

# GLOBAL PRODUCTION WITH EXPORT PLATFORMS

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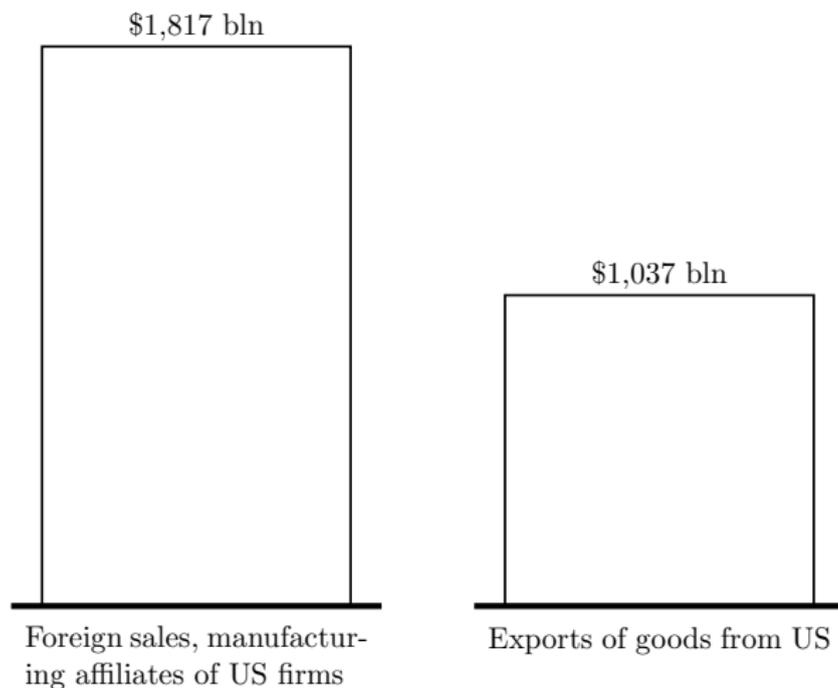
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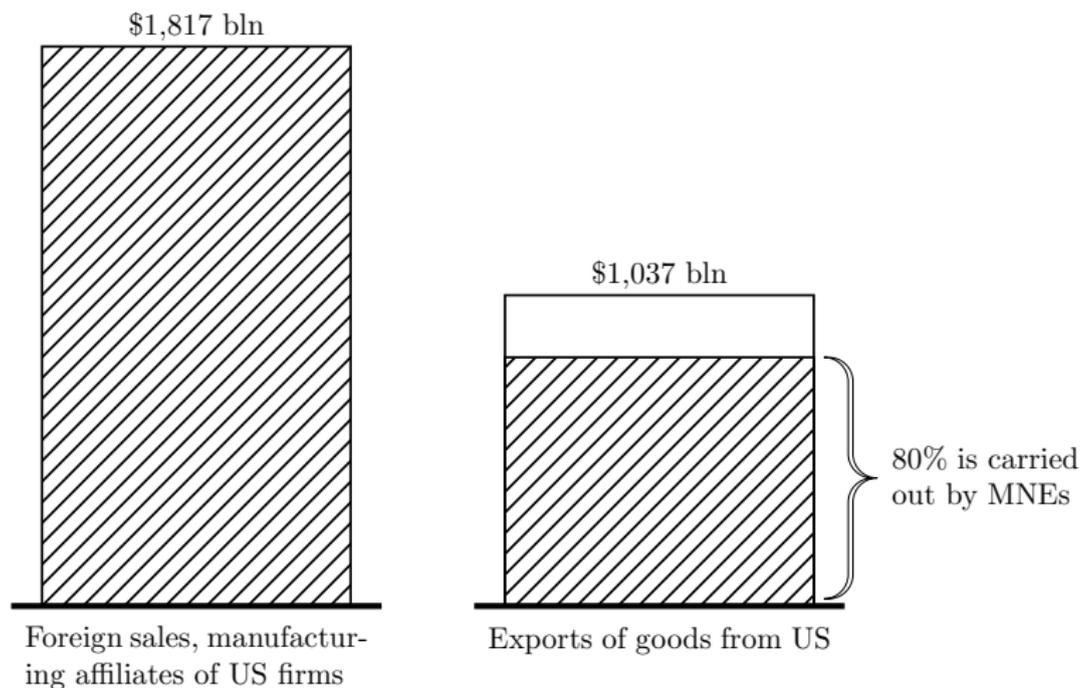
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- Some ‘pure’ trade models include binary choices whether to start producing in the home country and whether to export to a foreign market. (Krugman (1980), Melitz (2003))

