Structural Gravity and the Gains from Trade under Imperfect Competition

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Background and motivation

- The quantification of the aggregate trade creation, diversion, and welfare effects of trade liberalization episodes are a central question in empirical international trade.
- The most often used tool for this type of analysis is the so-called structural gravity equation, see Head and Mayer (2014), which relates observed trade flows to two key determinants: i) market sizes and ii) trade costs.

Background and motivation

- Standard gravity equations assume atomistic firms which operate in perfectly or monopolistically competitive markets.
  $\Rightarrow$ Constant/no profit margin of firms, no strategic interaction (orthogonal reaction functions).
- $\Rightarrow$ Standard gravity equations cannot speak to a major motivation for trade liberalization: **Pro-competitive** effects.
- EU Single Market: Key motivation was to reduce market power of domestic firms to enhance competition!
- We offer a modified structural gravity equation to scrutinize the (welfare) effects of trade (de-)liberalization under imperfect competition.
- Our model retains the **simplicity** of standard aggregate structural gravity equations: It nests the standard structural gravity equation and we can estimate its trade cost parameters using only publicly available aggregate trade data.

Background and motivation

- Complements literature on pricing to market behavior using detailed firm-destination-product data which are typically only available for a single country, preventing identification of third country and general equilibrium effects which are central for evaluation of trade creation and diversion effects of trade liberalization episodes, RTAs.

Preview of results

- Large literature of endogenous markups, we show it works with Dixit-Stiglitz (CES) and oligopoly.
- We show that gravity still holds for any oligopoly in prices or quantities with CES preferences.
- You can still estimate trade costs and use these estimates to quantify the trade effects of changes in trade costs using a modified gravity equation.
- We are able to distinguish between market power frictions and geographical frictions, and we show how to disentangle these frictions.
- Standard gravity estimates suffer from an omitted variable bias if they do not control for market power frictions.

Firm behavior under imperfect competition

The model setup in a nutshell:

- n countries may trade with each other.
- In what follows, we confine the analysis to the national champion model (one firm in each country; generalized in the paper).
- Utility of consumers in country j is given by a CES aggregator over the varieties produced by all national champions:

$$U_j = \left(\sum_{i=1}^{n} q_{ij}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

  where q_{ij} is the quantity consumed by consumers in country j of the variety from the national champion from country i.
- $\Rightarrow$ Setup as close as possible to canonical Anderson and van Wincoop (2003) model.
- Key difference: We allow for oligopolistic interaction between firms.

Model with multiple industries for industry-trade data

Firm behavior under imperfect competition

- For illustration: drop the country index j.
  - Firm i maximizes its profit by choosing optimal price (Bertrand competition, denoted by B):

$$\max \pi_i^B(p_i, p_{-i}) = (p_i - \tau_i c_i) q_i(p_i, p_{-i}) \text{ w.r.t. } p_i, \tag{2}$$

    where p_{-i} is a $n-1$ price vector that denotes the prices of all other firms, c_i denotes the marginal production cost, $\tau_i \geq 1$ iceberg trade cost.
  - First-order conditions in terms of mark-ups, denoted by μ_i^B and elasticities, denoted by ϵ_i^B. Nash equilibrium in prices:

$$\begin{aligned} \forall i : p_i^* &= \mu_i^B \tau_i c_i, \quad \mu_i^B = \frac{\epsilon_i^B}{\epsilon_i^B - 1}, \\ \epsilon_i^B &= \sigma - (\sigma - 1) \frac{\left(\mu_i^B \tau_i c_i\right)^{1-\sigma}}{\sum_{j=1}^n \left(\mu_j^B \tau_j c_j\right)^{1-\sigma}}. \end{aligned}$$

  - (We prove sufficiency, and existence and uniqueness using tools from aggregative games theory, see Anderson et al., 2020.)

▸ Cournot competition ▸ Strategic complements or substitutes?

Firm behavior: endogenous markups

Proposition

The markup of a firm decreases with its trade cost. Consequently, for both a Nash equilibrium in prices (Bertrand) and a Nash equilibrium in quantities (Cournot), any difference in a firm's equilibrium prices will be smaller than the difference in trade costs.

