On Barriers to Technology Adoption, Appropriate Technology and Deep Integration (with implications for the European Union)

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Abstract

Based on two strands of research, namely 'barriers to technology adoption' and 'appropriate technology', we propose a formal reappraisal of 'deep integration', a broad concept often used in trade policy discussions. We then evaluate the 2004-7 EU enlargement wave utilizing this operational reappraisal. More specifically, we first estimate, using 2007 data, total labor productivity (TLP) in the 27 EU member states, and show that in all but a few sectors, new member states clearly stand below the lower envelope technology frontier of the older members in their use of skilled and unskilled labor. We interpret this as being the result of past barriers to technology adoption that are likely to be removed by the integration process into the EU, with these new counties' TLP shifting to the incumbent members' lower envelope. We then explore the potential effects on all 27 EU member states of this 'deep integration' experiment using a calibrated intertemporal multisectoral general equilibrium model. Our main finding is that, for most parameter configurations, workers' welfare in incumbent member countries is not negatively impacted despite the rather drastic improvement in competitiveness experienced by new members.

JEL Classification: D58, E23, F12, J31, O14, R13

Keywords: Barriers to technology adoption, appropriate technology, technological upgrading, deep integration, European integration, calibrated general equilibrium

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1 Introduction

The literature on cross-country economic performance has now accumulated ample evidence to document large gaps in technology usage. Hence, the widespread and often implicit view that countries have access to the same technology, with differences in input combinations reflecting differences in factor prices only, is clearly over simplistic. Among the different theories that have been proposed to nuance this view, two important strands of literature single out as particularly appealing. The first highlights differences in productivity levels, acknowledges the existence of barriers to technology adoption, and identifies a large variety of factors that contribute to reduce adoption abilities and efficient use of knowledge in production. Among the important contributions to this 'barriers to technology adoption' literature, Parente and Prescott (1994, 2000) emphasize restrictions to foreign trade and limited access to international capital markets, Acemoglu and Robinson (2006) highlight the role of political and institutional organization, Alesina, Battisti, and Zeira (2015) single out the role of labor market regulations, Comin and Hobijn (2004) underline differences in factor endowments and Ferraro (2017) argues that volatility is a contributing factor. The importance of factor endowments and complementarities in cross-country technology diffusion are also emphasized by the related 'appropriate –or endogenous– technology' literature. Based on the seminal work of Atkinson and Stiglitz (1969), influential papers include, among others, Diwan and Rodrik (1991), Basu and Weil (1998), Acemoglu and Zilibotti (2001), Caselli and Coleman (2006) and Vandenbussche, Aghion, and Meghir (2006). One key implication of this literature is the existence of an efficiency frontier, rather than a single 'state-of-the-art' production function; by making technological choices endogenous, it emphasizes that differences in factor endowments will induce countries to pick optimally different technologies on their frontiers.

A third strand of research has independently developed in the trade literature around the concept of 'deep integration' (Lawrence, 1996). This concept, has become widely used in policy discussions on trade and more recently on 'new regionalism', with EU integration serving as the most vivid example (see e.g. Ethier, 1998; Baldwin, 1997). The literature on 'deep integration' refers to an extremely broad –and hence somewhat vague– state of integration between economies, inclusive but indeed much broader than what can be achieved by the elimination of standard barriers to trade in goods and to capital flows.[1] Such integration requires, amongst others, "disciplines such as infrastructure, institutions, competition policy, the standardization and harmonization of product regulations (Orefice and Rocha 2011, p.2).[2] This attractive concept of integration involves dimensions that are clearly beyond the scope of trade, and it can therefore hardly be surprising that "the empirical literature on the relationship between trade and deep integration is very limited. One of the main

[1] The latter more restrictive definition of integration is in contrast referred to as 'shallow integration'.

[2] See also Birdsall and Lawrence (1999), Rodrik (2002) and Gasiorek and Holmes (2008).

reasons for this derives from the difficulties that arise when defining and measuring the depth of an agreement." (Orefice and Rocha 2011, p.3).[3] Lack of an implementable definition of deep integration is in particular problematic for quantitative evaluations of successive European enlargements.

It should be apparent from the discussions in the previous paragraphs that the process of deep integration refers to disciplines that are related to those necessary to achieve efficient diffusion of knowledge in production. Building on the 'barriers to technology adoption' literature, and drawing on 'appropriate technology', our first contribution in this paper is to propose an alternative interpretation of deep integration that can be used in counterfactual policy exercises. We show how our reformulation of the concept can be converted into a quantifiable technological shock immediately implementable into numerical models to deliver quantitative policy evaluations.

Our formalized definition of deep integration is especially relevant to the context of Europe's enlargement process. The enlargement episode of 2004-7, in particular, involved simultaneous integration of a large set of countries of which some have populations of significant sizes;[4] the shock is therefore likely to have non trivial indirect effects, in particular on factor prices in incumbent member states. Can we be confident that such a shock will not redistribute welfare at the expense of labor –and in particular of the lower-skilled workers– in older member states? In the current context of widespread anti-EU resentment and of rising populism that threaten the future of the European integration project, understanding these effects and assessing their potential magnitudes is an important task for economists. Our second contribution in this paper is to shed light on those issues by implementing our definition of deep integration in a calibrated general equilibrium (GE) model of the EU in order to assess the potential consequences of the 2004-7 enlargement wave. The model is a two-period (short vs long term) intertemporal (agents make optimal savings decisions under perfect foresight) multi-country (each of the twenty-seven EU national economies) and multi-sectoral (we distinguish ten different industries, some of which are characterized by monopolistic competition) set-up calibrated on 2007 data. It is a dynamic highly sophisticated version of the so-called 'footloose capital with vertical linkages' model of the new economic geography literature (see e.g. Baldwin et al, 2003). Even though we do solve the model for the long run equilibrium geographical location of the firms, our interest is

[3] Within this framework, examples for quantifiable evaluations of the concept mostly rely on constructed depth indicators, based on the content of (preferential) trade agreements (Horn, Mavroidis, and Sapir 2010). Models used for the analysis of the consequences of 'integration' on the other hand, often take (exogenously) increased factor mobility along with lower trade costs as indicators of 'increased regional integration' (Ludema and Wooton 2000).

