Incorporating Modern Trade Theory into CGE Models

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Motivation

- Divide between world of CGE modellers focused mainly on policy questions and using "old" modelling tools and world of "modern" trade economists building increasingly complex models (number of sectors, preferences) and thus partially redoing work in CGE world
- One goal of the paper is to bring tools used by CGE modellers in line with modern trade theories with scholars struggling to incorporate firm heterogeneity in multisector, multicountry models like CGE models
  - Balistreri, Hillberry and Rutherford (2011, JIE), BRT include firm heterogeneity in one sector with perfect competition in other sectors
  - Costinot and Rodriguez Clare (2014, Handbook Chapter) explore the welfare gains from trade, but do not explore trade liberalization for many countries and many sectors
  - Dixon and Rimmer (2016), Itakura and Oyamada (2016) and Akgul, Villoria and Hertel (2016) all propose ways to include firm heterogeneity into GEMPACK-GTAP but run into dimensionality problems. Maximum dimension is 4countriesx3sectors

Motivation

- Debate on welfare gains from trade and liberalization in different models
  - Arkolakis, Costinot and Rodriguez Clare (2012, AER), ACR ask to what extent new micro-level questions like firm heterogeneity have affected the welfare gains from trade, arguing 'not much'
  - Various scholars disagree with this view
    - Balistreri, et al. (2011, EL) use a two sector model with larger welfare gains under firm heterogeneity than under perfect competition as a result of more intersectoral reallocation
    - Redding and Melitz (2014) show with a two country model that welfare gains have to be larger under firm heterogeneity since productivity is endogenous and can thus respond to shocks like trade liberalization

Contribution: Overview

- We show that the Ethier-Krugman model of homogeneous firms and the Melitz model of heterogeneous firms can be defined as a generalized Armington model by:
    1. Generalizing the expression for marginal costs
    2. Generalizing the expression for iceberg trade costs
    3. Allowing for a demand externality when representing the Melitz model.
- With this representation of the firm heterogeneity model we can reduce the computational dimensionality of the model by eliminating pairwise variables like the cutoff productivity and provide valuable insight into the functioning of the models
- We incorporate firm heterogeneity into a multi-sector/multi-factor model with intermediate linkages and calibrated to the GTAP9 database and simulate experiments with 11 sectors, 11 regions, and 4 production factors
- We calibrate the substitution elasticity and the Pareto shape parameter to the empirically observable tariff elasticity and a measure for the degree of granularity

Contribution: Simulation Results

- A second goal is to compare the effects of trade cost reductions in different models in different settings
  1. Welfare gains in Melitz collapse to the welfare gains in Ethier-Krugman when firm size distribution moves to granularity in Melitz
  2. In a symmetric two-country setting as in Melitz and Redding (2013, AER) we show that parameter calibration is crucial for the welfare effects
     - Melitz and Redding calibrate to the structural substitution elasticty
     - We calibrate to the empirically observable tariff elasticity implying a different substitution elasticity in the two models
     - With Melitz-and-Redding-calibration welfare is larger under firm heterogeneity whereas with calibration to the tariff elasticity welfare is larger in firm homogeneity model
  3. In calibrated multi-sector/multi-country models the welfare effects do not hinge on parameter calibration and welfare effects from global trade cost changes are consistently larger in Melitz model than in Ethier-Krugman:
     - Intermediate linkages are crucial
     - Multiple factors, multiple sectors, endogenous labour supply and heterogeneous tariff elasticities are of second order importance

Setup: Generalized Armington Model

- Agents in country j having CES preferences over varieties from each exporter i:

$$q_j = \left(\sum_i (e_j q_{ij})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

- e_j is a demand side externality/shifter playing a role in the firm heterogeneity version of the model. Solving for demand from source i, q_{ij}, gives:

$$q_{ij} = \frac{1}{e_j} \left(\frac{p_{ij}}{p_j} \right)^{-\sigma} q_j \tag{2}$$

- p_{ij} is the price of the representative good traded and p_j the price index to q_j:

$$p_j = \left(\sum_i (p_{ij})^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{3}$$

$$p_{ij} = \frac{ta_{ij} t_{ij} c_i p_{Z_i}}{e_j} \tag{4}$$

- ta_{ij} is the import tariff from i to j, t_{ij} the generalized iceberg trade cost, c_i the generalized marginal cost, and p_{Z_i} the price of input bundles (wage)