# HOW DO FIRMS SERVE FOREIGN MARKETS?



## WHICH FIRMS SERVE FOREIGN MARKETS?



# FRAMEWORKS FOR HORIZONTAL MULTINATIONALS

- Proximity-concentration trade-off
  - Firms invest abroad to avoid marginal trade costs (proximity benefit)
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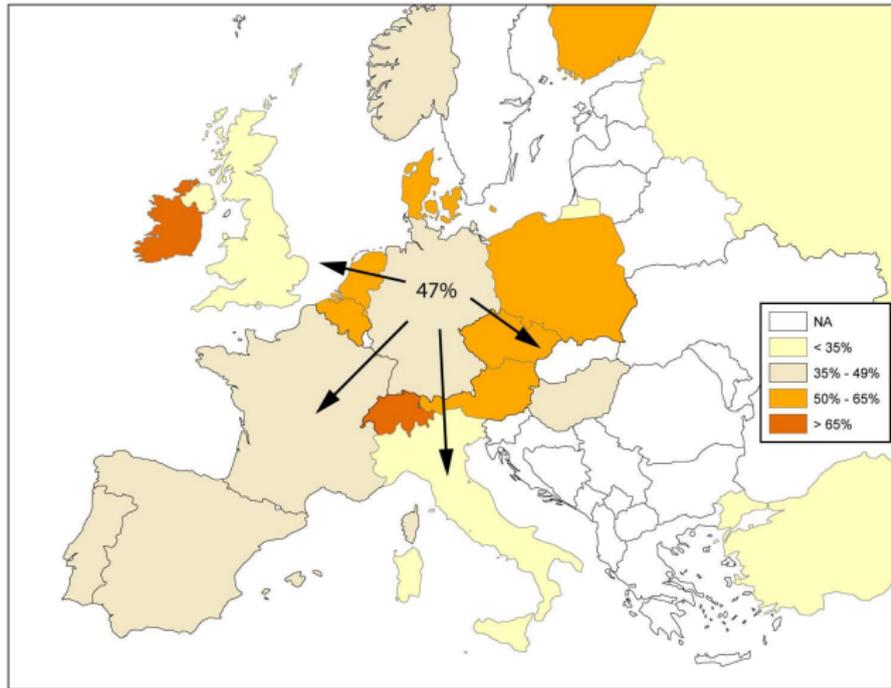
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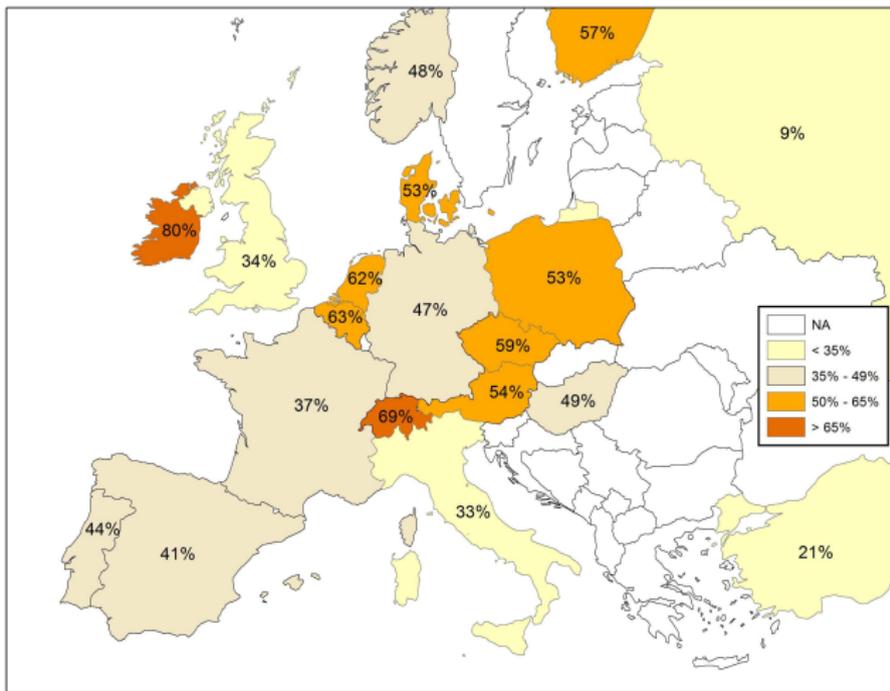
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- Binary choice whether to establish an affiliate in a foreign country
- Key assumption: firms cannot use their foreign affiliate to export to other countries

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Share of exports in sales of US affiliates in Europe

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  - How do regional trade and investment agreements affect participants and non-participants of the agreement?

