Information Frictions, Internet and the Relationship between Distance and Trade
– Online Appendix –

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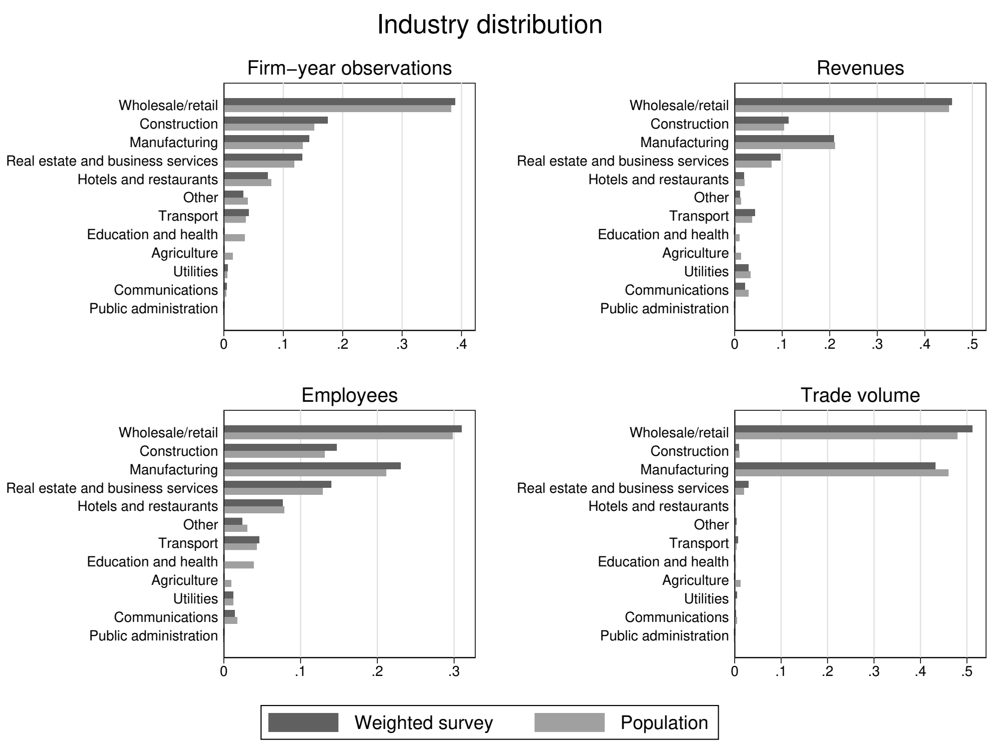
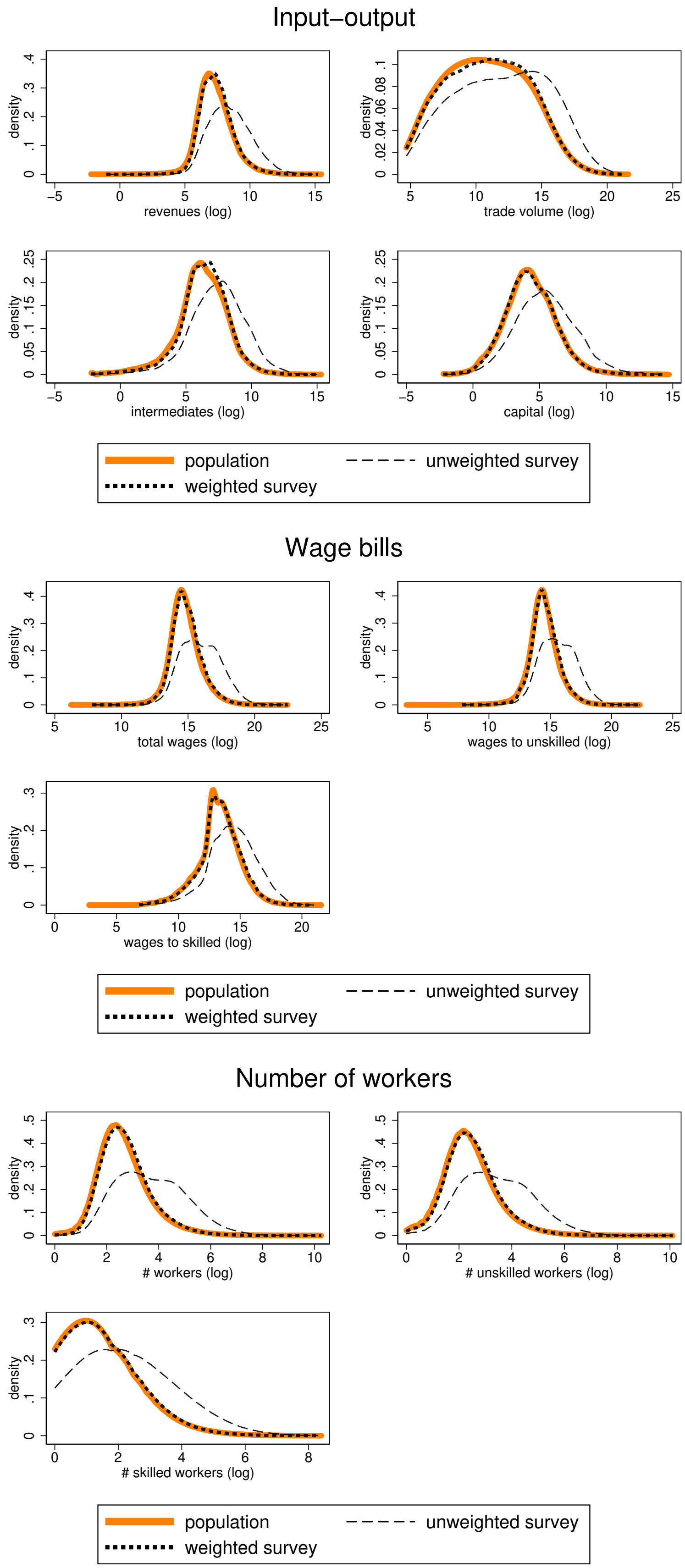
A Appendix A: Data and expansion