- Implication: Incomplete pass-through = pricing-to-market.
- Reintroduce subscript: Firm i from country i charges price p_{ij} in destination market j.
- For both Bertrand and Cournot competition, equilibrium prices are given by

$$p_{ij}^{*} = \mu_{ij}\tau_{ij}c_{i}.$$

Compare this to equilibrium prices in standard quantitative trade models:

$$p_{ij}^{*} = \tau_{ij}p_{i}.$$

- $\Rightarrow$ Monopolistic competition (and standard gravity) assumes μ_{ij} to be constant and exogenous (0 under perfect competition, and $p_i = c_i$); endogenous in oligopoly.

Gravity equation under imperfect competition

Aggregate trade from country i to country j is given by:

$$X_{ij} = \frac{GDP_i GDP_j}{G} \left(\frac{t_{ij}}{Q_i P_j} \right)^{1-\sigma} = \frac{GDP_i GDP_j}{G} \left(\frac{\mu_{ij} \tau_{ij}}{Q_i P_j} \right)^{1-\sigma}, \tag{3}$$

with outward and inward multilateral resistance terms

$$Q_i^{1-\sigma} = \sum_{j=1}^{n} \theta_j \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma}, P_j^{1-\sigma} = \sum_{i=1}^{n} \theta_i \left(\frac{t_{ij}}{Q_i} \right)^{1-\sigma}.$$

- Striking resemblance with standard gravity by Anderson and van Wincoop (2003).
- Key difference: Bilateral trade flows now not only depend on trade costs τ_{ij} but also on markups charged by firms μ_{ij}.
- Standard gravity estimates measure the combined impact of a regressor on trade costs **and** markups.

The gains from trade and the new gravity equation

- We can use our model to derive a simple statistic for calculating the gains from trade, generalizing Arkolakis et al. (2012) to oligopoly.
- Let $\widehat{\lambda}_{ij}$ denote the change in the share of country j's expenditure for goods from country i.
- Assume that each country uses only labor as factor of production and the endowment of labor is equal to L_j for country j. Let Π_j^{*0} $\left(\Pi_j^{*1}\right)$ denote the aggregate profit of all firms located in country j before (after) trade liberalization.
- The gains from trade under oligopoly are given by

$$\widehat{W}_j = \frac{\widehat{Y}_j}{\hat{\mu}_{jj}} \widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}.$$

where $\widehat{Y}_j = \left(L_j + \Pi_j^{*1}\right) / \left(L_j + \Pi_j^{*0}\right)$.

▸ Welfare formula with multiple industries

The gains from trade and the new gravity equation: channels

$$\underbrace{\widehat{W}_j}_{\text{welfare change}} = \underbrace{\frac{\widehat{Y}_j}{\hat{\mu}_{jj}}}_{\text{new}} \times \underbrace{\widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}}_{\text{standard}} .$$

Three channels:

1. **Standard**: Change in expenditure share for the domestically produced variety $\widehat{\lambda}_{jj}^{\frac{1}{1-\sigma}}$: Lower share = larger market share of foreign firms due to lower foreign prices (as in Arkolakis et al., 2012).
2. **New**: Change in the domestic markup $\widehat{\mu}_{jj}$.
3. **New**: Real income changes $\widehat{Y}_j$: changes in domestic profits can either amplify or reduce the welfare gains.

▸ illustration in two country model

Estimating the welfare and competition effects of the European Single Market I

- Goals:
  - **Estimate** the framework using publicly available bilateral trade data used in the quantitative trade theory literature.
  - Use parameter estimates to **quantify** the welfare and markup effects of a **counterfactual** abolition of the EU Single Market.
  - **Compare** results to state of the art perfect/monopolistic competition frameworks used in the quantitative trade theory literature.
- Data: World Input-Output Database (WIOD), aggregate trade between 43 countries 2000 – 2014 (including internal trade).
- Assumptions: (i) national champions; (ii) universal activity.
  $\Rightarrow$ As close as possible to Anderson and van Wincoop (2003) benchmark! Only difference is allowing for market power.