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- Firm heterogeneity, monopolistic competition, CES preferences

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- Fixed costs explain why most firms concentrate their production in only a few locations
- A model without fixed costs leads to different quantitative answers to welfare and policy questions

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  - Smooth substitutability between the firm's plants

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- Effects of regional trade and investment agreements:

CETA could divert around seven percent of European MNE's production from US to Canada

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- Quantitative models of trade and multinational production  
Ramondo and Rodriguez-Clare (2012),  
Arkolakis, Ramondo, Rodriguez-Clare, and Yeaple (2012)

# OUTLINE

- Model
- Estimation with firm-level data
- Calibration with aggregate data
- G.E. Counterfactuals

# Model

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  - Country of origin  $i$ , core productivity level  $\phi$ , fixed cost vector  $\eta$ , and plant productivity shifter  $\epsilon$
- Trade costs  $\tau_{lm}$  to serve country  $m$  from country  $l$
- Efficiency loss  $\gamma_{il}$  for firms from country  $i$  in country  $l$

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- Technical restriction:  $\theta > \sigma - 1$

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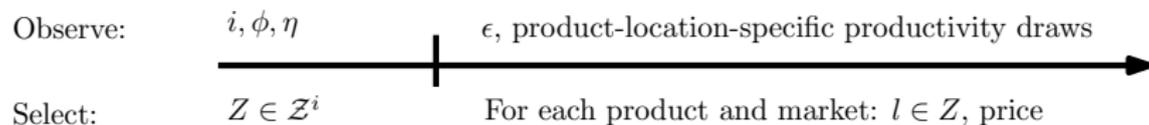
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  - ② After plants are selected:
    - Observe vector of plant-specific productivity shifters,  $\epsilon$ , and receive product-location-specific productivity draws
    - Decide for each product which market to serve from where
    - Set prices for each product



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- Firm selects for each product and market the plant with the minimum cost
- If  $l \in Z$ :

$$r_l(i, \phi, Z, \epsilon) = \kappa \phi^{\frac{\sigma-1}{\theta}} \sum_m \frac{Y_m}{P_m^{1-\sigma}} \frac{(\gamma_{il} w_l \tau_{lm})^{-\theta} \epsilon_l^\theta}{\left( \sum_{k \in Z} (\gamma_{ik} w_k \tau_{km})^{-\theta} \epsilon_k^\theta \right)^{\left( \frac{\theta+1-\sigma}{\theta} \right)}}$$

## LOCATION CHOICE

- Expected variable profits from location set  $Z$ :

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- Each firm chooses the set of locations that maximizes its expected profits.

$$Z(i, \phi, \eta) \in \arg \max_{Z \in \mathcal{Z}^i} E_{\epsilon}(\Pi(i, \phi, Z, \epsilon, \eta))$$

## MOTIVATION TO BUILD FOREIGN PLANTS

- Proximity to markets
- Comparative advantage
- Benefits get reduced by efficiency losses of foreign production,  $\gamma_{il}$
- Trade-off between these benefits and fixed costs

## AGGREGATION AND EQUILIBRIUM

- Aggregate over the choices of firms  $(\phi, \eta, \epsilon)$  from all countries  $(i)$ .
- Profits are distributed to consumers in countries in which the firms originated
- Equilibrium definition is standard (monopolistic competition):
  - Consumers / Firms optimize
  - Markets clear
  - Fixed point for price indices and income in every country.

## EQUILIBRIUM COMPUTATION

- Consumers and firms need to know  $A_l = \frac{Y_l}{P_l^{1-\sigma}}$  and  $w_l$ ,  $l = 1, \dots, N$  in order to make their decisions.
- Given parameter vector  $\beta$ , the equilibrium can be computed as a solution for  $A$  and  $w$  of:

$$A_l(\beta, w, A) = A_l \quad \forall l = 1, \dots, N$$

$$L_l^d(\beta, w, A) = L_l \quad \forall l = 1, \dots, N - 1$$

## REMARKS

- Special case: Anderson and van Wincoop (2003)
- Model is suitable to address both firm level and aggregate data
- Continuum of products and product-location-specific productivity shocks make it feasible to solve and estimate the model

# Estimation

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- Estimate distribution of fixed costs,  $\tilde{\eta}_{t,k} \sim \log \mathcal{N}(\mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}})$ , unit input costs,  $\tilde{w}_k = w_k \gamma_{ik}$ , and other distributional parameters via Maximum Likelihood

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- Fix  $\sigma = 6$ ,  $\theta = 7$  ▶ Estimation of  $\theta$

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- The extensive margin – in which sets of countries do the firms establish plants – identifies the fixed cost parameters.
- The size distribution of firms identifies the core productivity level distribution parameters and the noise in the output of the firm the dispersion parameter of the plant-wide productivity shifters.

# LIKELIHOOD FUNCTION

- Parameters:  $\Theta = \{\tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}, \mu_\phi, \sigma_\phi\}$
- Likelihood function:

$$\begin{aligned} & L(\Theta; \{Z_t, r_t\}_{t=1}^T) \\ &= \prod_{t=1}^T \int_{\phi} \Pr^*(Z = Z_t \mid \phi; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}) g(r_t \mid Z_t, \phi; \tilde{w}) dG(\phi \mid \mu_\phi, \sigma_\phi) \end{aligned}$$

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- Control for unobserved heterogeneity in core productivity levels