Setup: Generalized Armington Model

- In our calibrated multi-country/multi-sector model we
  - collapse the GTAP data to 11 regions, 11 sectors, and 4 factors of production
  - account for several taxes such as export subsidies and group- and importer-specific import tariffs
  - strip transport services from the GTAP data
- The Armington model, the Krugman/Ethier model and the Melitz model can all be modelled with the above structure, depending upon how the demand externality e_j, generalized iceberg trade costs t_{ij}, and generalized marginal cost c_i are specified.
- In the Armington economy with love of variety among varieties from different countries we have the following expressions for c_i, t_{ij} and e_j:

$$c_i = b_i \tag{5}$$

$$t_{ij} = \tau_{ij} \tag{6}$$

$$e_j = 1 \tag{7}$$

- with b_i marginal cost and τ_{ij} iceberg trade costs

Ethier-Krugman Economy: Variety Scaling

- In the Ethier-Krugman model preferences display love for variety at the firm level and production takes place under increasing returns to scale
- The combination of the two elements implies that an increase in the number input bundles in country i leads to a more than proportional increase in representative output from country i.
- Representative output with an Ethier-Krugman setup is called variety scaled output by Francois (1998): if country i has more resources, it can produce more different varieties and so representative or variety-scaled output rises more than proportionally with the number of inputs
- So, in the Ethier/Krugman economy we have the following expressions for c_i, t_{ij} and e_j:

$$c_i = \frac{b_i a_i^{\frac{1}{\sigma-1}}}{\gamma_{ek}} Z_i^{\frac{1}{1-\sigma}} \tag{8}$$

$$t_{ij} = \tau_{ij} \tag{9}$$

$$e_j = 1 \tag{10}$$

- with a_i fixed cost and Z_i the number of input bundles (labor)

Melitz Economy: Setup

- In the Melitz economy preferences are like in Ethier/Krugman characterized by love for variety but varieties are produced by firms with heterogeneous productivity
- Firms draw a productivity parameter φ from a distribution $G_i(\varphi)$ after paying a sunk entry cost en_i.
- The distribution of initial productivities is Pareto with a shape parameter θ and a size parameter κ_i:

$$G_i(\varphi) = 1 - \frac{\kappa_i^{\theta}}{\varphi^{\theta}} \tag{11}$$

- A higher θ reduces the dispersion of the productivity distribution.
- We have to impose $\theta > \sigma - 1$ to guarantee that expected revenues are finite.
- $\theta = \sigma - 1$ corresponds with a so-called granular firm size distribution where the most productive firms have large market shares

Melitz Economy: Production

- Firms produce with an increasing returns to scale technology with marginal cost equal to $\frac{1}{\varphi}$.
- Firms pay fixed costs f_{ij} for each market in which they sell in contrast to Ethier-Krugman where destination specific fixed costs are absent
- Fixed costs are paid in bundles of both the origin and destination country
- Market-specific fixed costs imply a partitioning of firms: some firms can export and others not and so an extensive margin is operative
- Like in Ethier-Krugman with love for variety and increasing returns,an increase in the number of input bundles leads to a more than proportional increase in utility.
- Hence, output of the representative firm is charecterized by variety-scaling
- Since productivity is heterogeneous, representative output and its cost c_i is also affected by input costs.

Melitz Economy: Generalized Marginal Cost

- So in the Melitz model we write generalized marginal cost as follows:

$$c_i p_{Z_i} = \gamma_m \left(\frac{\kappa_i^{\theta} Z_i}{\delta en_i} \right)^{\frac{1}{1-\sigma}} \left(p_{Z_i}^{\theta-\sigma+1+\mu \frac{\theta-\sigma+1}{\sigma-1}} \right)^{\frac{1}{\sigma-1}} p_{Z_i} \tag{12}$$

- To provide intuition for the expression for generalized marginal cost, we follow Head and Mayer (2013) and argue that changes in input costs lead to an adjustment in demand along three margins, an intensive margin, an extensive margin and a compositional margin.
  - Lower costs lead to more sales of firms already in the market, the intensive margin. This is a price effect and hence affects the price of variety scaled output proportionally, the term p_{Z_i}
  - Lower costs raise the mass of firms that can produce profitably, the extensive margin. This leads to a fall in the price of variety scaled output because it makes both marginal and fixed costs lower through the term $p_{Z_i}^{\theta+\mu\frac{\theta}{\sigma-1}}$
  - And lower costs reduce the average productivity of firms in the market, as more firms can survive, the compositional margin. This margin raises the price of variety scaled output: $p_{Z_i}^{\sigma-1+\mu}$