Estimating the welfare and competition effects of the European Single Market II

- Specification of combined trade and market power frictions:

$$
\begin{aligned}
t_{ijt}^{1-\sigma} &= \mu_{ijt}^{1-\sigma}\tau_{ijt}^{1-\sigma} \\
&= \mu_{ijt}\exp(\mathbf{x}'_{ijt}\boldsymbol{\beta}) \\
&= \mu_{ijt}^{1-\sigma}\exp(\beta_1 EU_{ijt} + \beta_2 RTA_{ijt} + \xi_{ij}).
\end{aligned}
$$

Estimating the welfare and competition effects of the European Single Market III

- We can calculate (scaled) markups $\mu_{ijt}^{1-\sigma}$ using observed market shares s_{ijt} from the trade data:

$$s_{ijt} = \frac{t_{ijt}^{1-\sigma} c_i^{1-\sigma}}{\sum_\iota t_{\iota jt}^{1-\sigma} c_\iota^{1-\sigma}} = \frac{X_{ijt}}{\sum_\iota X_{\iota jt}} < 1,$$

as we can express markups μ_{ijt} as functions of market shares s_{ijt}:

$$\mu_{ijt}^B = \frac{\sigma - (\sigma - 1) s_{ijt}^B}{(\sigma - 1)\left(1 - s_{ijt}^B\right)} \quad \text{and} \quad \mu_{ijt}^C = \frac{\sigma}{(\sigma - 1)\left(1 - s_{ijt}^C\right)},$$

$$\epsilon_{ijt} = \begin{cases} \sigma - (\sigma - 1) s_{ijt}^B & \text{for Bertrand,} \\ \frac{\sigma}{1 + (\sigma - 1) s_{ijt}^C} & \text{for Cournot} \end{cases}$$

Specification of (adjusted) gravity equation

We estimate

$$X_{ijt} = \mu_{ijt}^{1-\sigma} \exp(\eta_{it} + \nu_{jt} + \beta_1 EU_{ijt} + \beta_2 RTA_{ijt} + \xi_{ij} + u_{ijt})$$

- using PPML, see Santos Silva and Tenreyro (2006), `ppmlhdfe` command by Correia et al. (2020)
- $\mu_{ijt}^{1-\sigma}$: exposure variable; $\sigma = 5.03$, see Head and Mayer (2014)
- η_{it}, ν_{jt} are exporter×year, importer×year fixed effects to control for multilateral resistance terms
- ξ_{ij} directional bilateral fixed effect to control for standard gravity variables such as distance, common border, ..., and endogeneity of trade policy
- EU_{ijt}: dummy for all international trade flows between member countries
- RTA_{ijt}: dummy for all international trade flows between RTA members (including the EU, effect of the EU : $\beta_1 + \beta_2$)
- EU_{ijt}, RTA_{ijt}: Mario Larch's RTA data set, see Egger and Larch (2008)

(Adjusted) gravity trade cost parameter estimates

Table 1: Trade cost estimates from adjusted gravity estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS			PPML					
	MC†	Bertrand	Cournot	MC†	Bertrand	Cournot	MC†	Bertrand	Cournot
EU_{ijt}	0.187**	0.212**	0.267***	0.426***	0.651***	1.041***	0.332***	0.404***	0.635***
	(0.063)	(0.064)	(0.065)	(0.053)	(0.072)	(0.122)	(0.069)	(0.089)	(0.142)
RTA_{ijt}	0.122**	0.137**	0.160***	0.136***	0.352***	0.515***	0.065*	0.200**	0.228*
	(0.044)	(0.044)	(0.045)	(0.041)	(0.033)	(0.041)	(0.029)	(0.069)	(0.094)
$INTER_{ijt}$	NO	NO	NO	NO	NO	NO	YES	YES	YES
N	27735	27735	27735	27735	27735	27735	27735	27735	27735

Notes: † MC: Monopolistic competition. Table reports regression coefficients of estimating the adjusted gravity equation from eq. (4) by PPML using `ppmlhdfe`. All regressions include exporter×year, importer×year and directional bilateral fixed effects. Standard errors are robust to multiway clustering across exporters and importers. For comparison, we present standard gravity estimates in columns (1), (4), and (7). Columns (2), (5) and (8) use μ^C_{ijt} from eq. (12) and columns (3), (6) and (9) use μ^B_{ijt}.