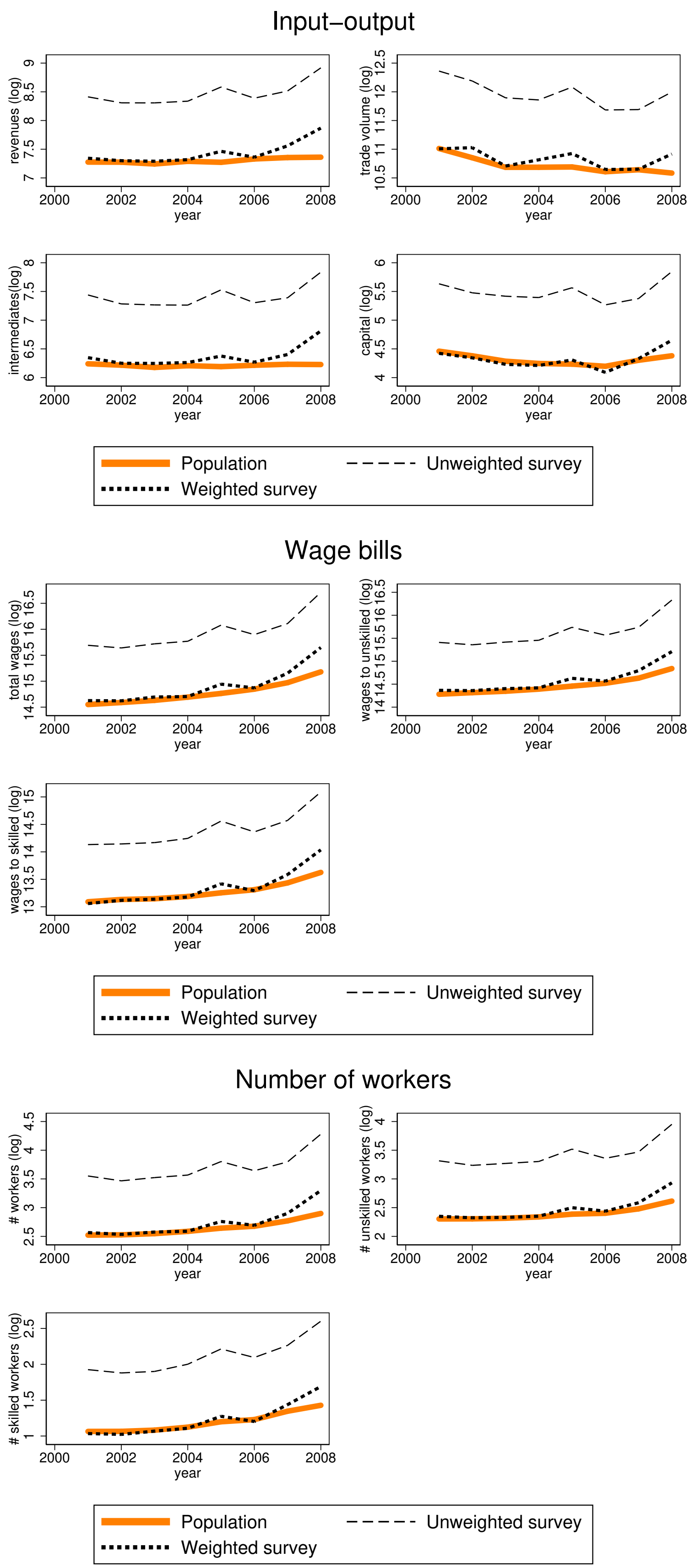
The figure compares the weighted survey sample of joint-stock firms to the population of joint-stock firms.