[4] The 'fifth wave' enlargement of the EU involved: Cyprus (CYP), the Czech Republic (CZE), Estonia (EST), Latvia (LVA), Lithuania (LTU), Hungary (HUN), Malta (MLT), Poland (POL), Slovakia (SVK) and Slovenia (SVN) in 2004; with Bulgaria (BGR) and Romania (ROU) in 2007. Throughout this paper, we shall refer to these counties somewhat loosely as the 'new' member states of the EU, as opposed to the 'old' member states, which are Austria (AUT), Belgium (BEL), Germany (DEU), Denmark (DNK), Spain (ESP), Finland (FIN), France (FRA), Great Britain (GBR), Greece (GRC), Ireland (IRL), Italy (ITA), Luxembourg (LUX), the Netherlands (NLD), Portugal (PRT) and Sweden (SWE).

not on changing trade costs, which we assume negligible.

The paper is organized as follows. In Section 2, we apply the cross-section regression methodology of Caselli and Coleman (2006)[5] on EU country data from year 2007. We first estimate, at sectorial level, the country specific technology frontiers jointly with the optimal location choice on this frontier, conditional on national endowments of skilled and unskilled labor (the appropriate technology choice). We document a clear pattern of systematic efficiency gaps between older member states and those that joined the EU in 2004 and 2007. We then generate, for each sector, a lower envelope to incumbent EU members' technology frontiers and compute the gap in total labor productivity (hereafter TLP) between each new member state and this lower envelope frontier. We interpret this as providing a measure of the efficiency losses caused by pre-membership barriers to technology adoption due to the various factors identified by the literature. Section 3 elaborates our reinterpretation of 'deep integration': because joining the EU involves a wide range of economic, political and institutional reforms to harmonize institutions, policies, standards etc., the conjecture here is that integration with the EU will induce a technological catch-up in the form of an upward shift in TLP that will place new members on the lower envelope frontier of the incumbent-member states. This shift in TLP defines the deep integration shock in our framework, to be implemented into the calibrated GE model of the EU described in Section 4. In the same section, we also report and discuss the numerical results of the deep integration shock. Section 5 offers a brief conclusion.

2 Measuring country specific technology frontiers within the EU

2.1 The econometric methodology

We follow CC (2006):[6] consider aggregate firms combining skilled and unskilled labor using a CES technology which we write as:

$$Lab = \theta \left[[A_{un} L_{un}]^{-\rho} + [A_{sk} L_{sk}]^{-\rho} \right]^{-1/\rho}; \qquad (1)$$

here, L_{un} and L_{sk} denote labor inputs indexed by skill levels with A_{un}, A_{sk} the associated parameters that convert the raw quantities into efficiency units, ρ is the parameter that characterizes substitutability (with $\sigma^{Lab} = 1/(1+\rho)$ the substitution elasticity), θ is a shift parameter (initially set to unity) measuring TLP. Parameters A_{un}, A_{sk} are allowed to vary across countries. They are interpreted as resulting from endogenous 'appropriate' technology choices from a menu of different production methods on a country specific technology

[5] Hereafter CC (2006).

[6] We however use a different notation. The reader is in particular cautioned on the fact that, in their paper, σ does not refer to a substitution elasticity.

frontier, by firms facing different factor endowments and levels of technology adoption. The econometric procedure proposed by CC (2006) makes it possible to simultaneously estimate, from a cross-section of country data set, country specific parameters γ and B from a technological frontier of the form:

$$A_{un}^{\omega} + \gamma A_{sk}^{\omega} \leq B \tag{2}$$

and each country's optimal location (parameters A_{un} and A_{sk}) on its frontier, conditional on a common estimated curvature parameter ω and an ex-ante chosen value of the substitution elasticity σ^{Lab}. The equation resulting from the constrained optimal technology choice that is to be estimated takes the following form:

$$log(\frac{A_{sk}^{i}}{A_{un}^{i}}) = \frac{1}{\omega+\rho} log\gamma^{i} + \frac{-\rho}{\omega+\rho} log\left(\frac{L_{sk}^{i}}{L_{un}^{i}}\right) \tag{3}$$

where i is the country index. The estimate of $\frac{-\rho}{\omega+\rho}$ can be obtained from the regression coefficient. Utilizing this estimate and the chosen value of σ^{Lab}, one can infer the value of ω. The trade-off parameter γ^{i}, can then be recovered for each country from regression residuals. Equation (2) then, backs-out each country's B^{i}, hence the country-specific technology frontier. All estimated parameters from equation (3) have to be positive.[7] Differences in the estimated values of the B^{i} parameters clearly provide a measure of the technology gap that exists between countries at a specific date.