# CONSTRAINED MAXIMUM LIKELIHOOD ESTIMATION

- Estimation problem

$$\begin{aligned} & \max_{\Theta, \psi} \log L(\Theta; \{Z_t, \psi_t\}_{t=1}^T) \\ \text{s.t. } & r_{t,l}(\tilde{w}, Z_t, \psi_t) = \kappa \sum_m \frac{Y_m}{P_m^{1-\sigma}} \frac{(\tilde{w}_l \tau_{lm})^{-\theta} \psi_{t,l}^\theta}{\left( \sum_{k \in Z_t} (\tilde{w}_k \tau_{km})^{-\theta} \psi_{t,k}^\theta \right)^{\left( \frac{\theta+1-\sigma}{\theta} \right)}} \end{aligned}$$

$$\forall t \in \{1, \dots, T\}, l \in \{1, \dots, N\} \text{ such that } l \in Z_t.$$

# PARAMETER ESTIMATES

	Unit input costs	Fixed costs		
	$\tilde{w}$	$\mu_{\bar{\eta}}$		
<i>Austria</i>	1.076 (0.021)	4.659 (0.423)		
<i>Belgium</i>	1.144 (0.038)	5.609 (0.500)		
<i>Canada</i>	1.324 (0.080)	5.067 (0.571)	S.d. log fixed cost, $\sigma_{\bar{\eta}}$	2.1902 (0.320)
<i>Switzerland</i>	1.264 (0.055)	4.468 (0.472)	Scale parameter productivity, $\mu_{\phi}$	1.1329 (0.017)
<i>Spain</i>	1.223 (0.018)	3.912 (0.335)	Shape parameter productivity, $\sigma_{\phi}$	5.1026 (0.620)
<i>France</i>	1.229 (0.023)	3.683 (0.243)	S.d. log productivity shock, $\sigma_{\epsilon}$	0.1844 (0.009)
<i>United Kingdom</i>	1.341 (0.021)	3.906 (0.321)	Log-Likelihood	-1.21E+004
<i>Ireland</i>	1.127 (0.052)	6.149 (0.671)	Number of firms, $T$	665
<i>Italy</i>	1.334 (0.039)	3.978 (0.309)		
<i>Netherlands</i>	1.194 (0.029)	5.303 (0.513)		
<i>United States</i>	1.420 (0.016)	3.847 (0.250)		

▶ Fixed costs in Euro

▶ Data summary by country

# DECOMPOSING THE SOURCES OF HOME BIAS IN PRODUCTION

- Average share of foreign production in the output of German MNEs across counterfactual production costs

Data	Model	No fixed costs	Same unit input costs as in Germany	No fixed costs and same unit input costs as in Germany
0.288	0.317 (0.013)	0.716 (0.009)	0.676 (0.021)	0.883 (0.001)

# Calibration

# CALIBRATION OF THE GENERAL EQUILIBRIUM

- Data:
  - Bilateral manufacturing trade flows from OECD
  - Bilateral MP from Ramondo, Rodriguez-Clare, and Tintelnot (in process)
  - Size of labor force and skill level from Barro and Lee (2010)
  - Gravity variables from CEPII
  - Estimates of German MNEs' production costs in various destination countries

# CALIBRATION TARGETS

- Targets:

- ① Trade shares:

$$\xi_{lm} = \frac{X_{lm}}{Y_m}$$

- ② MP-shares:

$$\kappa_{il} = \frac{\sum_m X_{ilm}}{\sum_m X_{lm}}.$$

- ③ Variable production costs for German firms in country  $l$  relative to costs at home ( $j$ ):  $\frac{\tilde{w}_l}{\tilde{w}_j} = \frac{w_l \gamma_{jl}}{w_j}$

## RESTRICTIONS ON PARAMETERS

- Variable iceberg trade and MP costs

$$\tau_{lm} = \beta_{const}^{\tau} (dist_{lm})^{\beta_{dist}^{\tau}} (\beta_{contig}^{\tau})^{contig_{lm}} (\beta_{lang}^{\tau})^{language_{lm}} \quad \text{for } l \neq m$$

$$\gamma_{il} = \beta_{const}^{\gamma} (dist_{il})^{\beta_{dist}^{\gamma}} (\beta_{contig}^{\gamma})^{contig_{il}} (\beta_{lang}^{\gamma})^{language_{il}} \quad \text{for } i \neq l$$

- Fixed MP costs:  $\eta_l \sim \log \mathcal{N}(\ln f_{il}, \beta_{\sigma}^f)$

$$f_{il} = \beta_{const}^f (dist_{il})^{\beta_{dist}^f} (\beta_{contig}^f)^{contig_{il}} (\beta_{lang}^f)^{language_{il}} \quad \text{for } i \neq l$$

- Fixed endowments:  $L_i, M_i$

- Fixed parameters:

- $\sigma = 6, \theta = 7$

- $\sigma_{\epsilon} = 0$

- $\phi \sim$  Pareto with shape parameter 5.5

## CALIBRATION PROCEDURE

- Fit of targets

$$d(\beta, w, A) = \begin{bmatrix} \xi(\beta, w, A) - \xi \\ \kappa(\beta, w, A) - \kappa \\ \frac{\tilde{w}(\beta, w, A)}{w_j} - \frac{\tilde{w}}{\tilde{w}_j} \end{bmatrix}$$