Figure A.1: Distribution of firms by industry



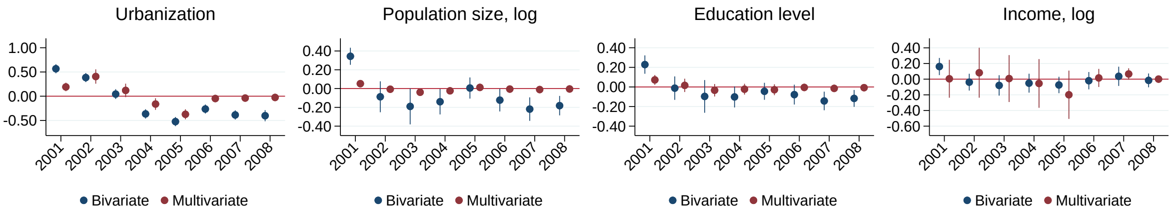
The figures compare the weighted survey sample of joint-stock firms to the population of joint-stock firms. Detailed descriptions of the variables are given in Appendix Table.

Figure A.2: Cross-sectional distribution of key firm variables

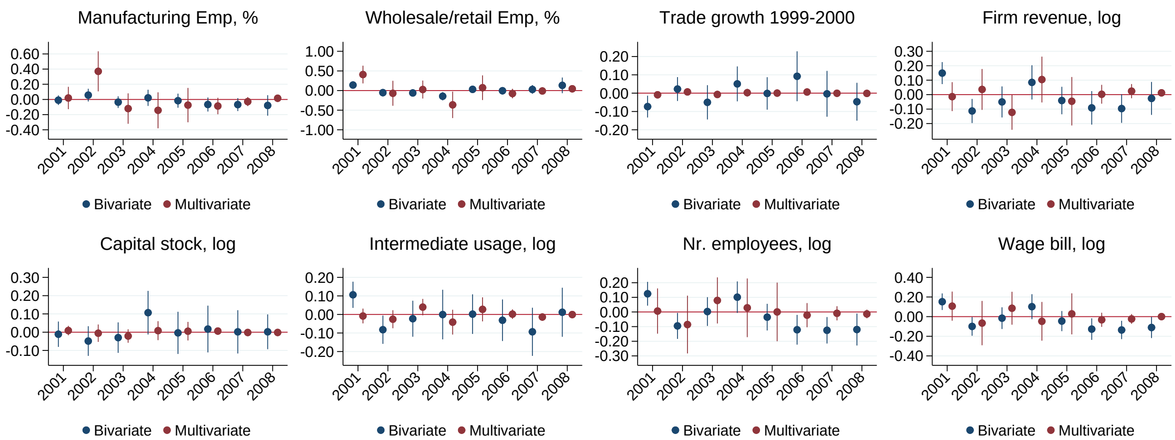


Note: The figures compare the weighted survey sample of joint-stock firms to the population of joint-stock firms. Detailed descriptions of the variables are given in Appendix Table.

