth rate of research employment, which Jones calculated as 0.048. Using (17), $\eta = 0.5$, $g_L = 0.048$ and setting $g = 0.01$ (also from Jones, 2002), then $\theta = 7.2$. Jones and Romer (2010) follow this kind of reasoning and argue that $\frac{1+\eta}{\theta} = 1/4$, which implies $\theta = 6$, although they acknowledge that different interpretations of the mapping between model and data could also justify setting $\frac{1+\eta}{\theta}$ as high as 1 or 2.

Our second calibration approach is to calibrate θ by noting that our model is fully consistent with the Eaton and Kortum (2002) model of trade. Eaton and Kortum (2002) estimate values of θ between 3 and 12, with a preferred estimate of $\theta = 8$. More recent estimates using different procedures range between 3 and 8: Donaldson (2010) estimates $\theta = 3.8$; Costinot, Donaldson, and Komunjer (2011) estimate $\theta = 6.5$; Simonovska and Waugh (2011) estimate $\theta \in [2.5, 4.5]$; Caliendo and Parro (2011) estimate $\theta = 8.2$; and Arkolakis et al (2011) estimate $\theta = 5.6$.

Finally, a third approach is to use the results of Alcala and Ciccone (2004), who show that controlling for geography (area), institutions and openness (trade), larger countries (in terms of population) have a higher real GDP per capita with an elasticity of 0.3.[7] We interpret this result in the context of equation (15). If geography controls for H_n and D_n, institutions control for T_n, and openness controls for the last three terms on the RHS of (15), then since M_n is proportional to population, the result of a 0.3 elasticity in Alcala and Ciccone (2004) implies that $(1+\eta)/\theta = 0.3$. With $\eta = 1/2$ this implies that $\theta = 5$.

[6] Steady state growth rates are the same for all countries, and not affected by openness. This implies that the growth rate for the open economy is the same as the one for the closed economy.

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

Given these estimates, we choose $\theta = 6$ as our central value and then explore robustness of our results with alternative values of $\theta = 4$ and $\theta = 8$.

3.2 Preliminary results: the Danish puzzle

We start with the model of a closed economy with no domestic frictions. For that case we have $H = D = 1$ so equation (5) implies that the real wage is given by

$$\frac{w_n}{P_n^f} = \tilde{\gamma} \left(M_n T_n \right)^{(1+\eta)/\theta} . \tag{18}$$

We need an empirical measure of $M_n T_n$. We assume that $\overline{T}_n$ varies directly with the share of R&D employment observed in the data (from World Development Indicators) and then note that $M_n T_n = L_n \overline{T}_n$. Thus, our measures of L_n and $\overline{T}_n$ lead to a measure of $M_n T_n$.

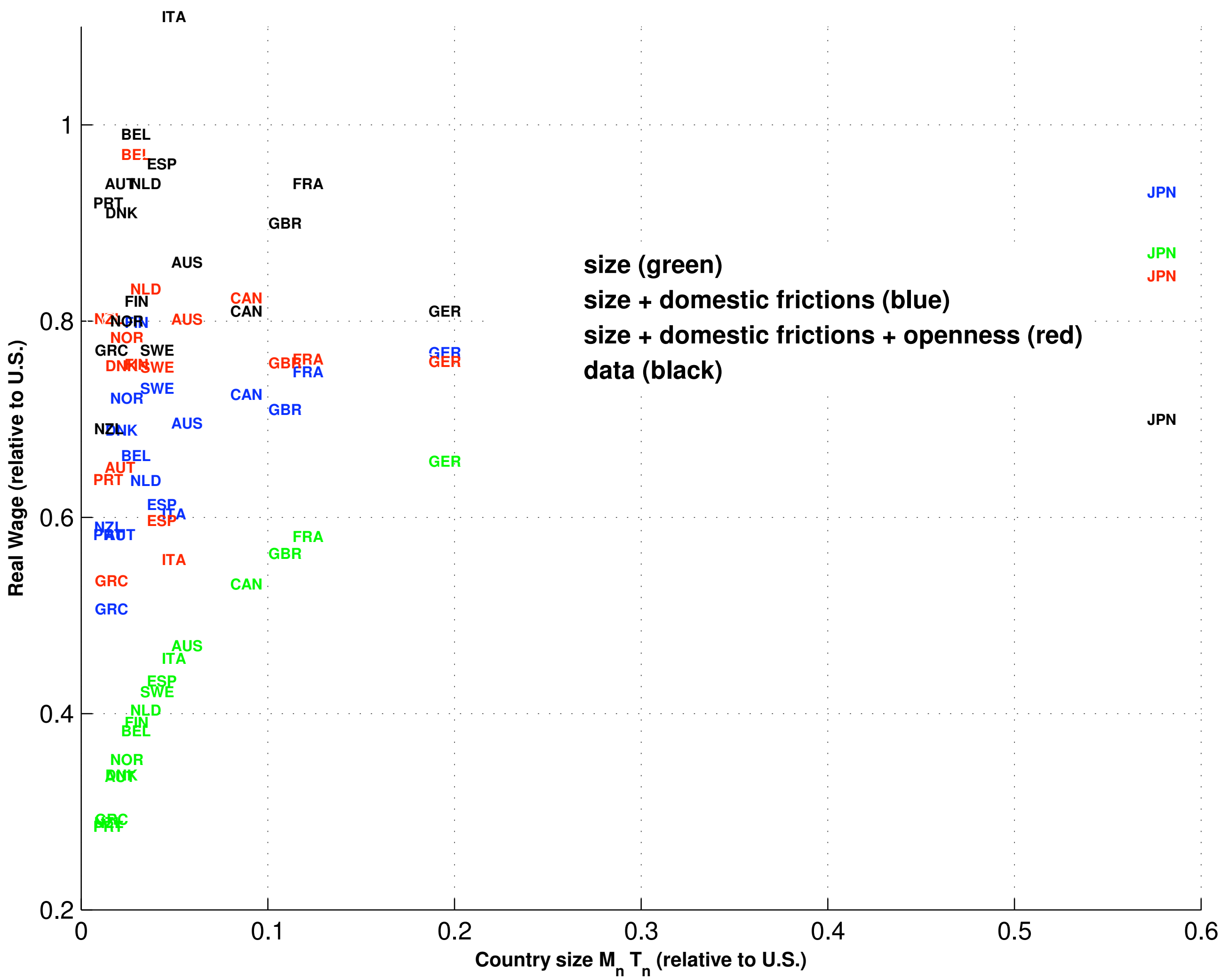
In Figure 1 we plot the model's implied real wage against our measure of size adjusted by R&D intensity, $L_n \overline{T}_n = M_n T_n$, both relative to the United States. We see that the closed-economy model substantially under-predicts the income level of small countries (green dots for the model under isolation against the black dots representing the data).

As an example, consider Denmark. The model implies an income of 35% of the U.S. level while the relative income in the data is 91%. We refer to this as the Danish puzzle, but it is common to all the small countries in our sample. In the rest of this section we explore whether allowing for openness and domestic frictions resolves the puzzle.

3.3 Adding gains from openness

In this section we explore how much of the gap between the real wage under isolation and the one observed in the data can be explained by the gains from trade and MP. To

Figure 1: Real Wage: Data and Model.



Calibration with $\theta = 6$. "Size", "size + domestic frictions", and "size + domestic frictions + openness" refer to the terms on the RHS of equation (15). The data refer to the real GDP per capita (PPP-adjusted) from Penn World Tables, an average over 1996-2001.

do so, we assume that there are no domestic frictions, and then note that the real wage is the same as that in autarky plus the gains from openness. From (18) and the results of Proposition 1, the real wage is given by

$$\frac{w_n}{P_n^f} = \tilde{\gamma} \left(M_n T_n \right)^{(1+\eta)/\theta} GO_n \tag{19}$$

where GO_n are the gains from openness in country n and given by (16). In the next subsection we explain how we compute the three terms on the RHS of the previous equation and in the subsection that follows we present the results of this exercise.