Aggregate country data may cover important sectoral differences (among which, the type of competition prevailing), which we do not want to neglect: we therefore depart from CC (2006) by adapting their methodology to a multisector setup. This essentially requires a sector-level definition of factor endowments. Imperfect as it is, we make the assumption that intersectoral mobility of labor is low enough for actual employment in a sector to be a reasonably good proxy for factor endowments as perceived by an individual firm in the same sector.

The aggregate economy is partitioned through out this paper into the following ten sectors of activity: Primary; Food, Beverages and Tobacco; Textiles and Textile Production; Chemicals and Plastics; Basic and Fabricated Metals; Electrical and Optical Equipment; Transport Equipment; Construction; Other Manufacturing; and Services.

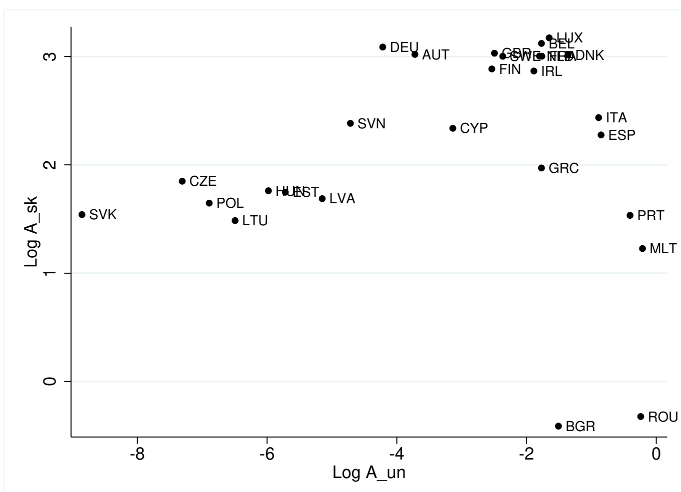
2.2 Estimation results

To be able to apply this econometric methodology, we first have to generate, for all EU member countries and for each sector, the values of the efficiency parameters A_{un} and A_{sk}. For this, we use the FOC of the maximization problem of the representative firm so that the inputs to production from our data set

[7] The restriction for unique interior equilibrium, where all firms within a country choose the same technology (A_{un}, A_{sk}) and the same factor ratios (L_{un}/L_{sk}) is $\omega > -\rho/(1+\rho)$. See CC (2006) for details.

are fully consistent with the output and skill-premium in each country/sector.[8] Though numbers do differ across sectors –in some cases significantly– a common pattern clearly emerges as Figure 1 illustrates at the aggregate level. We see that old EU-member countries tend to be concentrated on the upper-right, revealing rather similar levels of absolute technological efficiency. As is no surprise, within this group of countries, the German economy stands out with a relatively skill-biased technology, suggesting higher levels of skill abundance. In contrast, firms in the Mediterranean countries tend to make more unskilled labor-intensive technology choices consistent with relatively high unskilled labor abundance. In sharp contrast, new member countries display much higher heterogeneity in their technology choices, in terms of both relative and absolute factor efficiencies. Among these, three groups distinctly emerge: the first group, with Slovakia as an extreme, reveals highly skill-biased labor technology choices reflecting relatively abundant skilled labor endowments. At the other extreme are Bulgaria and Romania, both economies characterized by low levels of skilled labor. In between these groups are Cyprus and Slovenia which not only differ by their more balanced labor technology choices but also by higher levels of absolute total labor efficiency.

Figure 1: Efficiency of skilled and unskilled workers - aggregate economy, 2007



Our next step is to use these efficiency parameters (A_{un} and A_{sk}) in cross-EU country regressions (equation (3)) in order to back-out each country's technological frontier (equation (2)). We perform these regressions for each sector, conditional on a common, ex-ante specified, value of $\sigma^{Lab} = 1.4$ that is gener-

[8]For this step, we complement the detailed set of social accounting matrices for year 2007, constructed by Álvarez-Martínez and López-Cobo (2016) with sectoral data on skilled and unskilled employment and the corresponding wage rates from the World Input Output Database (WIOD) (Dietzenbacher et al, 2013).

ally adopted as a reasonable benchmark value.[9] The resulting parameter values that define the country and sector specific technology frontiers are reported in Table 1.[10] Across the sectors displayed on the table, the Bs obtained for the old member states are, on average, 75% higher than those of the new members, and also show 33.6% lower variability, indicating relatively homogeneous technology choice sets for the old members. Also note that for the core group of the old members (that is, excluding the Mediterranean countries), the technology choices (A_{sk}/A_{un})s are also comparable. The (relative) variabilities of the Bs and of the efficiency ratios, are much higher for the new members.

It is illuminating to compute, for each sector, the upper and lower envelopes of the technology frontiers of the old member states: to conserve on space, we only display in Figure 2 the resulting graphs for a subset of sectors. Not surprisingly, Germany lies on the upper envelope in sectors including 'electrical and optical equipments' and 'transport equipments', Great Britain outperforms others in 'food, beverages and tobacco', 'textiles and metal products', and Luxembourg in 'services'. Not surprisingly either, Greece and Portugal generally lag behind, being either on, or very close to, the lower envelope in all sectors. Worth mentioning is the position of Spain that performs almost as well as Italy in most sectors.

In Figure 3, we report (for the same selected sectors as in Figure 2) the efficiency position of the new EU-member states relative to the lower technology envelope of the older member countries. All the new member states are significantly below this frontier in all but a few sectors, with the exception of Slovenia and, to a lesser extent, Cyprus, as the graphs clearly illustrate. Note that in these graphs, the axes report logs. To give a better idea of the magnitude of the technology gap involved, we can compute the values of the shift parameters θ in equation (1) that would be necessary, everything else equal, to place the new member states on the lower envelope in each sector of activity. These numbers are reported in Table 2.