Translated: Column (4), MC: typical RTAs increase trade on average by 15 percent – EU increases trade by 53 percentage points more than the typical RTA. Column (5), Bertrand: typical RTA increases trade by 42 percent – EU by additional 92 percentage points. Column (6), Cournot: typical RTA increases trade by 67 percent – EU by additional 183 percentage points.

How would welfare and domestic markups change if we counterfactually abolish the European Single Market?

Table 2: Welfare and markup changes of abolishing the European Single Market (in %)

Country	$\%\Delta W_j$			$\%\Delta \mu_{jj}$	
	Monop. Comp.	**Bertrand**	**Cournot**	**Bertrand**	**Cournot**
Australia	0.3	0.6	1.1	0.0	0.0
China	-0.2	-0.5	-0.9	-0.0	-0.0
United States	0.1	0.6	2.4	0.0	0.0
Austria	-5.3	-7.7	-10.3	0.3	3.8
Bulgaria	-4.0	-7.0	-9.0	6.6	13.5
Denmark	-4.4	-7.1	-10.0	0.5	4.4
Greece	-2.7	-4.3	-6.8	2.1	9.7
Netherlands	-3.6	-5.2	-7.2	0.1	1.0
France	-2.9	-3.3	-3.1	0.5	4.2
Germany	-1.3	-1.1	-0.2	0.2	2.7
Italy	-1.6	-0.8	-0.1	0.8	8.0
Spain	-1.9	-2.4	-4.5	2.3	10.6
United Kingdom	-2.0	-2.5	-3.2	0.5	4.1

Notes: Table reports welfare changes of removing the European Single Market in percent. Estimated trade cost parameters used are from Table 1: Monopolistic competition uses parameters from column (7), Bertrand competition from column (8), and Cournot from column (9).

▸ results with trade costs estimated under monopolistic competition across all competition modes

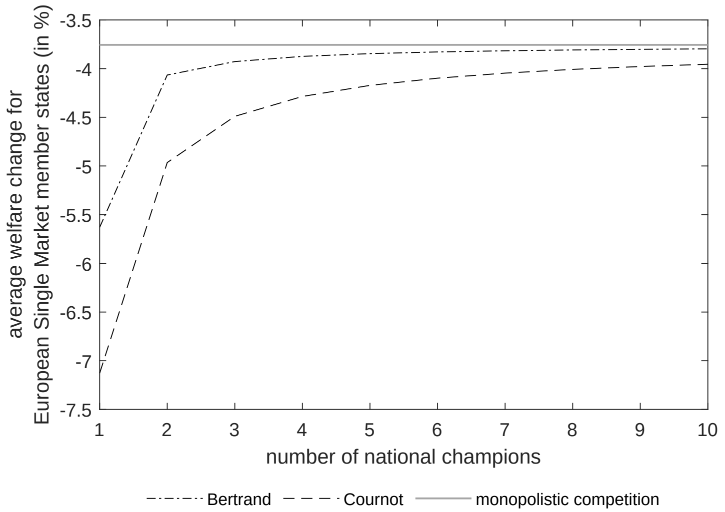
How would markups change on average if we counterfactually abolish the European Single Market?

Table 3: Average changes of markups (in %)

	Bertrand	Cournot
all countries		
average across all markets	0.01	0.03
average across all export markets	-0.01	-0.07
average across all domestic markets	1.10	4.33
EU members		
average across all EU domestic markets	1.62	6.42
average across all EU export markets	-0.03	-0.17
average across all non-EU export markets	-0.00	0.00
non-EU members		
average across all non-EU domestic markets	0.00	0.00
average across all EU export markets	0.01	0.02
average across all non-EU export markets	0.00	-0.00

Notes: Table reports average changes in markups of removing the European Single Market in percent. Estimated trade cost parameters used are from Table 1: Bertrand competition from column (8), and Cournot from column (9).

Average welfare effects with multiple national champions



Conclusions

- Good news # 1: Gravity holds on firm level with oligopoly and CES preferences.
- Good news # 2: Trade and market power frictions can be disentangled.
- Quantification:
  - Arkolakis et al. (2012): "How large are the welfare gains from trade? A crude summary of our results is: So far, not much."
  - Really? Do not use a model with orthogonal reaction functions (monopolistic competition) to estimate pro-competitive effects.
  - Q: Does it matter? A: So far, very much, as monopolistic competition seems to underestimate the gains from globalization substantially.
  - This effect does not disappear with a large number of firms as long as trade frictions exist.