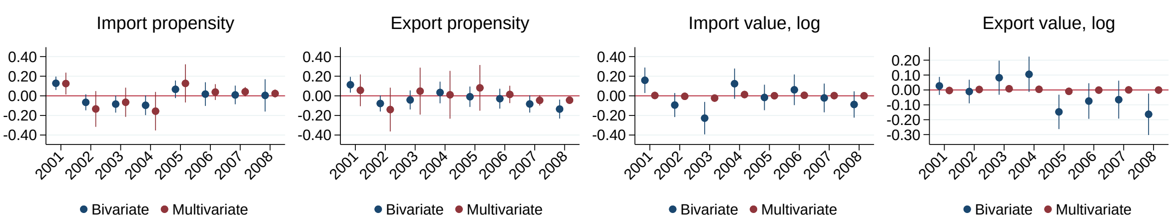
Figure A.3: Time trends in key firm variables



(a) Demography



(b) Industry structure



(c) Trade

Figure A.4: Expansion graphs

Table A.1: Variable definitions

Variable	Description
Firm accounts	Source: The Account Statistics.
Revenues	Total sales by a firm in year t.
Industry	4-digit code classifying a firm's main activity in year t according to the Nomenclature of Economic Activities (NACE2002) system.
Municipality	4-digit code for the municipality in which a firm is located in year t.
Export volume	Total value of exported goods of a firm in year t.
Import volume	Total value of imported goods of a firm in year t.
Trade volume	Total value of exported and imported goods of a firm in year t.
Internet variables	Source: The community survey on ICT in firms
Broadband	Dummy variable for whether a firm has adopted broadband internet (speed at or above 256 kilobits per second) in year t.
Share of workers using a PC	Share of workers that use a PC in a firm in year t.
Individual characteristics	Source: National Education Database and Central Population Register.
Education level	Years of schooling.
Language	Source: EF English Proficiency index, sixth edition (2016).
EF English Proficiency Index	A score of English proficiency in a country as reported by the language firm EF.
Geography	Source: CEPII (Centre d'Etudes Prospectives et d'Informations Internationales).
Distance	The distance between population weighted central points of Norway and another country as described in Mayer and Zignago (2011).
Other country characteristics	Source: World Development Indicators (World Bank).
GDP	The gross domestic product of a country
Internet usage	The share of people who have used the internet in the last 12 months.
Product characteristics	Source: Rauch (1999).
Homogenous	If a good is traded on an organized exchange or if it is reference priced
Differentiated	If a good is neither of the above.
Internet availability	Source: Norwegian Ministry of Government Administration.
Availability rate	Fraction of households in year t in a given municipality for which broadband internet is available, independently of whether they take it up.
Demographics	Source: Central Population Register.
Urbanization	Population share living in densely populated area in a given municipality in year t.
Income	Average annual disposable income across individuals aged 16–59 years in a given municipality in year t.
Education	Average years of schooling across individuals aged 16–59 in a given municipality in year t.
Unemployment	Unemployment rate among individuals aged 16–59 in a given municipality in year t.
Industry and firm	Source: The Account Statistics and Register of Employers and Employees.
Share of skilled workers	Share of employed workers with a college degree in a given municipality in year t.
Share of total wages to skilled workers	Share of the total wage bill paid to workers with a college degree in a given municipality in year t.
Share of employment by industry	Share of workers in the manufacturing/wholesale/service industry in a given municipality in year t.
Average input levels	Average level of capital stock/value added/number of workers/wages paid/revenues across firms in a given municipality in year t.