3.3.1 Data on Trade and Multinational Production

The gains from openness can be directly calculated using data on trade flows, MP sales, and gross manufacturing production. We use data on manufacturing trade flows from country i to country n from STAN as the empirical counterpart for trade in intermediates in the model, X_{ni}, and we think of total absorption in manufacturing (calculated as gross production minus total exports plus total imports) as the empirical counterpart of $\eta w_n L_n$ in the model.

Data on the gross value of production for multinational affiliates from i in n, from UNCTAD, is used as the empirical counterpart of bilateral MP flows in the model, $Y_{ni} \equiv Y_{ni}^f + Y_{ni}^g$. These MP flow data is not disaggregated by sector, so we do not observe MP flows in manufacturing (Y_{ni}^g) and non-manufacturing (Y_{ni}^f) separately. We observe MP flows in manufacturing only for the United States, and there we see that such flows represent approximately one half of the total MP flows – i.e.,

$$\sum_{i \neq US} Y_{US,i}^g = \frac{1}{2} \sum_{i \neq US} Y_{US,i}.$$

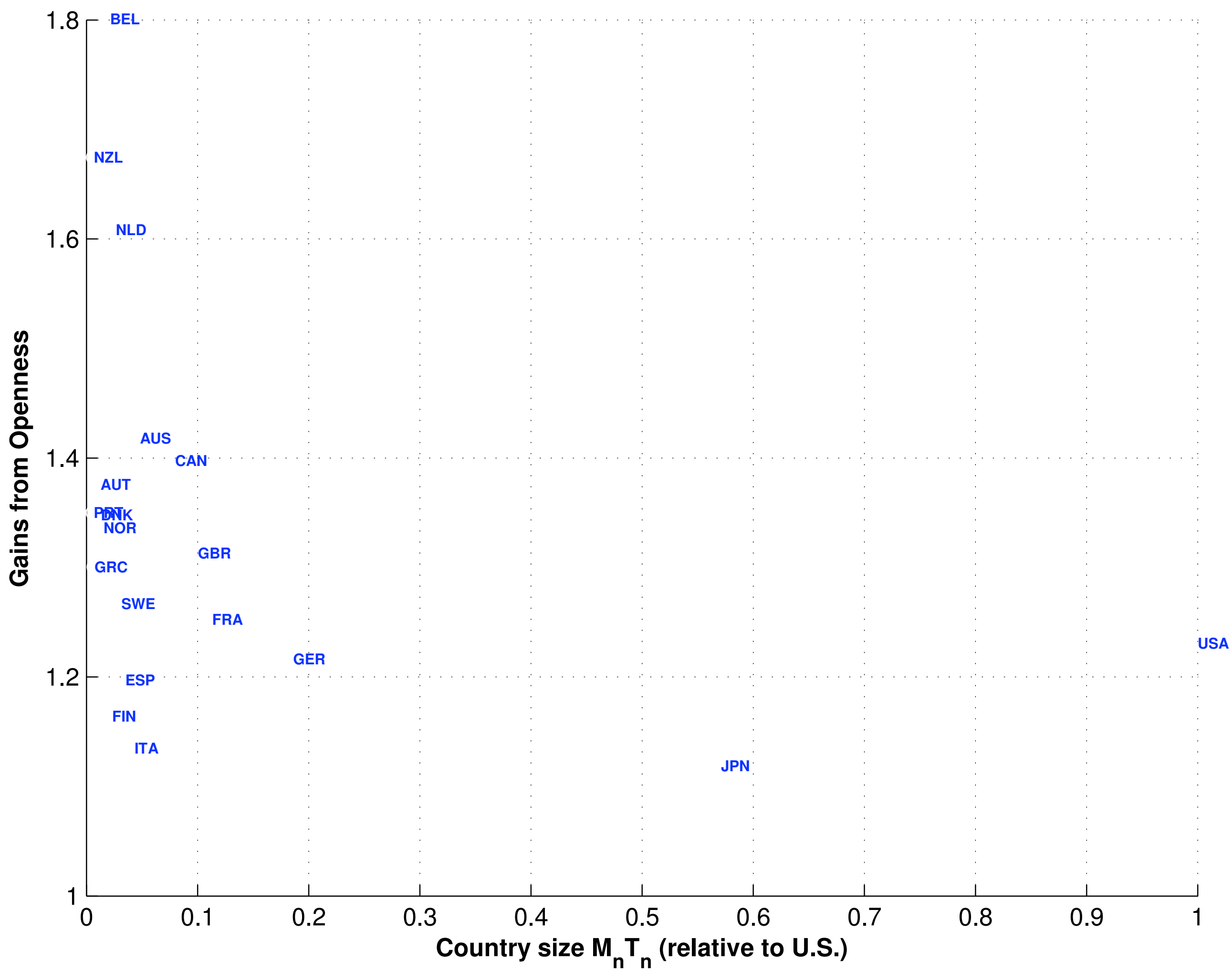
This suggests using one half of the total MP flows as the empirical counterpart for Y_{ni}^g, and similarly for Y_{ni}^f. We use GDP in current dollars (from World Development Indicators) as the empirical counterpart of $w_n L_n$ in the model.

All variables in the data are averages over the period 1996-2001. Details on the MP data are in the Appendix. Table 7 in the Appendix presents the results for the domestic trade shares, $\frac{X_{nn}}{\eta w_n L_n}$, and the domestic MP shares in final and intermediate goods, $\frac{Y_{nn}^f}{w_n L_n}$ and $\frac{Y_{nn}^g}{\eta w_n L_n}$, for all the countries in our sample.

3.3.2 Does openness resolve the Danish puzzle?

Figure 2 presents the results of the gains from openness (GO_n) against our adjusted measure of size, $L_n\overline{T}_n$, relative to the United States. As expected, small countries gain much more than large countries. Does this explain the Danish puzzle?

Figure 2: Gains from Openness and Size.



Calibration with $\theta = 6$. Gains from openness are calculated using equation (**??**), and data on trade and MP shares.

With no domestic frictions, the relative real wage for country n can be written as

$$\frac{w_n/P_n^f}{w_{US}/P_{US}^f} = \underbrace{\frac{(M_n T_n)^{(1+\eta)/\theta}}{(M_{US} T_{US})^{(1+\eta)/\theta}}}_{\text{size}} \underbrace{\frac{GO_n}{GO_{US}}}_{\text{openness}}. \tag{20}$$

The first column of Table 1 presents the real wage under isolation with no domestic frictions – this is the first term on the RHS of equation (20).[8] As mentioned before, the model implies that small countries would be much poorer than in the data. The second column presents the real wage taking into account the gains from openness – this is the relative real wage as implied by (20).

Table 1: Calibration's results: Model without domestic frictions. Small countries.

	size	openness	real wage model	real wage data
Portugal	0.29	1.10	0.31	0.92
New Zealand	0.29	1.36	0.39	0.69
Greece	0.29	1.06	0.31	0.77
Austria	0.34	1.12	0.38	0.94
Denmark	0.34	1.10	0.37	0.91
Norway	0.35	1.09	0.38	0.80
Belgium	0.38	1.46	0.56	0.99

Calibration with $\theta = 6$. Countries ordered by R&D-adjusted size ($T_i M_i = L_i \overline{T}_i$). Column 1 refers to the term "size", column 2 to the term "openness", and column 3 to the product of both terms in equation (20). Column 4 is the real GDP per capita (PPP-adjusted) from Penn World Tables, an average over 1996-2001. All variables are calculated relative to the United States.