- Calibration problem

$$\min_{\beta, w, A} d(\beta, w, A)'d(\beta, w, A)$$

subject to:

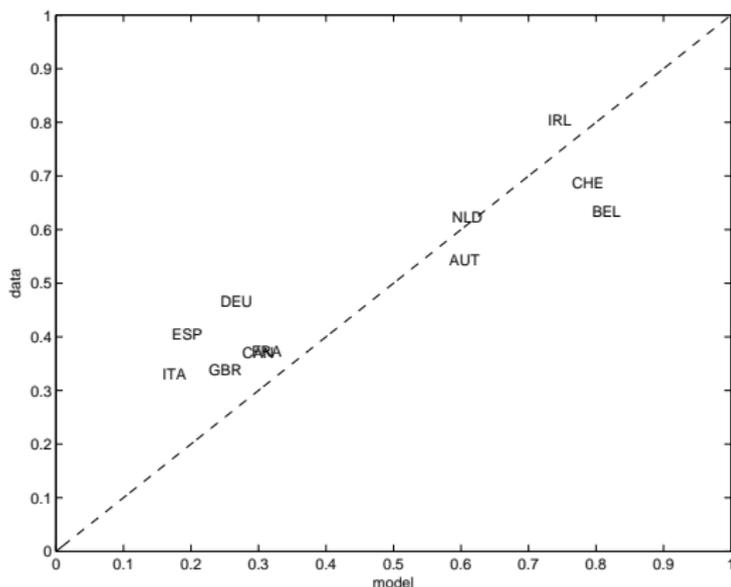
$$A_l(\beta, w, A) = A_l \quad \forall l = 1, \dots, N$$

$$L_l^d(\beta, w, A) = L_l \quad \forall l = 1, \dots, N - 1$$

# TRADE AND MP COSTS ESTIMATES

	Pure trade model	Global production model
Trade cost		
constant	0.722	0.789
distance	0.139	0.121
language	0.922	0.929
contiguity	0.934	0.925
Variable MP cost		
constant		1.259
distance		0.006
language		0.962
contiguity		0.963
Fixed MP cost		
constant		0.089
distance		0.073
language		1.025
contiguity		1.105
dispersion		0.299
Norm trade fit	0.258	0.262
Norm MP fit		0.158

# SHARE OF EXPORTS IN PRODUCTION OF US AFFILIATES: DATA AND MODEL



**Figure:** Export platform shares for US multinationals - data and model

# G.E. Counterfactuals

# THE BENEFITS OF FOREIGN TECHNOLOGY

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- Suppose all US firms improve their productivity by 20 percent.
- With and without multinational production, US welfare improves by around 20 percent.

# BENEFITS FROM US TECHNOLOGY IMPROVEMENT

	Pure trade model	Global production model
Austria	0.45	14.52
Belgium	0.26	9.34
Canada	3.53	28.69
Switzerland	0.37	9.26
Germany	0.15	7.07
Spain	0.26	14.11
France	0.17	7.76
United Kingdom	0.32	13.60
Ireland	1.12	20.93
Italy	0.18	10.92
Netherlands	0.32	13.03
United States	100.00	100.00

# EFFECTS FROM CETA

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  - Some European firms want to have only one plant in North America
  - Re-optimization by multinational firms induces a third-country effect additional to the terms of trade effect.

# EFFECTS FROM CETA

	Difference in inward MP-shares		Rel. welfare
	Canada	United States	
Canada	-10.56	0.05	102.45
EU countries	23.23	-0.47	100.07 - 100.19
Switzerland	-0.19	0.01	99.90
United States	-12.48	0.41	99.95

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- The overall share of foreign production in the US would fall by 6 percent.
- Canada would experience the largest welfare gains.

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- Remark: Free entry may lead to different welfare outcomes (future work).



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  - Quantification of the size and importance of fixed costs of foreign investment both in partial and general equilibrium
  - Demonstrated the usefulness of the framework for current policy analysis
- Extensions / future applications:
  - Competition for multinationals by national governments.

Thank you for your attention!