Thank you

Thank you for your attention!
We are looking forward to your questions and comments.

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CESifo Working Paper No. 8121 (first version);
https://benediktheid.weebly.com/research.html (most recent version).

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Firm behavior under imperfect competition: multiple industries I

- The model setup:
  - n countries may trade with each other.
  - Each country hosts a continuum of industries that are defined over the interval $[0, 1]$.
  - In what follows, we confine the analysis to the national champion model (one firm in each country in each industry; generalized in the paper).
  - Firms have market power: They are large in the small and small in the large as in Neary (2016).
- Utility:
  - Upper tier: Cobb-Douglas utility function $\ln W_j = \int_0^1 \alpha_k \ln U_{jk} dk$, $\int_0^1 \alpha_k = 1$.
  - Lower tier: CES subutility

back

The gains from trade and the new gravity equation with multiple industries I

- Let $\widehat{\lambda}_{ijk}$ denote the change in the share of country j's expenditure from industry k for goods from country i.

Proposition

Assume that each country uses only labor as factor of production and the endowment of labor is equal to L_j for country j. Let Π_j^{*0} $\left(\Pi_j^{*1}\right)$ denote the aggregate profit of all firms located in country j before (after) trade liberalization. The gains from trade under oligopoly are given by

$$\widehat{W}_j = \widehat{Y}_j \prod_k \left(\frac{\widehat{\lambda}_{jjk}^{\frac{1}{1-\sigma}}}{\widehat{\mu}_{jjk}} \right)^{\alpha_k}.$$

where $\widehat{Y}_j = \left(L_j + \Pi_j^{*1}\right) / \left(L_j + \Pi_j^{*0}\right)$. back

Firm behavior: Cournot competition

Cournot competition, denoted by C:

- Exercise: max $\pi_i^C(q_i, q_{-i}) = (p(q_i, q_{-i}) - \tau_i c_i)q_i$ w.r.t. q_i, q_{-i} is an $n-1$ output vector that denotes the outputs of all other firms.
- First-order conditions in terms of mark-ups, denoted by μ_i^C, and elasticities, denoted by ϵ_i^C. Nash equilibrium in quantities:

$$\forall i : p_i(q_i^*, q_{-i}^*) = \mu_i^C \tau_i c_i, \mu_i^C = \frac{\epsilon_i^C}{\epsilon_i^C - 1},$$
$$\epsilon_i^C = \frac{\sigma}{1 + (\sigma - 1)\frac{\left(\mu_i^C \tau_i c_i\right)^{1-\sigma}}{\sum_{j=1}^n \left(\mu_j^C \tau_j c_j\right)^{1-\sigma}}}.$$

- (We prove sufficiency, and existence and uniqueness using tools from aggregative games theory, see Anderson et al., 2020.)

back

Firm behavior under imperfect competition I

Lemma

(i) Prices are strategic complements in the sense of Bulow et al. (1985) for Bertrand competition. For Cournot competition, a firm i will increase (decrease) its output in response to an increase in rival output if $q_i^{(\sigma-1)/\sigma} > (<) \sum_{\iota \neq i} q_\iota^{(\sigma-1)/\sigma}$.
(ii) For an identical market share, the markup is higher in case of Cournot competition than in case of Bertrand competition.

back

A simple illustration in a two country model

Gains from trade in a symmetric Krugman model of two countries = firms only.

- All industries are completely symmetric and their marginal production costs are normalized to unity.
- Both firms will be active in both countries, and we reduce the bilateral and symmetric trade friction for each exporter to free trade for different levels of trade frictions to begin with.
- V is the ratio of welfare after to the welfare before trade liberalization on the vertical axis, welfare is measured by the inverse of the price index in a country ($\widehat{Y}_j = 1$).
- τ on the horizontal axis gives the initial level of trade costs from which these trade costs are reduced to unity, so $V = 1$ for $\tau = 1$.