It is important to emphasize that all these results for real wages are relative to the United States, so column 2 is not simply column 1 multiplied by GO_n. The reason is that the United States also gains from openness, and this is taken into account in the result of column 2. Thus, for example, the gains from openness for Denmark are 35% while for the United States these gains are 23%, so the net effect of openness in solving the Danish puzzle is not as large: Denmark's gains from openness are percentage points higher (1.10)

[8]In the tables in the text we restrict attention to the seven smallest countries in our sample. Results for the rest of the countries are presented in the Appendix.

than the gains for the United States.

Overall, the puzzle remains significant: even taking into account the role of openness, the model still implies that Denmark would be only 37% as rich as the United States.

3.4 Adding domestic frictions

Allowing for domestic frictions and openness, real wages are given by equation (15), and hence real wage relative to the United States can be written as

$$\frac{w_n/P_n^f}{w_{US}/P_{US}^f} = \underbrace{\frac{(M_n T_n)^{(1+\eta)/\theta}}{(M_{US} T_{US})^{(1+\eta)/\theta}}}_{\text{size}} \underbrace{\frac{(H_n)^{1/\theta}\,(D_n)^{\eta/\theta}}{(H_{US})^{1/\theta}\,(D_{US})^{\eta/\theta}}}_{\text{domestic frictions}} \underbrace{\frac{GO_n}{GO_{US}}}_{\text{openness}}. \tag{21}$$

The role of domestic frictions is captured in the second term on the RHS of this expression. To proceed, we need to calibrate d_{nn} and h_{nn}^f for all countries, and also decide on the empirical counterpart of M_n.[9]

3.4.1 Calibrating domestic frictions

For the number of towns, M_n, we start by setting $M_{USA} = 51$ and fix $\bar{L} = L_{USA}/M_{USA}$, for all countries in the sample. We then calculate $M_n = L_n/\bar{L}$, for all $n \neq USA$, using for L_n our measure of equipped labor in the data described above. Notice that, given our calibration of M_n, the concept of a "town" is consistent across different countries. Our calibrated M_n is highly correlated (0.90) with the number of cities with more than 250,000 habitants in each country. The last two columns in Table 7 in the Appendix compare these two variables.

To calibrate the domestic trade cost, d_{nn}, we use data on shipments between the fifty one states (fifty states and the District of Columbia) of the United States from the Commodity Flow Survey, for the years 2002 and 2007. Let $V_{mk,n}$ be the value of shipments

[9] Under the assumption that $h_{nn}^g > d_{nn}$, the value of h_{nn}^g has no importance.

from town k to town m in country n, and $\widetilde{V}_{m,n} = \sum_{k \neq m} V_{mk,n}$ the value of shipments from all towns $k \neq m$ to town m within country n. The model establishes that (see derivation in the Appendix)

$$d_{nn}^{-\theta} = \frac{\widetilde{V}_{m,n}}{V_{mm,n}\left(M_n - 1\right)}. \tag{22}$$

Using data on shipments between the fifty one states we compute $\widetilde{V}_{m,n}$ and $V_{mm,n}$ for each state and using $M_n = 51$ and a value for the parameter θ we then compute a value for d_{nn} according to (22). This gives us a value for d_{nn} according to the data for each state m, $n = USA$. Our estimate of d_{nn} for $n = USA$ is just an average of these fifty one estimates of d_{nn}.[10]

Table 2 reports the results of our estimation of d_{nn} for three different values of θ (4, 6, and 8). The average estimates of domestic trade costs among the United States are very similar across years. As expected, the estimate decreases with the value of θ.

Table 2: Domestic trade cost for United States: Summary statistic.

	2002			2007		
	$\theta = 4$	$\theta = 6$	$\theta = 8$	$\theta = 4$	$\theta = 6$	$\theta = 8$
Average	2.27	1.72	1.50	2.33	1.76	1.52
Standard Deviation	0.31	0.16	0.11	0.30	0.15	0.10
Maximum	3.02	2.09	1.74	3.17	2.16	1.78
Minimum	1.21	1.14	1.10	1.63	1.39	1.28

Own calculations using data from the Commodity Flow Survey for the Unites States, for 2002 and 2007.

Domestic frictions for both trade and MP are crucial variables in our empirical exercise. Here we assume that d_{nn} is the same as the one for the United States for the remaining countries in our sample. We take the estimate of d_{nn} for 2002 for $\theta = 6$, $d_{nn} = 1.7$, as our benchmark. We also assume MP frictions in final goods are as large as trade frictions in that $h_{nn}^{f} = d_{nn}$.

[10] We do observe all the bilateral trade flows between states, but it is enough for the estimation procedure aggregate flows from each state, $\widetilde{V}_{m,n}$.

In the Appendix, we present alternative calibrations of the domestic trade cost d_{nn}. Following the same procedure as for the fifty one states of the United States, we use data on trade flows between 10 provinces and 3 territories of Canada, $M_{can} = 13$, for 2002 and 2007. For the three different values of θ, we obtain a remarkably similar estimate for d_{nn} as the one obtained using U.S. data.[11] Results are presented in Table 5 in the Appendix. We also use more disaggregated data from the Commodity Flow Survey for the Unites States, for 2007. We consider shipments between 99 geographical units, among which we have Consolidated Statistical Areas (CSA), Metropolitan Statistical Areas (MSA), and the remaining portions of (some of) the states. Estimates are slightly higher than the estimates using states. As shown in Table 6 in the Appendix, for $\theta = 6$ we get $d_{nn} = 1.86$ using more disaggregated geographical units, against $d_{nn} = 1.7$ using states.[12]

Finally, table 10 in the appendix presents the implied number of towns coming from using the three different data sets on internal trade explained above. Calculations are analogous to the ones for U.S. states: $M_i = L_i/\overline{L}$ where $\overline{L} = M_k/L_k$, with k corresponding to U.S. states, U.S. sub-regional units (CSA-MSA), and Canadian provinces, alternatively. This table also shows the number of towns with more than 250,000 habitants observed in the data, for each country. Moreover, we also record the implied contribution of domestic frictions to the (relative) real wages (second term on the RHS of equation 21) for the different calibrated number of towns M_i.

3.4.2 Do domestic frictions resolve the Danish Puzzle?

Before we present the results, we show how h^f_{nn} and d_{nn} independently matter for our results. Figure 3 shows the relationship between these two domestic frictions and the

[11] Our results for d_{nn} for $n = CAN$ are very similar to those in Tombe and Winter (2012).

[12] We also explored the idea of using equation (10) to estimate D_l as a dummy in a standard gravity equation. Unfortunately, we cannot disentangle D_l from the effect of importer-specific and exporter-specific effects on bilateral trade costs. That is, we can recover D_l from a gravity regression with exporter- and importer-fixed effects only if we assume that trade costs d_{nl} have no exporter- or importer-specific components. This would go against Eaton and Kortum (2002), who assume importer-specific effects on trade costs, and Waugh (2010), who assumes exporter-specific effects on trade costs.

relative real wage implied by the model for Denmark. The left panel of Figure 3 considers changes in d_{nn} while keeping $h^f_{nn} = 1.7$. In the data, Denmark's relative real wage is 0.91. In the model, Denmark's relative real wage increases with d_{nn}: increasing d_{nn} from $d_{nn} = 1$ (no frictions) to $d_{nn} = 4$ (for both Denmark and the U.S.) increases Denmark's relative real wage from a little less than 0.6 to almost 0.8. Similarly, the right panel of Figure 3 considers changes in h^f_{nn} for both Denmark and the U.S. while keeping $d_{nn} = 1.7$. Results are similar to the ones coming from changing d_{nn}, but as the MP domestic frictions increase, Denmark would catch up faster with the United States. The reason for this is that domestic frictions in final goods have a stronger effect on the real wage than domestic frictions in intermediates (see term $H_n^{1/\theta} D_n^{\eta/\theta}$ in equation 15 given $1/\theta > \eta/\theta$).[13] Not surprisingly, higher domestic frictions in either trade or MP hurt the larger country more than the small country and so allow the smaller country to catch up.