# Back-up

# THE GAINS FROM TRADE

	Global Production model			Pure Trade model
	Welfare change	Real profit change	Real wage change	Welfare / Real wage change
Austria	1.193	1.585	1.154	1.208
Belgium	1.344	1.837	1.296	1.379
Canada	1.098	1.356	1.068	1.108
Switzerland	1.317	1.843	1.268	1.342
Germany	1.060	1.175	1.043	1.068
Spain	1.050	1.188	1.031	1.054
France	1.075	1.232	1.053	1.084
United Kingdom	1.059	1.201	1.040	1.066
Ireland	1.306	1.795	1.263	1.324
Italy	1.043	1.155	1.027	1.048
Netherlands	1.189	1.524	1.151	1.208
United States	1.012	1.035	1.008	1.013

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# THE GAINS FROM MULTINATIONAL PRODUCTION

Global Production model			
	Welfare change	Real profit change	Real wage change
Austria	1.017	0.740	1.073
Belgium	1.015	0.746	1.069
Canada	1.021	0.779	1.069
Switzerland	1.018	0.731	1.075
Germany	1.006	0.879	1.031
Spain	1.011	0.817	1.049
France	1.008	0.857	1.038
United Kingdom	1.011	0.832	1.047
Ireland	1.021	0.684	1.088
Italy	1.009	0.844	1.042
Netherlands	1.011	0.783	1.056
United States	1.002	0.956	1.012

# THE GAINS FROM OPENNESS

Global Production model			
	Welfare change	Real profit change	Real wage change
Austria	1.262	0.918	1.331
Belgium	1.440	1.058	1.516
Canada	1.154	0.880	1.208
Switzerland	1.414	1.015	1.494
Germany	1.083	0.947	1.110
Spain	1.076	0.870	1.117
France	1.104	0.939	1.137
United Kingdom	1.089	0.896	1.127
Ireland	1.400	0.938	1.492
Italy	1.065	0.891	1.100
Netherlands	1.245	0.965	1.301
United States	1.018	0.970	1.027

# BENEFITS FROM US TECHNOLOGY IMPROVEMENT

RESTRICTED GLOBAL PRODUCTION MODEL WITHOUT FIXED COST

	Relative to benchmark	Relative to US gains
Austria	1.018	8.5042
Belgium	1.0106	4.9942
Canada	1.0219	10.3312
Switzerland	1.0152	7.1452
Germany	0.9993	-0.312
Spain	1.0033	1.5672
France	1.0001	0.0656
United Kingdom	1.0009	0.4332
Ireland	1.028	13.223
Italy	1.0008	0.3998
Netherlands	1.0088	4.1482
United States	1.2121	100

# DEMAND

- Utility of representative consumer in country  $j$

$$U^j \equiv \left( \int_{\Omega} \int_0^1 q_j(\omega, v)^{(\sigma-1)/\sigma} dv d\omega \right)^{\sigma/(\sigma-1)} .$$

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- Goods are substitutes,  $\sigma > 1$
- The quantity demanded in country  $j$  of variety  $v$  supplied by firm  $\omega$  is

$$q_j(\omega, v) = p_j(\omega, v)^{-\sigma} \frac{Y_j}{P_j^{1-\sigma}} .$$

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$$p_j(\omega) \equiv \left( \int_0^1 p_j(\omega, v)^{1-\sigma} dv \right)^{1/(1-\sigma)}$$

- Aggregate price index in country  $j$

$$P_j \equiv \left[ \int_{\Omega_j} p_j(\omega)^{(1-\sigma)} d\omega \right]^{1/(1-\sigma)}.$$

# PRICE INDEX

- The consumer price index in market  $m$  is

$$P_m = \left[ \sum_i M_i \int_{\phi} \sum_{Z' \in \mathcal{Z}^i} \rho_{Z'}^{i, \phi} E_{\epsilon} (p_m(i, \phi, Z', \epsilon))^{1-\sigma} dG(\phi) \right]^{1/(1-\sigma)} \quad (1)$$

► Equilibrium

## LABOR MARKET CLEARING

- Labor market clearing condition

$$\begin{aligned}w_k L_k &= \frac{\sigma - 1}{\sigma} \sum_m X_{km} \\ &+ \sum_{i \neq k} M_i \int_{\phi} \int_{\eta} \sum_{Z \in \Delta_k^i} \mathbb{1}[Z = Z(i, \phi, \eta)] f_{ik} \eta_k w_k dF(\eta) dG(\phi)\end{aligned}\tag{2}$$

- Set of location vectors that includes a location in country  $k$ :  
 $\Delta_k^i = \{Z \in \mathcal{Z}^i \mid Z_k = 1\}$

▶ Equilibrium

▶ Equilibrium computation

# INCOME AND CURRENT ACCOUNT BALANCE

- Income in country  $m$

$$\begin{aligned} Y_m &= w_m L_m \\ &+ M_m \int_{\phi} \int_{\eta} \sum_{Z \in \mathcal{Z}^m} \mathbb{1} [Z = Z(i, \phi, \eta)] E_{\epsilon}(\Pi | i, \phi, Z, \epsilon, \eta) \\ &dF(\eta) dG(\phi) \end{aligned} \tag{3}$$

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- Current account balance implies that

$$\sum_l X_{lm} = Y_m$$

## EQUILIBRIUM DEFINITION

Given  $\tau_{ij}, \gamma_{ij}, M_i, F(\eta), G(\phi), H(\epsilon), Z^i, \forall i, j = 1, \dots, N$ , a global production equilibrium is a set of wages,  $w_i$ , price indices,  $P_i$ , income,  $Y_i$ , allocations for the representative consumer,  $q(\omega, v)$ , prices,  $p_m(i, \phi, Z, \epsilon)$ , and location choices,  $Z(i, \phi, \eta)$ , for the firm, such that

- (I)  $q(\omega, v)$  is the solution of the consumer's optimization problem.
- (II)  $p_m(i, \phi, Z, \epsilon)$  and  $Z(i, \phi, \eta)$  solve the firm profit maximization problem.
- (III)  $P_i$  satisfies equation (1).
- (IV) The labor market clearing condition, (2), holds.
- (V)  $Y_m$  satisfies equation (3).