[9]We have explored the sensitivity of the estimated results with respect to the common value of σ^{Lab} –using values between 1.1 and 2.0– : absolute numbers obviously change, but the relative position turns out to be quite stable, except for Malta.

[10]It can be checked that for all sectors except Primary the estimated values of ω satisfy the symmetry condition (see CC (2006)) that $\omega > -\rho/(1+\rho))$ for $\sigma^{Lab} = 1.4$ which guarantees *interior* solutions with positive efficiency parameters. For Primary, the estimate of ω slightly falls short of the condition for a range of σ^{Lab} values chosen on both sides of 1.4; for $\sigma^{Lab} = 1.4$, $\hat{\omega} = 0.3965 < 0.4$.

Table 1: Estimated parameters for country/sector specific technology frontiers, 2007

	Primary			Food, Beverages and Tobacco			Textiles and Textile Prod.			Chemicals and Plastics			Basic and Fabricated Metals		
	$log(A_{sk}/A_{un})$	γ	B	$log(A_{sk}/A_{un})$	γ	B	$log(A_{sk}/A_{un})$	γ	B	$log(A_{sk}/A_{un})$	γ	B	$log(A_{sk}/A_{un})$	γ	B
Old Members															
AUT	2.24	0.954	2.52	2.81	0.913	3.24	2.81	0.913	3.23	2.81	0.913	3.66	2.81	0.913	3.58
BEL	0.83	1.071	3.22	1.57	1.056	4.14	1.57	1.056	3.95	1.57	1.056	4.89	1.57	1.056	4.32
DEU	2.60	0.987	2.91	3.17	0.875	2.98	3.17	0.875	3.24	3.17	0.875	3.87	3.17	0.875	3.55
DNK	1.07	1.011	3.23	1.49	1.034	4.18	1.49	1.034	4.02	1.49	1.034	4.54	1.49	1.034	4.06
ESP	-0.20	0.980	2.31	0.82	1.030	3.16	0.82	1.030	2.88	0.82	1.030	3.76	0.82	1.030	3.39
FIN	1.34	1.075	2.91	2.00	1.066	3.95	2.00	1.066	3.62	2.00	1.066	4.19	2.00	1.066	4.01
FRA	1.20	1.063	3.15	1.87	1.006	3.65	1.87	1.006	3.65	1.87	1.006	4.54	1.87	1.006	3.94
GBR	2.16	0.916	3.12	2.21	0.952	4.25	2.21	0.952	4.25	2.21	0.952	4.25	2.21	0.952	4.25
GRC	-0.47	0.966	2.31	0.68	1.084	2.68	0.68	1.084	2.35	0.68	1.084	2.80	0.68	1.084	2.94
IRL	0.11	1.057	2.93	1.73	1.048	3.52	1.73	1.048	3.24	1.73	1.048	3.93	1.73	1.048	3.38
ITA	0.35	0.916	2.47	0.79	1.043	3.50	0.79	1.043	3.24	0.79	1.043	3.91	0.79	1.043	3.49
LUX	0.74	1.021	3.24	1.50	1.003	3.35	1.50	1.003	3.75	1.50	1.003	4.01	1.50	1.003	4.22
NLD	1.30	0.994	3.41	1.64	0.990	4.01	1.64	0.990	3.79	1.64	0.990	4.34	1.64	0.990	3.92
PRT	-3.10	1.031	1.96	-0.22	0.947	2.36	-0.22	0.947	2.06	-0.22	0.947	2.83	-0.22	0.947	2.38
SWE	1.17	1.088	3.33	1.80	1.087	3.93	1.80	1.087	3.84	1.80	1.087	4.41	1.80	1.087	3.95
New Members															
BGR	-2.55	0.957	1.15	-0.22	0.947	1.24	-0.22	0.947	1.13	-0.22	0.947	1.36	-0.22	0.947	1.45
CYP	0.31	1.026	2.01	0.89	1.089	2.50	0.89	1.089	2.14	0.89	1.089	2.63	0.89	1.089	2.85
CZE	3.14	1.000	1.94	3.32	0.989	2.00	3.32	0.989	1.80	3.32	0.989	2.17	3.32	0.989	2.12
EST	2.77	0.985	1.84	2.14	1.099	2.20	2.14	1.099	1.75	2.14	1.099	2.23	2.14	1.099	2.14
HUN	1.94	0.988	1.71	2.71	0.938	1.78	2.71	0.938	1.38	2.71	0.938	2.14	2.71	0.938	1.88
LTU	2.05	1.006	1.64	2.49	1.110	1.95	2.49	1.110	1.69	2.49	1.110	2.36	2.49	1.110	2.45
LVA	1.38	1.037	2.47	2.32	1.021	1.86	2.32	1.021	1.66	2.32	1.021	2.14	2.32	1.021	2.06
MLT	-2.53	0.975	1.78	-0.22	0.947	2.67	-0.22	0.947	2.45	-0.22	0.947	2.05	-0.22	0.947	2.73
POL	2.28	0.957	1.94	3.63	0.930	1.77	3.63	0.930	1.28	3.63	0.930	2.06	3.63	0.930	1.71
ROU	-3.02	1.022	1.77	-0.22	0.947	1.99	-0.22	0.947	1.38	-0.22	0.947	1.98	-0.22	0.947	1.75
SVK	3.36	0.966	1.67	4.09	0.927	1.72	4.09	0.927	1.49	4.09	0.927	1.82	4.09	0.927	2.01
SVN	1.16	0.976	2.53	2.35	0.979	2.57	2.35	0.979	2.22	2.35	0.979	2.96	2.35	0.979	2.58
ω	0.3965			0.4101			0.4101			0.4101			0.4101		