Table 3 presents the results for relative real wages taking into account domestic frictions as calibrated above (i.e., $d_{nn} = h^f_{nn} = 1.7$).

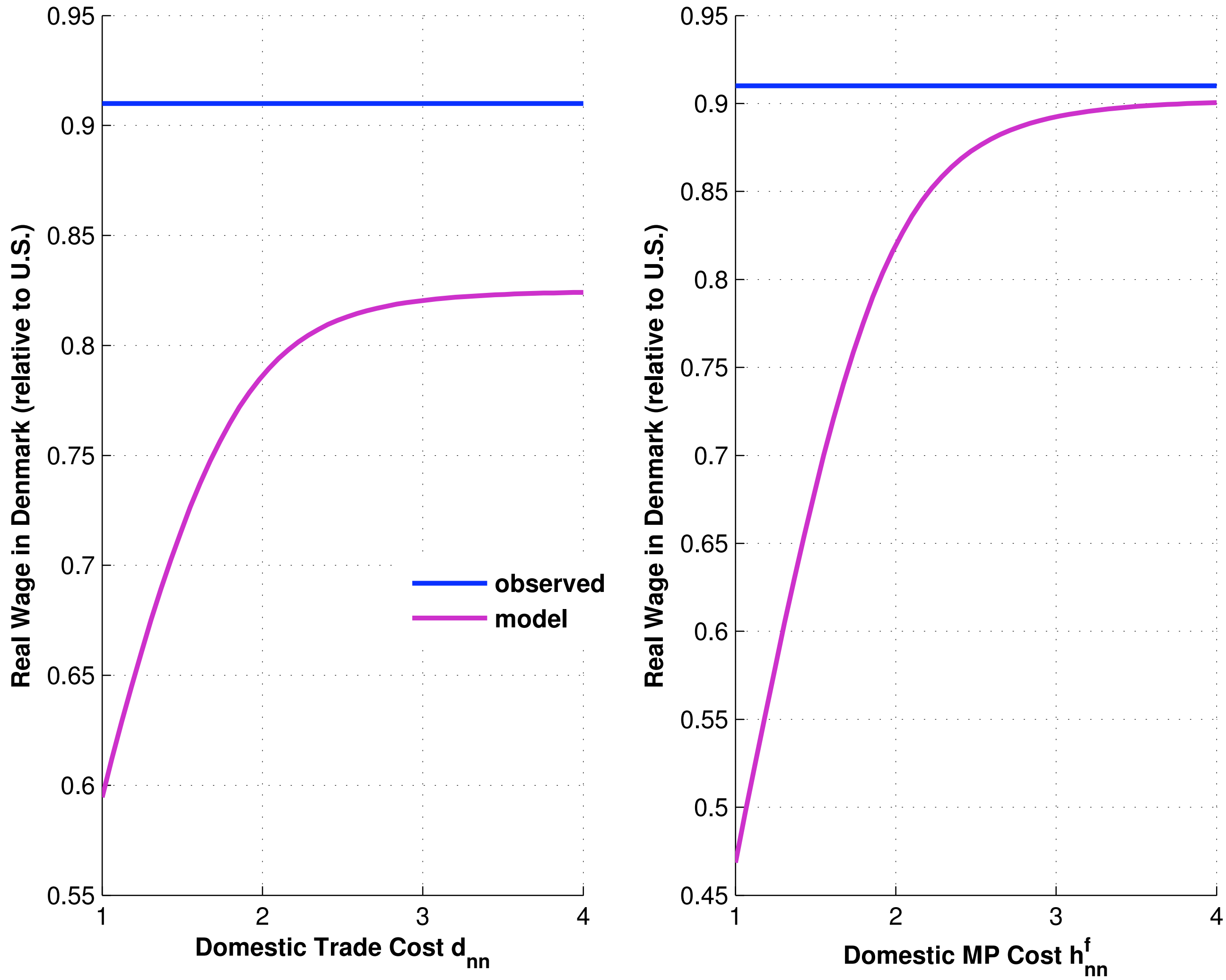
Table 3: Calibration's results: Model with domestic frictions. Small countries.

	Size	Domestic frictions	Openness	Real wage model	Real wage data
Portugal	0.29	2.04	1.10	0.64	0.92
New Zealand	0.29	2.04	1.36	0.80	0.69
Greece	0.29	1.73	1.06	0.54	0.77
Austria	0.34	1.73	1.12	0.65	0.94
Denmark	0.34	2.04	1.10	0.75	0.91
Norway	0.35	2.04	1.09	0.78	0.80
Belgium	0.38	1.73	1.46	0.97	0.99

Calibration with $\theta = 6$. Countries ordered by R&D-adjusted size ($T_i M_i = L_i \overline{T}_i$. Column 1 refers to the term "size", column 2 to the term "domestic frictions", column 3 to the term "openness", and column 4 to the product of the three terms in equation (21). Column 5 is the real GDP per capita (PPP-adjusted) from Penn World Tables, an average over 1996-2001. All variables are calculated relative to the United States.

[13] At $h^f_{nn} = 4$, the model would almost match the relative real wage observed in the data. With such high frictions for final goods, the scale effects become weak, and Denmark's higher gains from openness compared to the US (1.36 against 1.23, respectively) compensates for its smaller size and its lower R&D (the share of labor employed in R&D in Denmark is 75% as high as in the US).

Figure 3: Domestic Frictions and Real Wage: the Case of Denmark



Column 1 presents the relative real wage under isolation, while column 2 takes into account domestic frictions –the first and second terms of the RHS of equation (21). Column 3 presents the gains from openness (relative to U.S.), and finally, column 4 shows the relative real wage implied by the model that takes into account both domestic frictions and openness –all the terms on the RHS of the same equation.

As expected, domestic frictions diminish the strength of aggregate economies of scale and this helps small countries relative to larger ones. For example, Denmark's relative real wage in isolation increases from 0.34 to 0.69 (0.34×2.04) when domestic frictions are considered. Interestingly, domestic frictions help to close the Danish puzzle much more than openness. For Denmark, domestic frictions bring the relative real wage from 0.34 to 0.69 whereas openness takes it from 0.69 to 0.75.

For most of the small countries, there is still an unexplained gap between the relative real wage in our calibrated model and in the data. Again, for Denmark, the relative real wage in the calibrated model is 0.75 while in the data it is 0.91. The only exception is New Zealand, for which the model with domestic frictions and openness actually over-predicts the relative real wage. Figure 1 shows, for the nineteen countries in the sample, the observed real wage, the calibrated real wage under isolation in a world with and without domestic frictions, and the calibrated real wage in a world with domestic frictions as well as trade and MP flows as observed in the data. Countries are ordered by their R&D-adjusted size (given by $T_i M_i$).

Figure 1 makes clear that it is among small countries that we have an unexplained gap between the real wage in the data and the calibrated model. For larger countries, the calibrated model often over-predicts the real wage as a share of U.S. real wage. Again, the factors that contribute the most to close the income gap with the United States are not the gains from trade and MP, but the presence of frictions for these two flows within a country (see green against blue, and blue against red in the figure).

Table 4 illustrates how the gap between calibrated and observed real wage varies with different values of θ when domestic frictions are recalibrated accordingly. A higher value for θ increases the relative real wage implied by the full model (with domestic frictions and openness). Thus, the Danish Puzzle disappears when $\theta = 8$. To understand this further, notice that by simultaneously changing θ and d_{nn} such that equation equation (22) is satisfied, neither H_n nor D_n are affected by changes in θ. Moreover, letting

$$A_n \equiv \left(\frac{Y^f_{nn}}{w_n L_n}\right)^{-1} \left(\frac{Y^g_{nn}}{\eta w_n L_n}\right)^{-\eta} \left(\frac{X_{nn}}{\eta w_n L_n}\right)^{-\eta},$$

Table 4: Calibration's results for different values of θ. Small countries.