## ESTIMATION OF DISPERSION PARAMETER OF PRODUCT-LEVEL PRODUCTIVITY DISTRIBUTION

- Product-level sales to market  $m$  are distributed Frechet with dispersion parameter  $\frac{\theta}{\sigma-1}$ .
- Ideally I would estimate  $\frac{\theta}{\sigma-1}$  from firm-product bilateral export data or sales data in particular country.
- Data for entire manufacturing sector would be most appropriate.
- When using car model sales data in five European countries available from Goldberg and Verboven (2001) I find an estimate of  $\widehat{\frac{\theta}{\sigma-1}} = 1.02$ .

## MULTINATIONAL PRODUCTION IS LARGE \_\_\_\_\_

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- U.S. multinationals also account for half of aggregate U.S. exports in goods
- In North America and Western Europe, between 47 percent (Belgium) and 14 percent (U.S.) of output is produced by affiliates of foreign multinationals.
- Foreign output of U.S. multinationals have been growing faster than U.S. trade over the last decade.

# GERMAN AND AMERICAN MULTINATIONAL FIRM SALES VERSUS AGG. EXPORTS

**Table: Trade and foreign affiliate sales**

Country	Exports	Foreign affiliate sales
USA	732.9	1,560
Germany	843.2	387.5

Note: In billion US dollars; data are for the manufacturing sector in year 2004. Majority owned foreign affiliates only.

# REWRITING THE CONDITIONAL DENSITY OF REVENUES

$$g(r_t | Z_t, \phi; \tilde{w}) = |J_t(\phi; \tilde{w})| \prod_{l \in Z_t} h\left(\frac{\psi_{t,l}(\tilde{w})}{\phi} \mid \sigma_\epsilon\right)$$

▶ BACK

## PROBABILITY OF LOCATION CHOICE

- Probability that firm with core productivity  $\phi$  selects vector  $Z_t$ :

$$\begin{aligned} & \Pr(Z = Z_t \mid \phi_t; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}) \\ &= \int_{\tilde{\eta}} \{E_\epsilon(\Pi(\phi_t, Z, \epsilon, \tilde{\eta}; \sigma_\epsilon, \tilde{w})) \geq E_\epsilon(\Pi(\phi_t, Z', \epsilon, \tilde{\eta}; \sigma_\epsilon, \tilde{w})) \forall Z' \in \mathcal{Z}^i\} \\ & \quad dF(\tilde{\eta}; \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}) \end{aligned}$$

- Taking into account selection of the data:

$$\Pr^*(Z = Z_t \mid \phi_t; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}}) = \frac{\Pr(Z = Z_t \mid \phi; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}})}{1 - \Pr(Z = Z_{\text{domestic}} \mid \phi; \tilde{w}, \sigma_\epsilon, \mu_{\tilde{\eta}}, \sigma_{\tilde{\eta}})}$$

# PRELIMINARY EVIDENCE FOR BARRIERS TO MULTINATIONAL PRODUCTION \_\_\_\_\_

**Table:** Foreign production shares

Cardinality production locations	Number of firms	Mean share of foreign firm production	Mean share of foreign gross production
2	474	0.26	0.37
3	102	0.32	0.54
4	40	0.35	0.65
5	23	0.39	0.71
6	14	0.46	0.75
$\geq 7$	12	0.48	0.80
all	665	0.29	0.44

Note: Statistics for German MNE activities in 12 Western European and North American countries.