Melitz: Generalized Trade Costs and Demand Externality

- Generalized iceberg trade costs t_{ij} are a function of the iceberg trade costs τ_{ij}, fixed trade costs f_{ij} and tariffs ta_{ij}:

$$t_{ij} = \left(\tau_{ij}^{\theta-\sigma+1} ta_{ij}^{\theta-\sigma+1+\frac{\theta-\sigma+1}{(\sigma-1)}} f_{ij}^{\frac{\theta-\sigma+1}{\sigma-1}} \right)^{\frac{1}{\sigma-1}} \tau_{ij} \tag{13}$$

- Iceberg and fixed trade costs affect generalized iceberg trade costs in the same way through the extensive and compositional margin as the price of the input bundles p_{Z_i} generalized marginal costs
- Finally, the demand externality does play a role under firm heterogeneity, again driven by the extensive and compositional margin.

$$e_j = \left(\frac{P_j^{\sigma-1} E_j}{p_{Z_j}^{1-\mu}} \right)^{\frac{\theta-\sigma+1}{(\sigma-1)^2}} \tag{14}$$

- The logic is again similar: a larger price index P_j and a larger market size E_j raise the extensive margin relative to the compositional margin and thus raise the externality leading to a lower price

Nesting Ethier-Krugman and Armingon as Special Cases of Melitz

- The Melitz model tends to the Ethier-Krugman model (up to a constant) if θ tends to $\sigma - 1$ and marginal and fixed costs are equalized
- Average revenues tend to infinity for θ going to $\sigma - 1$, so Ethier-Krugman is a limiting case of Melitz
- Nesting Technically: $\theta = \sigma - 1$ implies that the demand externality e_j is 1 and that c_i and t_{ij} in the Melitz economy become equal to the ones in the Ethier/Krugman economy.
- Nesting Intuitively: If θ tends to $\sigma - 1$ the extensive margin cancels out against the compositional margin and only the intensive margin is left, the margin also operative under Ethier-Krugman homogeneous firms
- Ethier/Krugman can in turn be converted into Armington by dropping variety scaling: under Armington a larger number of input bundles does not raise output more than proportionally

Simulations: Setup and Calibration

- In the Armington and Ethier-Krugman model we only need estimates of the substitution elasticity, which we obtain from the tariff elasticity in a gravity equation
- The firm heterogeneity model requires estimates of both the substitution elasticity σ and the shape parameter θ of the productivity distribution.
- We combine estimates of the tariff elasticity with values for the degree of granularity of the firm size distribution
- We define the parameter ξ as $\xi = \frac{\sigma-1}{\theta}$, indicating the degree of granularity with $\xi = 1$ indicating full granularity and thus a model with identical effects as the Ethier-Krugman model
- We set ξ at 0.8 in the multisector simulations to accentuate the differences with the Ethier-Krugman model
- We follow the tradition in CGE modelling and assume that trade costs are such that import shares in the baseline are identical to actual import shares in the data
  - Since GAMS code is written in levels we have to calibrate the shifters and trade costs such that baseline import and spending shares are equal to those in the data

Gravity Estimation

- We can derive a gravity equation for the value of sales (in landed price terms, so inclusive of tariffs), v_{ij}, by multiplying the volume of trade in equation (2) by the price, p_{ij}.

$$v_{ij} = p_{ij} q_{ij} = p_{ij}^{1-\sigma} \left(p_j^m\right)^{-\sigma} q_j^m = ta_{ij}^{1-\sigma} \left(t_{ij} c_i p_{Z_i}\right)^{1-\sigma} \left(p_j\right)^{\sigma} q_j \tag{15}$$

- Substituting generalized trade costs, gives the Melitz gravity equation:

$$v_{ij} = ta_{ij}^{-\left(\theta + \frac{\theta-\sigma+1}{\sigma-1}\right)} \left(c_i p_{Z_i}\right)^{-\theta} \tau_{ij}^{-\theta} f_{ij}^{-\frac{\theta-\sigma+1}{(\sigma-1)}} \left(p_j\right)^{\sigma} q_j \tag{16}$$