	Real Wage (relative to U.S.)								
	$\theta=4$			$\theta=6$			$\theta=8$		
	size	d.f.	full	size	d.f.	full	size	d.f.	full
Portugal	0.15	0.33	0.37	0.29	0.58	0.64	0.39	0.74	0.80
New Zealand	0.16	0.33	0.53	0.29	0.59	0.80	0.39	0.75	0.94
Greece	0.16	0.27	0.29	0.29	0.51	0.54	0.40	0.67	0.69
Austria	0.19	0.33	0.40	0.34	0.58	0.65	0.44	0.74	0.80
Denmark	0.20	0.42	0.48	0.34	0.69	0.75	0.44	0.84	0.90
Norway	0.21	0.45	0.51	0.35	0.72	0.78	0.46	0.87	0.93
Belgium	0.24	0.41	0.72	0.38	0.66	0.97	0.49	0.81	1.08

"Size" refers to the first term in the RHS of equation (21); "d.f." (domestic frictions) refers to the first times second term of equation (21); "full" refers to size x domestic frictions x openness in equation (21).

then equation (16) implies that $GO_n = A_n^{1/\theta}$, where A_n is independent of θ. Equation (21) can then be rewritten as

$$\frac{w_n/P_n^f}{w_{US}/P_{US}^f} = \left[\left(\frac{M_n T_n}{M_{US} T_{US}}\right)^{1+\eta} \frac{H_n D_n^\eta}{H_{US} D_{US}^\eta} \frac{A_n}{A_{US}}\right]^{1/\theta}. \tag{23}$$

Countries for which the model implies a relative real wage that is lower than one have the term in parenthesis be lower than one. Hence, for these countries, a higher θ weakens the net scale effect and increases the relative real wage towards one. This is why the full model generates a higher relative real wage as θ increases. Table 11 in the Appendix shows the results for all countries in the sample.

4 Closing the Danish Puzzle

The results of the previous section show that openness and domestic frictions are not enough to solve the Danish puzzle when θ is at our benchmark value or lower. Of course, our model is very parsimonious: we have only allowed for size (M), R&D (T), and gains from openness (GO) in explaining differences in real income levels across countries (see equation 21). There are at least two important possibilities we have left out that could explain why small countries are rich. First, small countries could have better "institutions" that lead to a higher technology level T than the one implied by the share of labor devoted to R&D. Perhaps having good institutions is precisely what allowed these countries to remain small and independent in the first place. However, the data show that correlations between our measure of size L_i and (average years of) schooling, corruption in government, bureaucratic quality, and rule of law are 0.27, -0.22, 0.21, 0.09, respectively. (See Table 12 in the Appendix). These low correlations suggest that very little was left out of the model on this front.

Second, we have assumed that gains from openness arise through trade and MP, but this leaves out international technology diffusion taking place without MP (or trade). For example, U.S. technologies eventually diffuse to other countries, where they can be used for production by local firms. Unfortunately, except for the small part that happens through licensing, technology diffusion does not leave a paper trail that can be used to directly measure the value of production done in country l by country l firms with technologies from country i. Eaton and Kortum (1999) use international patent data to do such measurement indirectly, with the help of their model. Here we follow a simpler approach and assume that a share ϕ of the value of production in country i that is done with country l technologies is not recorded as MP. For example, the iPhone is produced in China by Foxconn. This reflects the use of a U.S. technology for production in China, but since it is produced by a Chinese firm, it is not recorded as MP. Setting $\phi > 0$ is a rough way of capturing this phenomenon and exploring its quantitative importance.

The value of ϕ affects the calculation of the gains from openness. Consider the case of final goods, for which we have $\sum_i Y_{ni}^f = w_n L_n$. As explained above, we measure Y_{ni}^f for $n \neq i$ from MP data, and we set $w_n L_n$ as GDP in country n. We then get Y_{nn}^f as a residual, $Y_{nn}^f = w_n L_n - \sum_{i \neq n} Y_{nn}^f$. When $\phi > 0$ then the actual value of production in n with foreign technologies is $\frac{1}{1-\phi}\sum_{i\neq n} Y^f_{ni}$ and hence

$$Y^f_{nn} = w_n L_n - \frac{1}{1-\phi}\sum_{i\neq n} Y^f_{ni}.$$

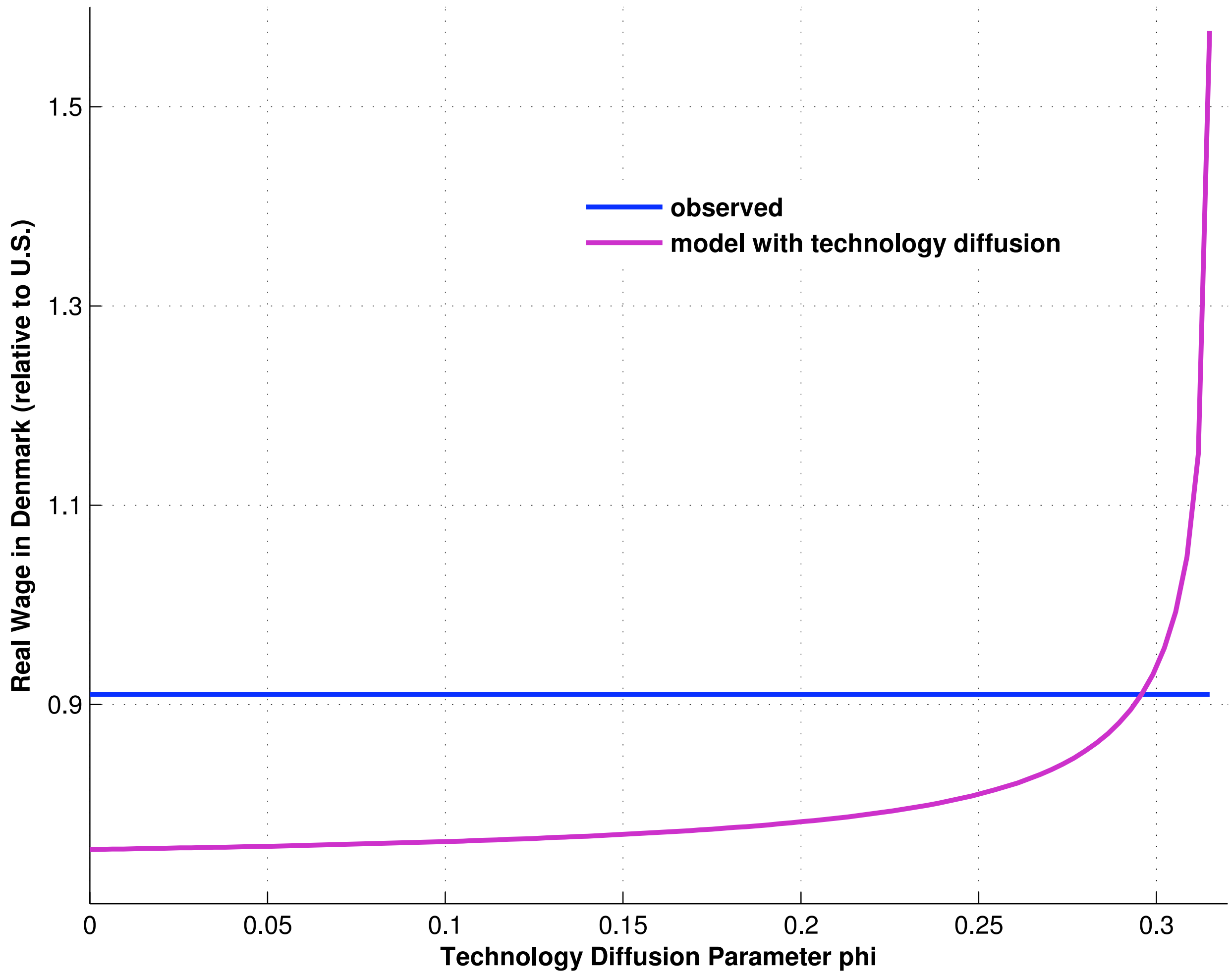
A higher value of ϕ implies a lower value for Y^f_{nn} and hence higher gains from MP in final goods. Something similar happens for intermediate goods.