# GERMAN MULTINATIONALS' ACTIVITIES BY COUNTRY

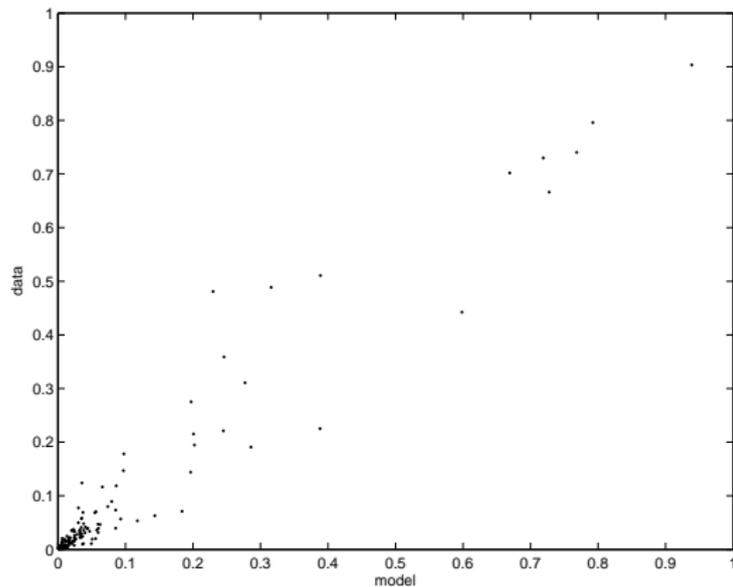
Country	Number	Mean output	Median output
Austria	91	76.3	34
Belgium	45	235.3	37
Canada	36	536.0	28.5
Switzerland	70	58.3	17
Germany	665	625.8	98
Spain	117	191.9	32
France	191	107.7	30
United Kingdom	121	119.4	23
Ireland	18	36.3	19.5
Italy	100	65.0	27.5
Netherlands	46	83.1	25
United States	211	569.0	26

Notes: Output in million Euro. Source: MiDi database.

# FIXED COSTS IN EURO

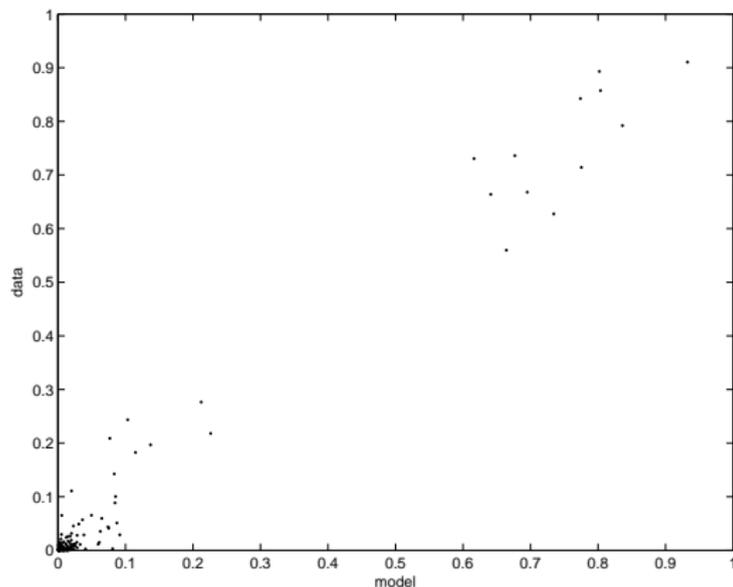
Country	Mean fixed cost of firms who set up a plant in the respective country in million Euro
Austria	7.107 (1.338)
Belgium	18.063 (7.515)
Canada	11.718 (6.497)
Switzerland	5.814 (2.715)
Spain	7.370 (2.474)
France	7.037 (1.423)
United Kingdom	6.653 (1.966)
Ireland	6.069 (1.665)
Italy	6.103 (1.041)
Netherlands	7.499 (2.332)
United States	6.799 (1.257)

# TRADE SHARES: DATA AND MODEL



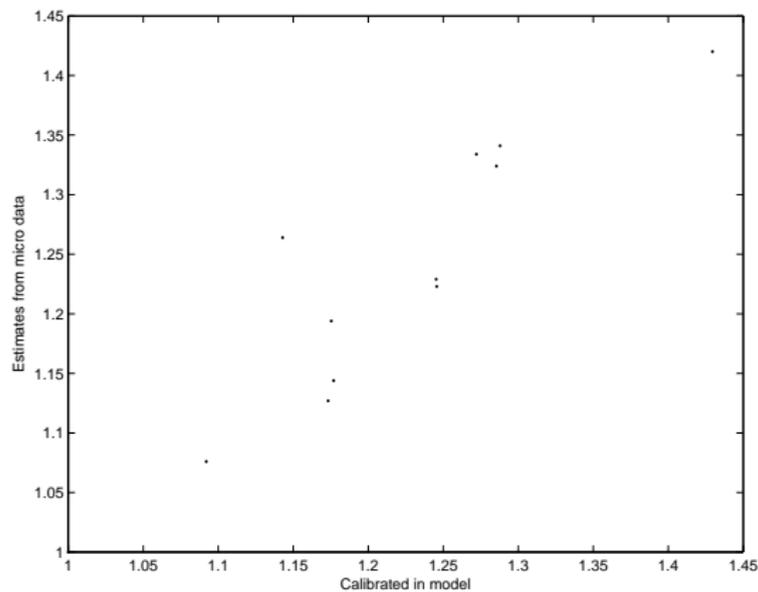
**Figure:** Bilateral trade shares - data and model

# INTERNATIONAL PRODUCTION SHARES: DATA AND MODEL



**Figure:** Bilateral international production shares - data and model

# VARIABLE PRODUCTION COSTS: DATA AND MODEL



**Figure:** Variable production costs for German firms