Welfare gains in simple Krugman model

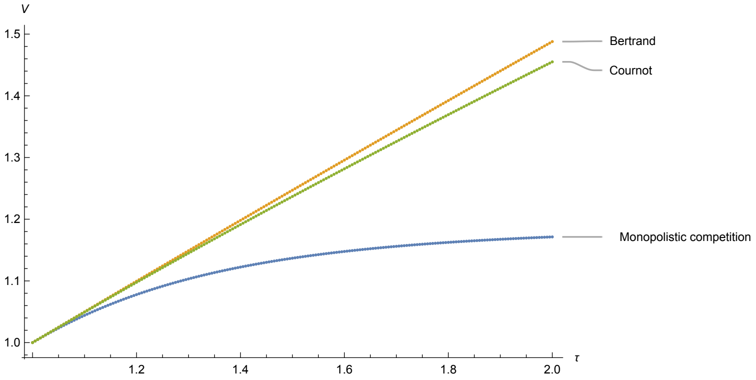

Figure 1: Welfare changes from trade liberalization in the Krugman model for $\sigma = 5$

other values of σ back

Krugman model with different σs I

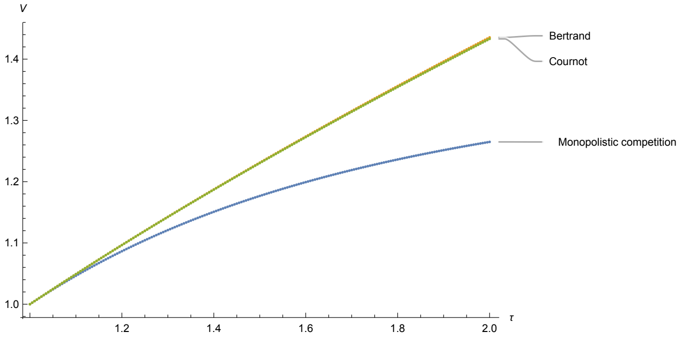

Figure 2: Welfare changes from trade liberalization in the Krugman model for $\sigma = 3$

back

Krugman model with different σs II

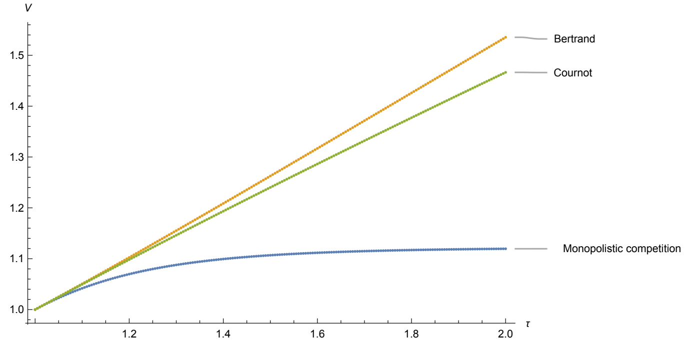

Figure 3: Welfare changes from trade liberalization in the Krugman model for $\sigma = 7$

back

How do markups change on average if we counterfactually abolish the European Single Market? Using the same trade cost estimates

Table 4: Welfare and markup changes of abolishing the European Single Market (in %) using the same monopolistic competition trade costs ▸ back

Country	$\%\Delta W_j$			$\%\Delta\mu_{jj}$	
	Monop. Comp.	**Bertrand**	**Cournot**	**Bertrand**	**Cournot**
Australia	0.3	0.2	0.2	0.0	-0.0
China	-0.2	-0.1	-0.1	0.0	-0.0
United States	0.1	0.0	-0.1	0.0	0.0
Austria	-5.3	-5.3	-5.2	0.2	0.9
Bulgaria	-4.0	-4.4	-4.3	3.5	4.6
Denmark	-4.4	-4.4	-4.4	0.2	1.0
Greece	-2.7	-2.8	-3.3	0.9	2.5
Ireland	-3.4	-3.3	-3.5	0.1	0.5
Netherlands	-3.6	-3.4	-3.5	0.0	0.3
Portugal	-4.2	-4.6	-4.9	1.9	3.4
France	-2.9	-2.9	-3.2	0.2	0.8
Germany	-1.3	-1.5	-1.8	0.1	0.3
Italy	-1.6	-1.8	-2.3	0.2	0.9
Spain	-1.9	-2.0	-2.7	0.6	1.9
United Kingdom	-2.0	-2.1	-2.5	0.2	0.8