- The tariff elasticity is not identical to the trade elasticity θ, because:
  - Tariffs affect trade flows also through the cutoff productivity. Higher tariffs reduce trade flows because less firms can enter the market profitably (the extensive margin relative to compositional margin effect), responsible for the second part $\left(\frac{\theta-\sigma+1}{\sigma-1}\right)$ of the elasticity.
- Under granularity the effect of fixed trade costs on trade values disappears

Single-Sector: Comparison Melitz-Redding (2013, AER)

- Melitz and Redding compare the welfare effects of trade and trade liberalization under firm heterogeneity and firm homogeneity in a symmetric two-country single-sector setting.
  - Crucially, they set the common structural parameter in the two models, the substitution elasticity, equal.
  - With this setup they find that the welfare gains (losses) from lower (higher) trade costs are unambiguously larger (smaller) under firm heterogeneity than under firm homogeneity.
- We replicate the simulations in Melitz and Redding and find that in the symmetric two-country model without intermediate linkages calibration of the substitution elasticity and the Pareto shape parameter is crucial for the welfare effects of trade liberalization
  - If the structural parameter σ is larger, firm heterogeneity generates larger welfare
  - If the structural parameters of the model are set such that empirically observable parameters (the tariff or trade elasticity) are identical, the firm homogeneity model displays larger welfare

Single-Sector: Comparison Melitz-Redding (2013, AER)

- The table shows different values for the two structural parameters, the substitution elasticity σ and the Pareto shape parameter θ, and the two empirical parameters, the tariff elasticity $\varepsilon_{v,ta}$ and the granularity of the firm size distribution, ξ.
- In the first four columns we calibrate the parameters starting from the empirically observable parameters with the values in the homogeneous firms model of Melitz and Redding as starting point, a tariff elasticity of 4
- In column 5 instead we follow Melitz and Redding and set the structural parameters with implied values for the empirical counterparts.

Param.	**Heterogen.**	**Homogen.**	**Plain EK**	**Granular**	**Melitz-Redding**
$\varepsilon_{v,ta}$	4	4	4	4	$\theta + \frac{\theta}{\sigma-1} = 5\frac{2}{3}$
ξ	$\frac{3}{4\frac{1}{4}}$	$\frac{3}{4\frac{1}{4}}$	–	1	$\frac{\sigma-1}{\theta} = \frac{3}{4\frac{1}{4}}$
θ	$\varepsilon_{v,ta} - \frac{1}{\xi} = 2\frac{7}{12}$	$\frac{\varepsilon_{v,ta}-1}{\xi} = 4\frac{1}{4}$	–	$\varepsilon_{v,ta} - \frac{1}{\xi} = 3$	$4\frac{1}{4}$
σ	$\varepsilon_{v,ta}\xi = 2\frac{14}{17}$	$\varepsilon_{v,ta} = 4$	$\varepsilon_{v,ta} = 4$	$\varepsilon_{v,ta}\xi = 4$	4

Table: Parameterization of the five models starting from tariff elasticity in homogeneous firms model Melitz and Redding (2014)

Comparison MR 2013: Results

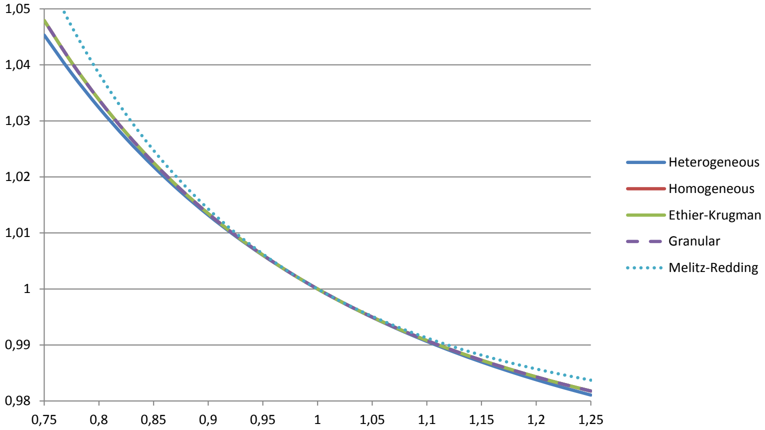


Figure: The real wage as a function of percentage change in iceberg trade costs for different ways of calibrating the modeling parameters θ and σ and calibration to the tariff elasticity, the overall import share and the share of exporting firms