B Appendix B: Sub-sample instrumental variable estimation

If we generically write the second stage as

$$y = X\beta + e$$

first-stage

$$X = Z\Pi + U$$

with corresponding reduced form

$$y = Z\gamma + v$$

Then we have

$$Z\gamma = Z\Pi\beta \Rightarrow \beta = (\Pi'Z'Z\Pi)^{-1}\Pi'Z'Z\gamma$$

which gives

$$\begin{aligned}
d\beta &= d((\Pi'Z'Z\Pi)^{-1}) \cdot \Pi'Z'Z\gamma + (\Pi'Z'Z\Pi)^{-1} d(\Pi'Z'Z\gamma) \\
&= -(\Pi'Z'Z\Pi)^{-1} d(\Pi'Z'Z\Pi) \underbrace{(\Pi'Z'Z\Pi)^{-1}\Pi'Z'Z\gamma}_{\beta} + (\Pi'Z'Z\Pi)^{-1} d\Pi'Z'Z\gamma \\
&= -(\Pi'Z'Z\Pi)^{-1} d(\Pi'Z'Z\Pi)\beta + (\Pi'Z'Z\Pi)^{-1} d\Pi'Z'Z \cdot \gamma
\end{aligned}$$

Now since

$$\begin{aligned}
d(\Pi'Z'Z\Pi) &= d\Pi'Z'Z \cdot \Pi + \Pi'Z'Zd\Pi \\
vec(d(\Pi'Z'Z\Pi)) &= (\Pi'Z'Z \otimes I) dvec\Pi' + (I \otimes \Pi'Z'Z) dvec\Pi
\end{aligned}$$

we obtain

$$\begin{aligned}
d\beta = vec(d\beta) &= vec(-(\Pi'Z'Z\Pi)^{-1} d(\Pi'Z'Z\Pi)\beta + (\Pi'Z'Z\Pi)^{-1} d\Pi'Z'Z\gamma) \\
&= vec(-(\Pi'Z'Z\Pi)^{-1} d(\Pi'Z'Z\Pi)\beta) + vec((\Pi'Z'Z\Pi)^{-1} d\Pi'Z'Z\gamma) \\
&= -(\beta' \otimes (\Pi'Z'Z\Pi)^{-1}) vec(d(\Pi'Z'Z\Pi)) + (\gamma' \otimes (\Pi'Z'Z\Pi)^{-1}) vec(d\Pi') \\
&= -(\beta' \otimes (\Pi'Z'Z\Pi)^{-1})((\Pi'Z'Z \otimes I) dvec\Pi' + (I \otimes \Pi'Z'Z) \cdot dvec\Pi) \\
&\quad + (\gamma' \otimes (\Pi'Z'Z\Pi)^{-1}) dvec\Pi' \\
&= -(\underbrace{\beta'\Pi'}_{\gamma'} \otimes (\Pi'Z'Z\Pi)^{-1}) dvec\Pi' - (\beta' \otimes (\Pi'Z'Z\Pi)^{-1}\Pi'Z'Z) dvec\Pi \\
&\quad + (\gamma' \otimes (\Pi'Z'Z\Pi)^{-1}) dvec\Pi' \\
&= -(\beta' \otimes (\Pi'Z'Z\Pi)^{-1}\Pi'Z'Z) dvec\Pi
\end{aligned}$$

which gives

$$d\beta / dvec\Pi = -(\beta' \otimes (\Pi'Z'Z\Pi)^{-1}\Pi'Z'Z)$$

We furthermore have

$$d\beta/d\gamma = (\Pi'Z'Z\Pi)^{-1}\Pi'Z'Z$$

We use these results to construct the covariance matrix of $\hat{\beta}$ using the Delta method. In a first step we directly get the covariance matrices of $\hat{\Pi}_k$ and $\hat{\gamma}$ from our OLS estimation. Let

$$\hat{\eta} = \begin{pmatrix} vec\hat{\Pi} \\ \hat{\gamma} \end{pmatrix} = \eta + (I_{K+1} \otimes (Z'Z)^{-1})Z'\xi$$

where

$$\xi = \begin{pmatrix} vecU \\ v \end{pmatrix}$$

then

$$Var(\hat{\eta}) = (I_{K+1} \otimes E[Z'Z]^{-1})E[Z'\xi\xi'Z](I_{K+1} \otimes E[Z'Z]^{-1})$$

and $E[Z'\xi\xi'Z]$ is obtained using the estimated residuals $\hat{\xi}$ and standard covariance matrix estimation using the method of moments. The final covariance matrix of $\hat{\beta}$ using the Delta method can then be computed as follows

$$V(\beta) = (\partial\beta/\partial\eta)'V(\hat{\eta})(\partial\beta/\partial\eta).$$