	Electrical and Optical Equip.			Transport Equip.			Construction			Other Manufacturing			Services		
	$log(A_{sk}/A_{un})$	γ	B	$log(A_{sk}/A_{un})$	γ	B	$log(A_{sk}/A_{un})$	γ	B	$log(A_{sk}/A_{un})$	γ	B	$log(A_{sk}/A_{un})$	γ	B
Old Members															
AUT	2.81	0.910	3.74	2.81	0.913	3.85	2.68	0.915	3.25	2.81	0.913	3.52	3.32	0.939	3.45
BEL	1.57	1.053	4.50	1.57	1.056	4.70	0.84	1.058	3.98	1.57	1.056	4.34	2.32	1.067	4.24
DEU	3.17	0.873	3.90	3.17	0.875	4.36	3.17	0.864	2.94	3.17	0.875	3.53	3.47	0.945	3.39
DNK	1.49	1.031	4.37	1.49	1.034	4.23	1.69	0.988	3.97	1.49	1.034	4.20	2.22	1.044	4.11
ESP	0.82	1.026	3.42	0.82	1.030	3.52	-0.16	1.030	3.11	0.82	1.030	3.31	1.80	1.009	3.29
FIN	2.00	1.062	4.36	2.00	1.066	4.04	1.38	1.066	3.76	2.00	1.066	4.13	2.48	1.098	3.86
FRA	1.87	1.003	4.23	1.87	1.006	4.28	1.26	1.007	3.56	1.87	1.006	3.98	2.14	1.060	4.09
GBR	2.21	0.949	4.23	2.21	0.952	4.25	1.75	0.993	3.91	2.21	0.952	4.25	2.44	1.047	3.82
GRC	0.68	1.080	2.86	0.68	1.084	2.98	-0.42	1.083	2.43	0.68	1.084	2.68	2.23	1.040	2.89
IRL	1.73	1.044	3.65	1.73	1.048	3.57	0.81	1.067	3.96	1.73	1.048	3.63	2.74	0.988	3.68
ITA	0.79	1.039	3.66	0.79	1.043	3.75	-0.13	1.029	3.15	0.79	1.043	3.55	1.76	1.040	3.52
LUX	1.50	0.999	3.79	1.50	1.003	3.35	-0.14	1.030	3.47	1.50	1.003	4.03	2.49	0.978	4.13
NLD	1.34	1.075	4.09	1.64	0.990	3.97	1.17	1.009	3.92	1.64	0.990	3.80	2.46	1.012	3.89
PRT	-0.22	0.943	2.88	-0.22	0.947	2.75	-0.95	0.932	2.24	-0.22	0.947	2.43	1.35	0.923	2.70
SWE	1.80	1.083	4.52	1.80	1.087	4.23	1.49	1.089	3.98	1.80	1.087	4.12	2.48	1.134	4.20
New Members															
BGR	-0.22	0.943	1.39	-0.22	0.947	1.55	-0.95	0.932	1.22	-0.22	0.947	1.34	1.12	0.968	1.43
CYP	0.89	1.085	2.79	0.89	1.089	2.81	0.49	1.079	2.82	0.89	1.089	2.95	3.34	0.918	2.74
CZE	3.32	0.986	2.11	3.32	0.989	2.29	3.81	0.987	1.97	3.32	0.989	2.08	4.36	1.004	2.23
EST	2.14	1.096	2.47	2.14	1.099	2.15	1.68	1.082	2.14	2.14	1.099	2.30	3.95	1.018	2.24
HUN	2.71	0.935	1.87	2.71	0.938	2.12	2.49	0.988	1.67	2.71	0.938	1.93	3.85	0.971	2.18
LTU	2.49	1.107	2.26	2.49	1.110	2.25	2.25	1.077	2.06	2.49	1.110	2.12	4.03	1.082	2.08
LVA	2.32	1.018	1.92	2.32	1.021	2.10	1.64	1.060	2.48	2.32	1.021	1.90	3.72	1.003	2.09
MLT	-0.22	0.943	2.49	-0.22	0.947	6.05	-0.95	0.932	1.94	-0.22	0.947	2.61	1.25	0.948	2.53
POL	3.63	0.928	1.90	3.63	0.930	1.72	3.09	0.922	1.71	3.63	0.930	1.77	4.87	0.944	1.95
ROU	-0.22	0.943	1.48	-0.22	0.947	1.68	-0.95	0.932	1.61	-0.22	0.947	1.73	1.07	0.973	1.80
SVK	4.09	0.925	1.67	4.09	0.927	1.91	4.02	0.949	1.75	4.09	0.927	1.75	5.09	0.946	1.80
SVN	2.35	0.976	2.61	2.35	0.979	2.63	2.48	0.954	2.40	2.35	0.979	2.56	4.40	0.943	2.71
ω	0.4100			0.4101			0.4054			0.4101			0.4027		

Figure 2: Lower and upper envelopes of old members' technology frontiers, selected sectors, 2007