We assume that ϕ is the same across countries and think of higher values of ϕ as implying higher technology diffusion. Figure 4 shows how ϕ affects the implied relative real wage for Denmark. In particular, for $\phi = 0$, the (relative) real wage for Denmark is 0.71 as implied by our baseline model. As ϕ increases, the (relative) real wage for Denmark increases to finally match the one observed in the data at a value of ϕ just below 0.30. Moreover, for $\phi > 0.30$, Denmark rapidly catches up with the United States becoming even richer.

5 Conclusions

TBD ...

Figure 4: Technology Diffusion and Real Wage: the Case of Denmark



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A Proofs

Price indices. We now derive the price indices for final and intermediate goods in the open economy. We let $z^f_{m,ni}(u)$ be the highest productivity among the set of technologies for final good u originating in country i with home town m in country n, and let $z^g_{m,ni}(v)$ be the highest productivity among the set of technologies for intermediate good v originating in country i with home town m in country n. Also, let $z^g_{li}(v) = \max_m z^g_{m,li}(v)$. By the properties of the Fréchet distribution, $z^f_{m,ni}(u)$ and $z^g_{m,ni}(v)$ are distributed Fréchet with parameters $L_i\bar{T}_i/M_n$ and θ.

Consider first the case of final goods. What are the different technologies available for town m in country n in consuming final good u? We have: (a) technologies from n with home town m at unit cost $c^f_n/z^f_{m,nn}(u)$, (b) technologies from $i \neq n$ with home town m at unit cost $h_{ni}c^f_n/z^f_{m,ni}(u)$, (c) technologies from n with home town different than m at unit cost $\min_{s\neq m} h_{nn}c^f_n/z^f_{s,nn}(u)$, (d) technologies from $i \neq n$ with home town different than m at unit cost $\min_{s\neq m} h_{nn}h_{ni}c^f_n/z^f_{s,ni}(u)$. This implies that

$$p^f_{m,n}(u) = \min\left(\frac{c^f_n}{z^f_{m,nn}(u)}, \frac{h_{ni}c^f_n}{z^f_{m,ni}(u)}, \min_{s\neq m}\frac{h_{nn}c^f_n}{z^f_{s,nn}(u)}, \min_{i\neq n}\min_{s\neq m}\frac{h_{nn}h_{ni}c^f_n}{z^f_{s,ni}(u)}\right).$$

What are the different technologies available for town m for using intermediate good v? We have: (a) technologies from n with home town m at unit cost $c^g_n/z^g_{m,nn}(v)$, (b) technologies from $i \neq n$ with home town m at unit cost $h_{ni}c^g_n/z^g_{m,ni}(v)$, (c) technologies from n with home town different than m at unit cost

$$\min\left\{\min_{s\neq m}\frac{h_{nn}c^g_n}{z^g_{s,nn}(v)}, \min_{s\neq m}\frac{d_{nn}c^g_n}{z^g_{s,nn}(v)}\right\},$$

(d) technologies from $i \neq n$ with home town different than m at unit cost

$$\min\left\{\min_{i\neq n}\min_{s\neq m}\frac{h_{nn}h_{ni}c^g_n}{z^g_{s,ni}(v)}, \min_{i\neq n}\min_{s\neq m}\frac{d_{nn}h_{ni}c^g_n}{z^g_{s,ni}(v)}\right\},$$

(e) technologies from $i \neq n$ used in their home town in country i and imported to m at unit cost $\min_i d_{ni} c_i^g / z_{ii}^g(v)$, (f) technologies from i used in their home town in $l \neq n$ and imported to m at unit cost $\min_{i,l} \xi_{nli}/z_{li}^g(v)$, where $\xi_{nli} \equiv d_{nl} h_{li} c_l^g$. Given $d_{nn} < h_{nn}$, this implies that

$$p_{m,n}^g(v) = \min\left(\frac{c_n^g}{z_{m,nn}^g(v)}, \min_{i\neq n} \frac{h_{ni}c_n^g}{z_{m,ni}^g(v)}, \min_{s\neq m} \frac{d_{nn}c_n^g}{z_{s,nn}^g(v)}, \min_{i\neq n}\min_{s\neq m} \frac{d_{nn}h_{ni}c_n^g}{z_{s,ni}^g(v)}, \min_{i\neq n} \frac{d_{ni}c_i^g}{z_{ii}^g(v)}, \min_{i\neq n, l\neq n} \frac{\xi_{nli}}{z_{li}^g(v)}\right).$$

As in the case of a close economy, these results together with the assumption that productivities are independently drawn from the Fréchet distribution imply that the price indexes for final and intermediate goods are given respectively by

$$\left(\gamma^{-1}P_n^f\right)^{-\theta} = \frac{L_n \bar{T}_n}{M_n}(c_n^f)^{-\theta}(1+(M_n-1)h^{-\theta}) + \sum_{i\neq n} \frac{L_i\bar{T}_i}{M_n}(h_{ni}c_n^f)^{-\theta}(1+(M_n-1)h^{-\theta}),$$

and

$$\begin{aligned}\left(\gamma^{-1}P_n^g\right)^{-\theta} \quad = \quad & \frac{L_n \bar{T}_n}{M_n}(c_n^g)^{-\theta}(1+(M_n-1)d_{nn}^{-\theta}) + \\ & \sum_{i\neq n, l=n} \frac{L_i\bar{T}_i}{M_n}(h_{ni}c_n^g)^{-\theta}(1+(M_n-1)d_{nn}^{-\theta}) + \\ & \sum_{i\neq n, l=i} M_i \frac{L_i\bar{T}_i}{M_i}(d_{ni}c_i^g)^{-\theta} + \sum_{l\neq n, l\neq i} M_l \frac{L_i\bar{T}_i}{M_l}\xi_{nli}^{-\theta}.\end{aligned}$$

Using the definitions of ξ_{nli}, D_n and H_n, we get the result of equations (6) and (7).

Proof of Lemma 1. First, we rewrite (12) as follows,

$$Y_{nn}^g = \frac{M_n T_n \left(c_n^g\right)^{-\theta} \Psi_n'}{\left(\gamma^{-1}P_n^g\right)^{-\theta}},$$

where

$$\Psi_n' = D_n \eta w_n L_n + \sum_{j\neq n} d_{jn}^{-\theta}\left(\gamma^{-1}P_n^g\right)^{-\theta} \eta w_j L_j \left(\gamma^{-1}P_j^g\right)^{\theta}. \tag{24}$$

Using the expression above for Y_{nn}^g and (14), it is easy to get the following expression for real wage,

$$w_n/P_n^f = \widetilde{\gamma}(M_n T_n)^{(1+\eta)/\theta} H_n^{1/\theta} \left(Y_{nn}^g\right)^{-\eta/\theta} \left(\frac{Y_{nn}^f}{w_n L_n}\right)^{-1/\theta} \left(\Psi_n'\right)^{\eta/\theta}. \tag{25}$$

To obtain the expression for real wage in equation (15), we first rewrite (24) as

$$\Psi_n' = D_n \eta w_n L_n + \eta w_n L_n \sum_{j \neq n} \left(\frac{d_{jn} P_n^g}{P_j^g}\right)^{-\theta} \frac{w_j L_j}{w_n L_n}.$$

Then, we use the gravity equation in (10) and $\sum_{j=1}^N X_{jn} = \eta w_n L_n$, to get

$$\Psi_n' = D_n \eta w_n L_n \left(\frac{\eta w_n L_n}{X_{nn}}\right).$$

Replacing in (25), we obtain (15).