C Appendix C: Model and predictions

We model information frictions as a restriction on the access to markets with which a region can trade, similar to how Arkolakis (2010) views the role of marketing to reach foreign consumers. Information frictions enter as a limitation on the share of the scope of existing varieties in foreign countries that a Norwegian municipality can buy. To simplify our analysis and to suit our empirical application, we take the set of goods in each country as given. This is similar to the approach by, for example, Chaney (2008) and Eaton and Kortum (2002).

As in Ottaviano et al. (2002) and Melitz and Ottaviano (2008), the utility function of a consumer in country k is given by

$$\begin{aligned} U_k &= q_0^c + \alpha \sum_{j \in K} \sum_{i=0}^{\omega_{jk} N_j} q_{jk}^c(i) - \frac{1}{2}\gamma \sum_{j \in K} \sum_{i=0}^{\omega_{jk} N_j} \left(q_{jk}^c(i) \right)^2 \\ & \quad - \frac{1}{2}\eta \left(\sum_{j \in K} \sum_{i=0}^{\omega_{jk} N_j} q_{jk}^c(i) \right)^2 \end{aligned} \quad (1)$$

where α, γ and η are positive parameters. q_0^c denotes the consumption of a numéraire good. The set of countries in the world is denoted by K. Each country $j \in K$ produces a fixed number of varieties, N_j, of differentiated varieties. Information frictions are denoted by $\omega_{jk} \in [0,1]$ which denotes the share of the set of country j varieties that country k consumers know about and can consume. If country j produces N_j varieties, for example, then $\omega_{jk} N_j$ varieties from j can be consumed in k. The parameter γ denotes the degree of product differentiation, the higher it is the more a consumer cares about distributing the consumption level as evenly across varieties as possible.

Consumer optimization given a budget constraint yields the following demand and inverse demand, respectively, in country k for a good i

$$q_k^c(i) = \frac{1}{\gamma}\left(\alpha - p_k(i) - \eta Q_k^c\right) \quad (2)$$

$$p_k(i) = \alpha - \gamma q_k^c(i) - \eta Q_k^c \quad (3)$$

where $p_k(i)$ indicates the price of good i in country k. Total consumption is $Q_k^c \equiv \sum_{j \in K} \sum_{i=0}^{\omega_{jk} N_j} q_{jk}^c(i)$. Equations (2) and (3) mean that

$$Q_k^c = \frac{\tilde{N}_k(\alpha - \tilde{p}_k)}{\gamma + \eta \tilde{N}} \quad (4)$$

where $\tilde{N}_k \equiv \sum_{j \in K} \omega_{jk} N_j$ denotes the number of varieties actually sold to country k and $\tilde{p}_k \equiv \frac{\sum_{j \in K} N_j \omega_{jk} p_{jk}}{\tilde{N}_k}$ denotes the average price of goods actually exported to country k. Both $\tilde{N}_k$ and $\tilde{p}_k$ are therefore adjusted for information frictions.

We insert equation (4) in equation (2) to retrieve the aggregate demand in k for a good from j:

$$q_k(i) = q_k^c L_k = \frac{L_k}{\gamma}\left(\frac{\alpha\gamma + \eta \tilde{N}_k \tilde{p}_k}{\gamma + \eta \tilde{N}} - p_k(i)\right) \quad (5)$$

where L_k denotes the total population in k.

It follows that the maximum possible price that a good can have in country k is

$$p_k^{max} = \frac{\alpha\gamma + \eta \tilde{N}_k \tilde{p}_k}{\gamma + \eta \tilde{N}}.$$

A price above this level results in zero demand.