Comparison MR 2013: Results

1. As in Melitz and Redding the welfare gains from trade liberalization are larger in the heterogeneous firms model than in the homogeneous firms model when the structural parameter, the substitution elasticity is set identical in the two models.
2. When the empirically observable parameter, the tariff elasticity, is identical in the two models, this conclusion is reversed and the homogeneous firms model generates larger welfare gains.
    - This shows that the way the model is calibrated is crucial for the relative welfare effects in the hetereogeneous and homogeneous firms models.
3. The welfare effects in the homogeneous firms models and in the model with a granular firm size distribution are again identical.
4. We also compare with Di Giovanni and Levchenko (2013, JIE) who argue that welfare effects are larger under granularity as we find. But two things are different:
    - They use fitted trade costs from a gravity estimation instead of calibrating them to import shares
    - They keep the empirical parameters constant and vary the structural parameter σ to capture variations in granularity

Multisector Results: Baseline

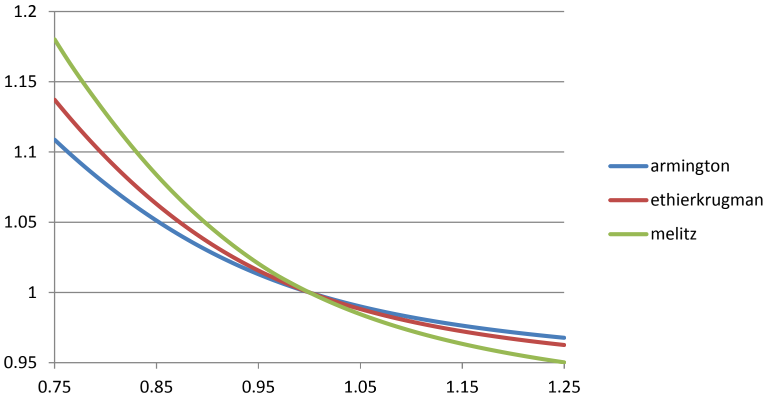


Figure: Utility as a function of percentage change in global iceberg trade costs in the three models

Multisector Results: Exogenous Labour Supply

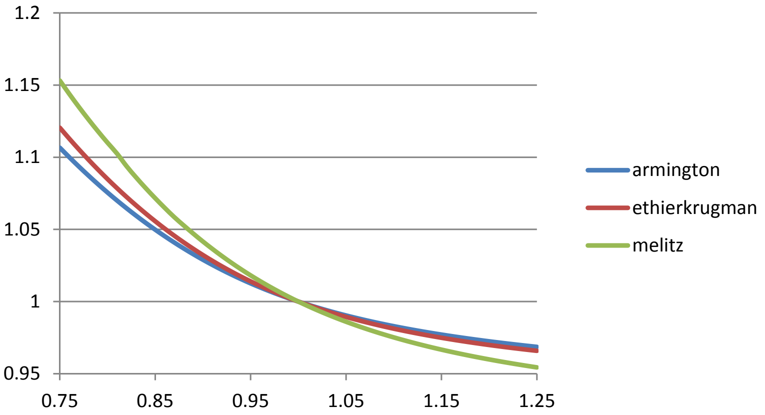


Figure: Utility as a function of percentage change in global iceberg trade costs in the three models with exogenous labour supply

Multisector Results: Identical Elasticities

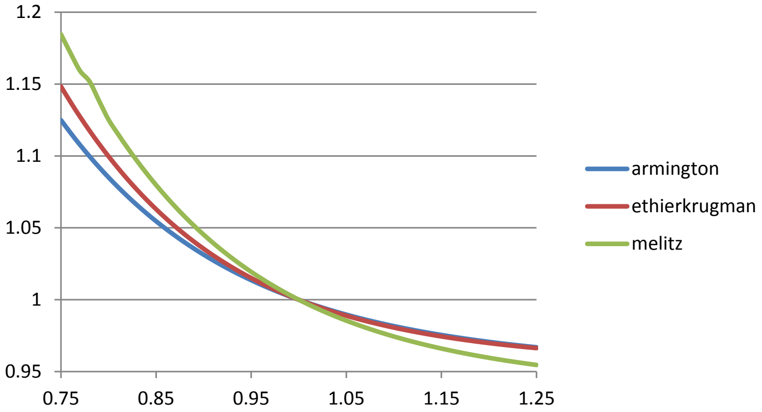


Figure: Utility as a function of percentage change in global iceberg trade costs in the three models with identical tariff elasticities