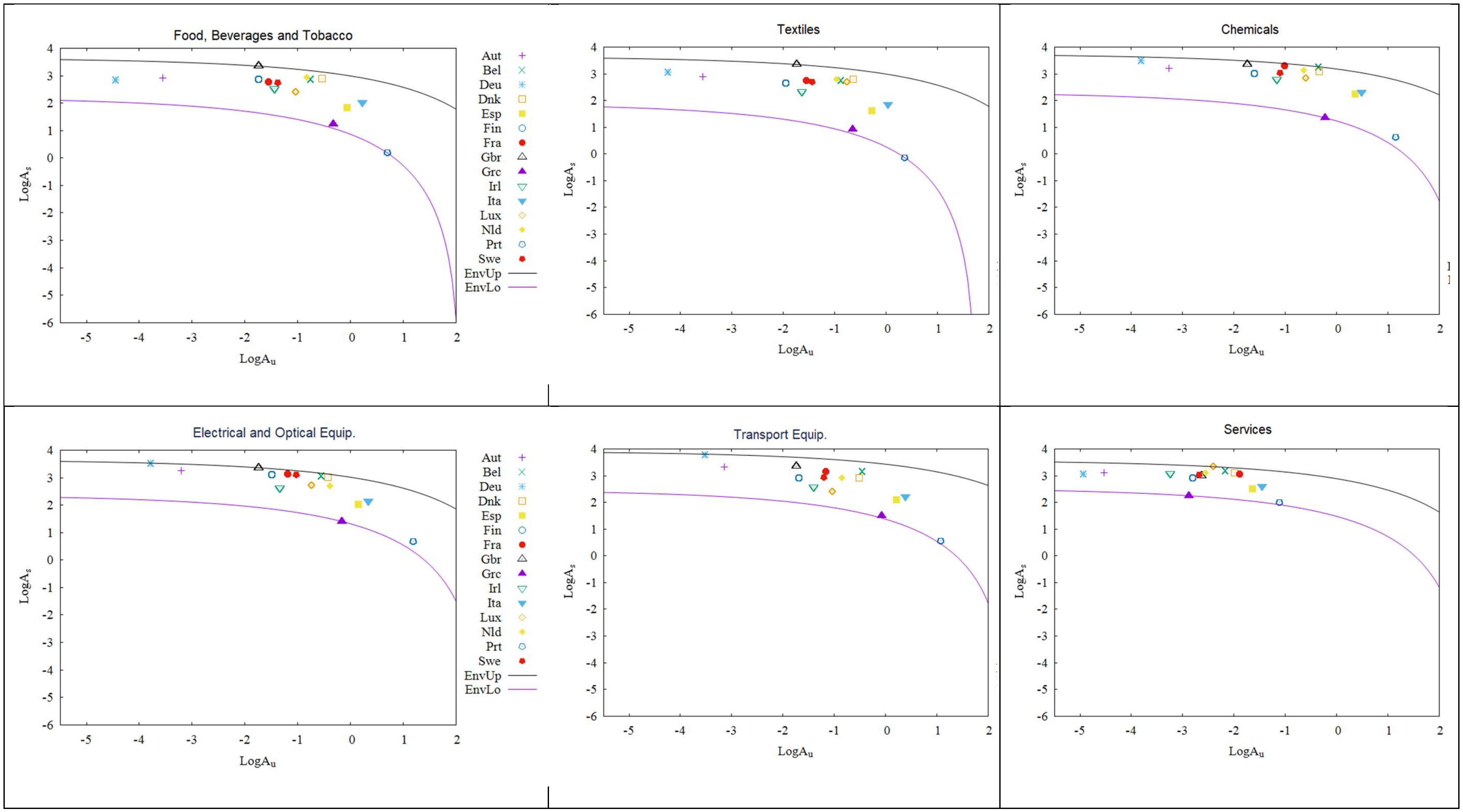


Figure 3: Technology gap between new members and lower envelope of old members, selected sectors, 2007