Proof of Proposition 1. It follows directly from the ratio of the real wage at the benchmark in equation (15) to the real wage in the closed economy in equation (5).

Flows between towns. Expenditure on goods from town k going to town m in country n is

$$V_{mk,n} = d_{nn}^{-\theta} \left(\gamma c_n^g / P_n^g\right)^{-\theta} \left[M_n T_n + \sum_{i \neq n} M_i T_i (h_{ni})^{-\theta}\right] \eta w_n \bar{L} M_n.$$

Thus, expenditure by town m on goods from all other towns in the same country is simply $\widetilde{V}_{m,n} = (M_n - 1) V_{mk,n}$. In town m in country n, the expenditure on goods coming from the same town is

$$V_{mm,n} = \left(\gamma c_n^g / P_n^g\right)^{-\theta} \left[M_n T_n + \sum_{i \neq n} M_i T_i (h_{ni})^{-\theta}\right] \eta w_n \bar{L} M_n.$$

B Data on Multinational Production: Description

Data on MP is from UNCTAD, Investment and Enterprise Program, FDI Statistics, FDI Country Profiles, published and unpublished data.[14] A foreign affiliate is defined in the data as a firm who has more than 10% of its shares owned by a foreigner. Most countries report magnitudes for majority-owned affiliates only (more than 50% of ownership).[15] The data refer to non-financial affiliates in all sectors with a few exceptions of countries that report data only on foreign affiliates in manufacturing.[16]

The UNCTAD measure of MP includes both local sales in n and exports to any other country, including the home country i. Out of 342 possible country-pairs, data are available for 219 country-pairs. We impute missing values by running the following OLS regression

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

where Y_{ni} is gross production of affiliates from i in n, $w_n L_n$ is GDP in country n, d_{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 S_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 language are from CEPII.

[14]Unpublished data are available upon request at fdistat@unctad.org.
[15]Majority-owned affiliates are the largest part of the total number of foreign affiliates in a host economy.
[16]The exceptions are Italy and United Kingdom.

C Alternative calibration of domestic frictions

This section shows results for domestic trade frictions calculated using different data on domestic trade flows, for the United States, Canada, and countries in the European Union. These alternative estimations are not very different from our benchmark.

C.1 Using trade between Canadian provinces

Data on internal trade are available for Canada. In particular, bilateral trade of goods and services, respectively, is recorded among the thirteen Canadian provinces, for the years 1999-2007.[17] We follow the same procedure described in the paper as for trade in goods within the United States, and use equation (22) with $M_{can} = 13$. The following table summarizes the results.

Table 5: Domestic trade cost for Canada: Summary statistic.

	2002			2007		
	$\theta = 4$	$\theta = 6$	$\theta = 8$	$\theta = 4$	$\theta = 6$	$\theta = 8$
Average	2.25	1.72	1.50	2.31	1.75	1.52
Standard Deviation	0.24	0.12	0.08	0.27	0.14	0.09
Maximum	2.74	1.96	1.65	2.81	1.99	1.68
Minimum	2.00	1.59	1.41	1.94	1.56	1.39

Own calculations using data from BCStats, for 2002 and 2007.

The statistics in Table 5 are remarkably similar to the ones presented in Table 2 for inter-state trade in the United States. In particular, for Canada, the average domestic trade cost is 1.72 in 2002, for $\theta = 6$, the same as in our benchmark calibration.

[17]The source is British Columbia Statistics, at $http://www.bcstats.gov.bc.ca/data/bus_stat/trade.asp$.

C.2 Using trade between sub-regional units for the United States

We also calculate domestic trade costs for sub-regional geographical units within the United States. We compute internal trade for 99 geographical units, from which 48 are Consolidated Statistical Areas (CSA), 18 are Metropolitan Statistical Areas (MSA), and 33 represent remaining portions of (some of) the states. The data source is the Commodity Flow Survey, for 2007. For each of the 99 geographical units, we compute the total purchases from the United States and subtract trade with themselves. Then, we use equation 22 in the text to calculate d_{nn}, for different values of θ. We consider $M_{USA} = 99 + 1$ (where the 100th geographical unit represents the "rest" of the United States). We also calculate d_{nn} using only trade among the 99 geographical units (in this case, $M_{USA} = 99$). Table 6 presents the results.

Table 6: Domestic trade cost for the United States (CSA and MSA): Summary statistic.

	$M_{USA} = 99^{\dagger}$				$M_{USA} = 100^{\ddagger}$			
	$\theta = 4$	$\theta = 6$	$\theta = 8$	$\frac{V_{mm,n}}{V_{mm,n}+\widetilde{V}_{m,n}}$	$\theta = 4$	$\theta = 6$	$\theta = 8$	$\frac{V_{mm,n}}{V_{mm,n}+\widetilde{V}_{m,n}}$
Average	2.68	1.92	1.63	0.34	2.52	1.85	1.58	0.29
Standard Deviation	0.46	0.21	0.13	0.13	0.39	0.19	0.12	0.12
Maximum	5.04	2.94	2.24	0.87	3.71	2.40	1.93	0.66
Minimum	1.40	1.25	1.18	0.04	1.29	1.19	1.14	0.03

Own calculations using data from CFS, 2007. †: trade between each of the 107 geographical unit and the rest of the United States. ‡: trade between the 107 geographical units only.

The estimates using smaller geographical units are around 9.5% higher than the benchmark that uses U.S. states (1.7 against 1.86 for $\theta = 6$). The average d_{nn} calculated using only the trade among the 99 units is slightly higher than the one calculated using trade of each of the 99 units with all the rest of the United States.

D Additional tables

Table 7: Data: Summary.

	Domestic MP shares final	Domestic MP shares intermediate	Domestic trade shares	Equipped labor	Real GDP per capita	Employment R&D
Australia	0.21	0.54	0.64	0.06	0.86	0.79
Austria	0.30	0.62	0.38	0.02	0.94	0.57
Belgium	0.27	0.38	0.03	0.03	0.99	0.79
Canada	0.28	0.52	0.44	0.11	0.81	0.74
Denmark	0.32	0.79	0.36	0.02	0.91	0.75
Spain	0.48	0.78	0.65	0.08	0.96	0.43
Finland	0.58	0.81	0.59	0.02	0.82	1.48
France	0.39	0.75	0.59	0.15	0.94	0.73
Great Britain	0.32	0.68	0.55	0.16	0.90	0.63
Germany	0.45	0.76	0.60	0.26	0.81	0.72
Greece	0.31	0.84	0.54	0.02	0.77	0.33
Italy	0.59	0.89	0.70	0.13	1.11	0.34
Japan	0.56	0.95	0.87	0.51	0.70	1.12
Netherlands	0.21	0.40	0.18	0.04	0.94	0.60
Norway	0.28	0.77	0.52	0.02	0.80	0.92
New Zealand	0.12	0.24	0.57	0.01	0.69	0.61
Portugal	0.31	0.52	0.53	0.02	0.92	0.35
Sweden	0.41	0.67	0.52	0.03	0.77	1.06
United States	0.37	0.80	0.77	1.00	1.00	1.00

Domestic MP in the final good sector is calculated as share of GDP. Domestic MP in the intermediate good sector is calculated as share of gross production in manufacturing. Domestic trade in manufacturing is calculated as share of absorption in manufacturing. $RGDPL$ is calculated as PPP- adjusted real GDP per capita times population, divided by equipped labor. R%D employment is shown as share of total employment. Equipped labor, real GDP per capita, and R&D employment are shown relative to the magnitudes for the United States. Variables are averages over 1996-2001.