The aggregate demand in equation (5) can therefore be written

$$q_k(i) = \frac{L_k}{\gamma}\left(p_k^{max} - p_k(i)\right).$$

The numéraire good is freely traded and characterized by constant returns to scale and unit cost. We assume that parameters are such that it is produced in all countries. This means that the nominal wage in all countries is unity. Regarding the differentiated sector, a firm in country j selling in country k has a marginal cost of c_{jk}. We will for simplicity assume that all existing firms are sufficiently productive to generate positive sales in all markets. The marginal cost c_{jk} includes a country-specific marginal cost, c_j and an iceberg trade cost of τ_{jk} such that $c_{jk} = \tau_{jk} c_j$. We make the assumption that the elasticity of iceberg trade costs with respect to distance is constant. The firm's profit-maximizing level of output is therefore

$$q_{jk}(i) = \frac{L_k}{\gamma}\left(p_{jk}(i) - c_{jk}\right)$$

for a firm in country j selling to country k.

This means that the optimal price is

$$p_{jk}(i) = \frac{1}{2}\left(p_k^{max} + c_{jk}\right) \tag{6}$$

and the markup $\mu_{jk}(i) = p_{jk}(i) - c_{jk}$ is

$$\mu_{jk}(i) = = \frac{1}{2}\left(p_k^{max} - c_{jk}\right).$$

How does reduced information friction affect these variables? We first analyze how p_k^{max} changes with an improvement in information about goods sold from country j to country k:

$$\frac{\partial p_k^{max}}{\partial \omega_{jk}} = \eta N_j \frac{p_{jk} - p^{max}}{\gamma + \eta \tilde{N}} \tag{7}$$

which is negative since the price must be lower than the maximum possible price in a market. This means that markups decrease and prices approach marginal costs when information improves.

In order to analyze the gravity equation, total sales from country j to country k is

$$r_{jk} = \omega_{jk} N_j \frac{L_k}{4\gamma}\left(\left(p_k^{max}\right)^2 - \tau_{jk}^2 c_j^2\right). \tag{8}$$

The effect of an improvement in information between countries$j$ and k affects sales in two ways: a direct positive effect and an indirect negative effect since competition increases in country k (p_k^{max} decreases). The overall effect is, however, positive.

Proposition 1. *The effect of an improvement in information between two countries increases trade between them.*

Proof. The direct effect is positive and with an elasticity of unity. To calculate the overall effect where we incorporate also the indirect effect through the level of competition, we calculate the elasticity of r_{jk} in equation (8) with respect to the information parameter ω_{jk} and after some manipulation we find that:

$$\frac{\partial r_{jk}/r_{jk}}{\partial \omega_{jk}/\omega_{jk}} = \frac{p_k^{max}\frac{\gamma+\eta\sum_{i\in K,i\neq j}\omega_{ik}N_i}{\gamma+\eta\sum_{j\in K}\omega_{jk}N_j}+\tau_{jk}c_j}{\left(p_k^{max}+\tau_{jk}c_j\right)}$$

which is positive. In the derivation we use the expressions in equations (6) and (7). □

The elasticity with respect to distance τ_{jk} is

$$\frac{dr_{jk}}{d\tau_{jk}}\frac{\tau_{jk}}{r_{jk}} = -\frac{2\tau_{jk}^2c_j^2}{\left(\left(p_k^{max}\right)^2-\tau_{jk}^2c_j^2\right)}. \tag{9}$$

The only endogenous variable in this expression is p_k^{max} and in equation (7) we see that it decreases when information improves. The absolute level of the elasticity of the value of trade from country j to country k therefore increases when information improves.

Proposition 2. *The absolute elasticity of the value of imports with respect to distance increases when information improves.*

It is important to observe that this is a change in the direct elasticity, not a change that operates indirectly through, for example, origin-time-specific multilateral resistance terms which would be the case under, for example, CES preferences. As a result, it will not be fully captured by origin-year fixed effects in our gravity regression.

Our model applies, strictly speaking, more to imports than exports. The majority of trade for Norwegian municipalities, both in terms of total volumes and the number of firms that engage in trade, consists of importing. Our model therefore applies to the majority of the data that we use. The advantage of using both exports and imports in the empirical section, however, is that we have more non-zero observations.

D Appendix D: Data citations

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