Multisector Results: Only Two Production Factors

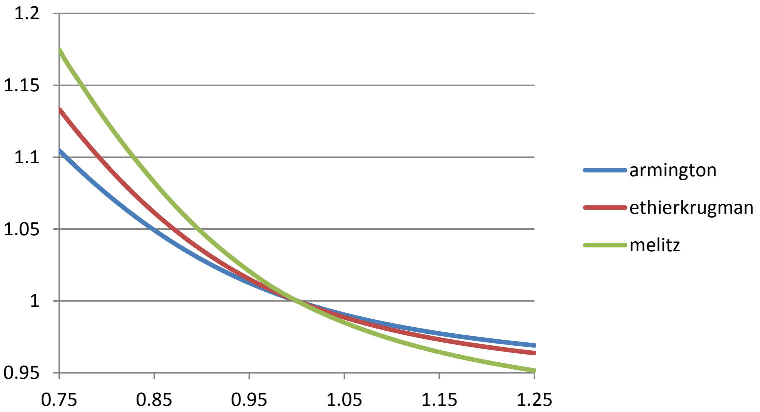


Figure: Utility as a function of percentage change in global iceberg trade costs in the three models with only two instead of four factors of production

Multisector Results: Only One Sector

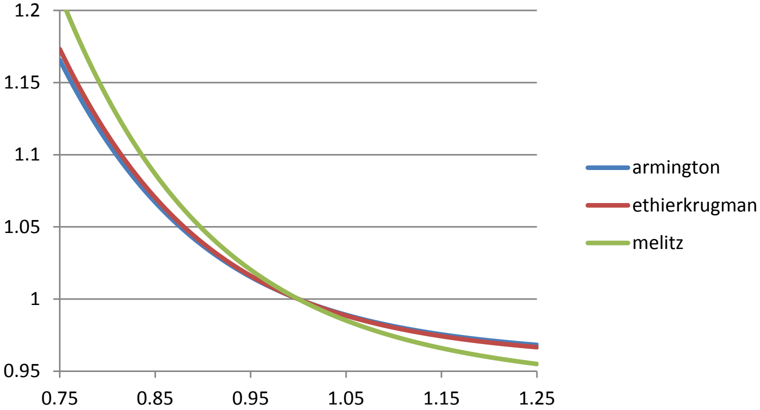


Figure: Utility as a function of percentage change in global iceberg trade costs in the three models with only one sector

Multisector Results: Comparison Welfare Effects

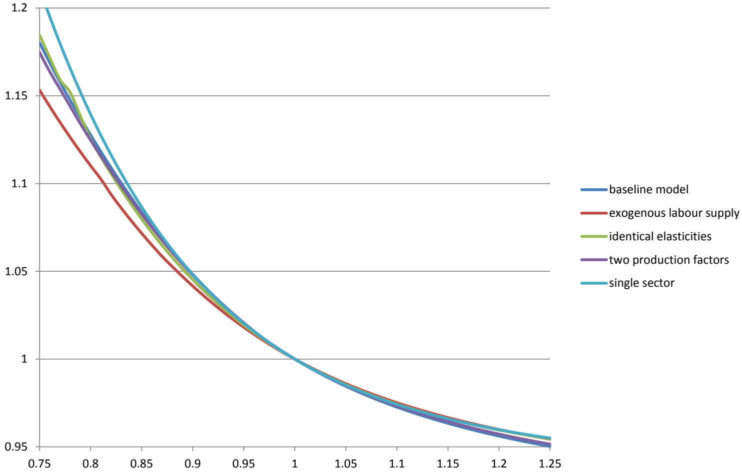


Figure: Utility as a function of percentage change in global iceberg trade costs in the Melitz model with different specifications

Multisector simulations: Results

- The welfare effects are fairly similar under different specifications with:
  1. Somewhat larger effects with endogenous labour supply in Melitz and Ethier-Krugman
  2. A very small influence of both heterogeneous versus identical tariff elasticities and two versus four factors of production
  3. In single sector model effects are larger in all three models and effects in Ethier-Krugman model are closer to Armington model (no scale effects between sectors)
- The role of different ways of calibration of the structural parameters θ and σ is very small and we do not see the envelope pattern anymore, but instead a crossing pattern
- The difference between the stylized single-sector model and the calibrated multi-sector model instead is driven by the presence of intermediate linkages