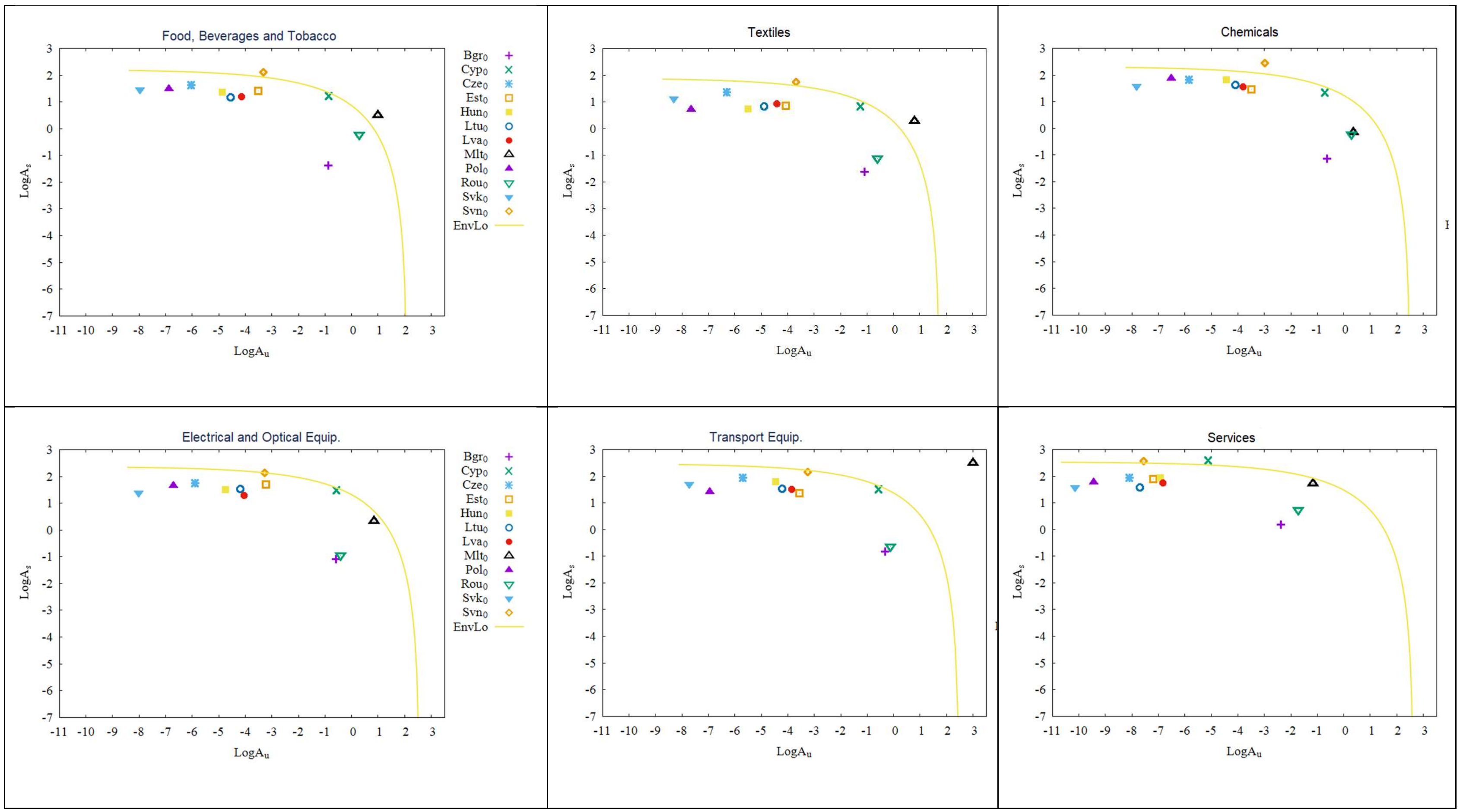


Table 2: Computed θ-values for new members to reach the lower envelope technology frontier of incumbent members, 2007

	Primary	Food, Beverage Tobaco	Textiles	Chem. & Plastics	Basic Metals	Electric & Opt. Equip.	Transport Equip.	Constr.	Other Man.	Services
BGR	3.79	4.76	4.33	4.98	3.35	4.98	3.86	4.26	4.08	5.02
CYP	1.00	1.08	1.15	1.16	1.00	1.06	1.10	1.00	1.00	1.00
CZE	1.00	1.62	1.52	1.49	1.47	1.68	1.51	1.33	1.47	1.73
EST	1.05	1.60	2.03	1.78	1.79	1.47	2.23	1.31	1.45	1.78
HUN	1.28	1.91	2.59	1.39	1.75	2.02	1.63	2.00	1.56	1.70
LTU	1.49	2.24	2.28	1.60	1.33	1.86	2.06	1.45	1.83	2.47
LVA	1.00	2.08	1.98	1.68	1.67	2.31	2.03	1.00	1.98	2.04
MLT	1.25	1.00	1.00	1.84	1.00	1.20	1.00	1.37	1.00	1.16
POL	1.00	1.89	3.01	1.46	2.14	1.89	2.65	1.62	1.89	2.08
ROU	1.28	1.50	2.63	2.00	2.11	4.25	3.17	2.16	2.20	2.85
SVK	1.28	2.02	2.06	1.97	1.44	2.53	2.04	1.63	1.92	2.56
SVN	1.00	1.00	1.00	1.00	1.00	1.00	1.06	1.00	1.00	1.00

3 On EU enlargement: a reinterpretation

The previous section has documented the existence of quite systematic technology differences between old and new EU member countries in 2007. Part of these differences reflect differences in factor endowments, as suggested by the 'appropriate-technology' literature. However, other explanations have to be provided for such strong differences in efficiency: the results clearly suggest existence of significant barriers to technology adoption in the recent past. Indeed, 20^{th} century history, and the fact that most –all except Cyprus and Malta– of the new member states under consideration were part of the Soviet bloc, favor an explanation based on restrictions to foreign trade and international capital, as well as to institutions not too favorably inclined towards competitive innovations or to regulations that restrict foreign access, that is, to all factors that limit adoption of better technologies. If that is indeed the case, then one should expect that, for those economies, joining the EU will not only mean removal of the barriers to trade, but also elimination of restrictions to capital flows, harmonization of legislation and regulations regarding intellectual property rights, international competition policy, product standards etc., leading to deeper integration.

Therefore, joining the EU, will not only induce the type of reallocations predicted, conditional on given technologies, by standard trade theory, but also

–and indeed possibly more importantly– it is likely to induce technological catch-up. To make this definition of 'deep integration' a workable concept, we still need to quantify the technology gap that can be attributed to previous barriers to technology adoption. The econometric results of the previous section provide a rather natural –and arguably conservative– candidate measure for this gap: the country's efficiency position relative to the lower technology envelope of incumbent member states. We attribute to the past barriers to technology adoption the responsibility for the new members' position below the lower envelope technology frontier of incumbent member states. Hence, by removing these barriers, integration within the EU should induce a shift of the TLP parameters θ so as to place the new member states on this lower envelope. The amplitude of the shift involved is precisely what has been reported in Table 2.