Table 8: Shipments 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.

Table 9: Calibration results. All countries.

	Size	Domestic frictions	Openness	Real wage model	Real wage data
Australia	0.47	1.48	1.15	0.80	0.86
Austria	0.34	1.73	1.12	0.65	0.94
Belgium	0.38	1.73	1.46	0.97	0.99
Canada	0.53	1.36	1.14	0.82	0.81
Denmark	0.34	2.04	1.10	0.75	0.91
Spain	0.43	1.42	0.97	0.60	0.96
Finland	0.39	2.04	0.95	0.76	0.82
France	0.58	1.29	1.02	0.76	0.94
Great Britain	0.56	1.26	1.07	0.76	0.90
Germany	0.66	1.17	0.99	0.76	0.81
Greece	0.29	1.73	1.06	0.54	0.77
Italy	0.46	1.32	0.92	0.56	1.11
Japan	0.87	1.07	0.91	0.85	0.70
Netherlands	0.40	1.58	1.31	0.83	0.94
Norway	0.35	2.04	1.09	0.78	0.80
New Zealand	0.29	2.04	1.36	0.80	0.69
Portugal	0.29	2.04	1.10	0.64	0.92
Sweden	0.42	1.73	1.03	0.75	0.77
United States	1.00	1.00	1.00	1.00	1.00

Calibration with $\theta = 6$. Column 1 refers to the term "size", column 2 to the term "openness", and column 3 to the product of both terms in equation (20). Column 4 is the real GDP per capita (PPP-adjusted) from Penn World Tables, an average over 1996-2001. All variables are calculated relative to the United States.

Table 10: Calibration results. All countries.

	No. of Towns calculated with				Domestic Frictions			
	States USA	CSA-MSA USA	Provinces Canada	Data	States USA	CSA-MSA USA	Provinces Canada	Data
Australia	4	7	8	10	1.48	1.38	1.36	1.27
Austria	2	3	3	2	1.73	1.65	1.67	1.78
Belgium	2	3	4	1	1.73	1.65	1.56	2.10
Canada	6	11	13	14	1.36	1.27	1.25	1.20
Denmark	1	2	3	1	2.04	1.81	1.67	2.10
Spain	5	9	11	16	1.42	1.32	1.28	1.18
Finland	1	2	2	2	2.04	1.81	1.83	1.78
France	8	16	19	7	1.29	1.20	1.18	1.36
Great Britain	9	17	20	18	1.26	1.19	1.17	1.16
Germany	14	26	32	27	1.17	1.12	1.10	1.10
Greece	2	3	3	2	1.73	1.65	1.67	1.78
Italy	7	13	16	12	1.32	1.24	1.21	1.23
Japan	26	51	62	89	1.07	1.04	1.04	0.99
Netherlands	3	5	6	4	1.58	1.48	1.44	1.52
Norway	1	2	3	2	2.04	1.81	1.67	1.78
New Zealand	1	2	2	3	2.04	1.81	1.83	1.62
Portugal	1	2	3	1	2.04	1.81	1.67	2.10
Sweden	2	3	4	3	1.73	1.65	1.56	1.62
United States	51	100	121	74	1.00	1.00	1.00	1.00

Calibration with $\theta = 6$. Columns 1-3 refer to the calibrated number of towns calculated using $M_n = L_n/\overline{L}$ where $\overline{L} = L_k/M_k$, with k coming from using data from U.S. states, sub-regional geographical units (CSA-MSA) in the United States, and Canadian provinces, respectively. Column 4 shows the number of towns with more than 250K habitants in the data. Columns 5-8 computes the term "domestic frictions" in equation (15) using the different measures of M_i.

Table 11: Calibration's results for different values of θ. All countries.

	Real Wage (relative to U.S.)								
	$\theta = 4$			$\theta = 6$			$\theta = 8$		
	size	d.f.	full	size	d.f.	full	size	d.f.	full
Australia	0.32	0.46	0.56	0.47	0.70	0.80	0.57	0.84	0.93
Austria	0.19	0.33	0.40	0.34	0.58	0.65	0.44	0.74	0.80
Belgium	0.24	0.41	0.72	0.38	0.66	0.97	0.49	0.81	1.08
Canada	0.39	0.50	0.61	0.53	0.73	0.82	0.62	0.86	0.94
Denmark	0.20	0.42	0.48	0.34	0.69	0.75	0.44	0.84	0.90
Spain	0.29	0.38	0.37	0.43	0.61	0.60	0.53	0.76	0.74
Finland	0.24	0.52	0.48	0.39	0.80	0.76	0.49	0.94	0.90
France	0.44	0.54	0.55	0.58	0.75	0.76	0.66	0.87	0.88
Great Britain	0.42	0.51	0.56	0.56	0.71	0.76	0.65	0.83	0.88
Germany	0.53	0.60	0.59	0.66	0.77	0.76	0.73	0.87	0.86
Greece	0.16	0.27	0.29	0.29	0.51	0.54	0.40	0.67	0.69
Italy	0.31	0.39	0.34	0.46	0.60	0.56	0.56	0.74	0.70
Japan	0.81	0.85	0.73	0.87	0.93	0.85	0.90	0.98	0.91
Netherlands	0.26	0.39	0.59	0.40	0.64	0.83	0.51	0.79	0.96
Norway	0.21	0.45	0.51	0.35	0.72	0.78	0.46	0.87	0.93
New Zealand	0.16	0.33	0.53	0.29	0.59	0.80	0.39	0.75	0.94
Portugal	0.15	0.33	0.37	0.29	0.58	0.64	0.39	0.74	0.80
Sweden	0.27	0.47	0.49	0.42	0.73	0.75	0.52	0.88	0.90
United States	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

"Size" refers to the first term in the RHS of equation (21); "d.f." (domestic frictions) refers to size x domestic frictions in equation (21); "full" refers to size x domestic frictions x openness in equation (21).

Table 12: Human Capital, Institutions, and Global Ideas.

	Schooling (avg. years)	Corruption in Gov.	Rule of Law	Bureaucracy Quality	Real Wage Gap data/model
Australia	10.24	5	6	6	1.00
Austria	6.64	4.96	6	5.98	1.26
Belgium	9.15	4.68	5.87	5.97	0.93
Canada	10.37	6	6	6	0.96
Denmark	10.33	6	6	6	1.16
Spain	5.58	4.33	5.5	4.27	1.54
Finland	9.49	6	6	5.81	1.03
France	6.52	5.05	5.61	5.8	1.24
Great Britain	8.65	4.9	5.75	6	1.16
Germany	8.54	5.53	5.81	6	1.05
Greece	6.73	5	4.98	3.9	1.25
Italy	6.28	3.6	5.31	4.85	1.97
Japan	8.46	4.96	5.68	5.85	0.83
Netherlands	8.57	6	6	6	1.06
Norway	10.38	5.81	6	5.42	0.98
New Zealand	12.04	5.81	5.96	6	0.75
Portugal	3.83	4.88	5.32	3.9	1.43
Sweden	9.45	6	6	6	0.95
United States	11.79	4.86	6	6	1.00

Average years of schooling are from Barro-Lee. 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). The real wage under "data/model" refers to the ratio of the real wage (relative to the U.S.) in the data and the model with size, domestic frictions, and openness (equation 15). The real wage in the data is real real GDP per capita (PPP-adjusted) from Penn World Tables, an average over 1996-2001.