Multisector Results: Different Parameter Calibrations

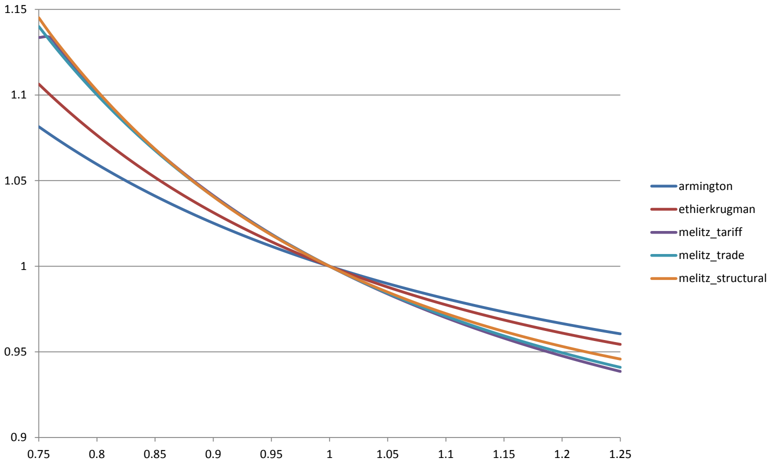
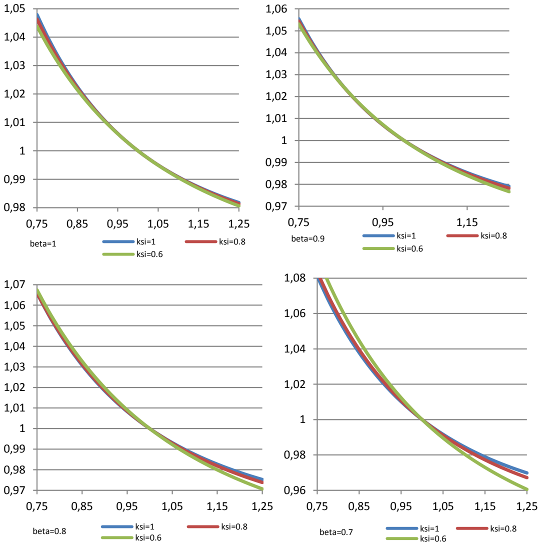


Figure: Utility as a function of percentage change in global iceberg trade costs with different ways of calibrating θ and σ

Single-Sector Results: Role of Intermediate Linkages



The Role of Intermediate Linkages

- The difference between the stylized single-sector model and the calibrated multi-sector model is driven by the presence of intermediate linkages
- The graph shows in four panels welfare as a function of the size of the granularity parameter ksi and the share of value added in gross output beta.
    - ksi=1: granularity (Ethier-Krugman) and ksi=0.6: firm heterogeneity forces are present
    - beta=1: no intermediate linkages and beta=0.6: strong intermediate linkages
- Without intermediate linkages (first panel) welfare is always larger under granularity (large ksi)
- With strong intermediate linkages (fourth panel) moving away from granularity and towards stronger firm heterogeneity forces (extensive relative to compositional margin) generates larger welfare effects from changes in trade costs, both positive and negative
- Interpretation: with intermediate linkages the firm heterogeneity "externalities" on the demand side get magnified

Concluding Remarks: Summary

- Proposed a way to include firm heterogeneity in CGE models without running into computational problems
- Requires:
  - Extending variety scaling with the price of input bundles on the supply side
  - Adding an externalitiy on the demand side
  - Writing generalized trade costs as a function of iceberg and fixed trade costs and tariffs
- Simulations show that:
  - In the two country single-sector model the welfare effects depend on the way parameters and trade costs are calibrated
  - In the calibrated multi-country multi-sector model welfare effects of changes in trade costs are unambiguously larger in the Melitz model
  - Endogenous labour supply, multiple production factors, multiple sectors, and heterogeneous trade elasticities play a relatively small role
  - Decisive for the larger welfare gains of trade liberalization in the Melitz model is the presence of intermediate linkages