Such a shock would have, if not limited interest, at least predictable consequences if it were experienced by a single country. In contrast, experienced by all new EU members simultaneously, it is likely to have non trivial indirect effects on incumbent member states, in particular on factor-income distribution, and more specifically on wages. These effects have of course never been evaluated: in the remainder of this paper, we shall provide a quantitative exploration of these issues by use of a calibrated GE model of production, trade, and growth.

4 Measuring EU enlargement: deep integration

4.1 The numerical methodology

We provide in this section a non-technical description of the main features of the numerical methodology, and relegate to Appendix B a detailed presentation of the equations of the GE model.

The year chosen for model calibration purposes is of course the same as the one used in our econometric estimations, 2007.[11] The choice of an appropriate base year is both important and difficult, particularly so, when the model is dynamic and calibration assumes a steady state. We choose year 2007 for the following reasons. 2007 is three years after the most important enlargement vague of the Union, with Cyprus, the Czech Republic, Estonia, Latvia, Lithuania, Hungary, Malta, Poland, Slovakia and Slovenia joining in: hence, we can reasonably assume that the standard direct reallocation effects of the removal of trade costs and restrictions (the effects of shallow integration) are already essentially reflected in the data for these countries. 2007 is also the year Bulgaria and Romania have formally joined the Union: even though most trade barriers have likely been de facto removed prior to that date, picking a base year a few years later would seem to have been better (in particular, more consistent with our assumption of negligible trade costs). However, 2007 is also prior to a decade

[11] We make use of detailed social accounting matrices for year 2007 based on Álvarez-Martínez and López-Cobo (2016), marginally complemented by WIOD data on employment and wages.

of severe recession, any year of which would clearly fail to qualify as a proper candidate for an approximate steady state equilibrium. For these reasons, year 2007 appears to be the most recent best compromise for our purpose.

The model is infinite horizon intertemporal, time-aggregated into two periods, a short term (t_1) and a long term (t_2), separated by a span of 30 years after which steady-state is imposed.[12] We are interested in deviations w.r.t. a reference path, and therefore abstract from exogenous trends.

The model includes the 27 member states of the European Union in 2007; all countries have identical structures; the model is closed by a 'rest-of-the-world' (here after RoW) that is kept exogenous except for the volume of its bilateral trade which is price responsive. The RoW prices serve as numeraire.

In each country, all national households are aggregated into a single representative agent endowed with constant elasticity of intertemporal substitution preferences (with substitution elasticity parameter denoted σ). The agent is also endowed with two types of labor, skilled and unskilled, that she allocates endogenously, within the country, to different sectors of activity in response to wage differentials. Intersectoral reallocations are very limited in the short run but made significantly easier in the second period. Households also own assets in the form of bonds and claims on physical capital, the latter of which they accumulate by endogenous savings decisions made by lifetime utility maximization, with consumption smoothing on the basis of the returns expected to be reaped from future capital ownership. Aggregate household consumption is –as are all other components of the demands for goods– allocated to different industries using optimal demand systems derived from multi-level CES (including possibly Dixit-Stiglitz sub-nests).

On the production side, we distinguish between ten broad sectors of activities. For a subset of these industries (namely, Primary; Other Manufacturing; and Services) we assume perfect competition with firms making use of constant returns to scale (hereafter CRS) production functions to produce homogeneous goods; the technology combines intermediate goods and production factors –capital, skilled and unskilled labor– through nested-CES structures. The remaining industries (namely Food, Beverages and Tobacco; Textiles and Textile Production; Chemicals and Plastics; Basic and Fabricated Metals; Electrical and Optical Equipment; Transport Equipment; Construction) may either be treated similarly, or assumed to be populated by symmetric (within national boundaries) producers operating increasing returns to scale (hereafter IRS) technologies to produce differentiated varieties within Nash games in prices (i.e., monopolistic competition) with long-run zero profits ensured by free entry/exit. In these monopolistically competitive sectors, the individual firm faces a fixed production cost –which we assume in the form of a real amount of foregone output– which adds to its variable costs determined from a nested-CES structure identical to the one used in CRS sectors. Of particular interest in this nested structure is the value added, produced by a CES technology combining capital and aggregate composite labor, the latter factor itself resulting from a

[12]On time aggregation issues in intertemporal models, see Mercenier and Michel (1994).

CES aggregation of skilled and unskilled labor as displayed in equation (1): this is of course where the technological upgrading shock is imposed in t_2.

The public sector is present in the model for base year replication purposes, but assumptions are made to keep its behavior as neutral as possible (in particular, the stock of public bonds is kept constant with public consumption defined residually).

Importantly, the model has to capture two characteristic features of modern capital: first, extremely mobile financial capital should erase systematic differences in rates of return expected on capital by households within the EU. Second, in spite of this, the capital rental cost, for firms, is far from being equalized across countries. We capture these features by pooling all the physical capital of EU households into a single stock –this ensures that all capital owners earn the same rental price for their physical assets. The aggregate stock is then optimally allocated (by maximizing the rental revenues of the pooled capital) to each country within the Union, and to each sector within each country, subject to a two-level nested Constant Elasticity of Transformation (CET) constraint.[13] The values of the transformation elasticities govern the concavities of the allocation frontiers, and therefore provide a convenient characterization of how mobile physical capital is, both internationally (the upper-level CET, with elasticity denoted σ_{E27}^{K}), and intersectorally (the lower level CET, with elasticity denoted σ_i^K). Yet, calibration of the CETs on base year data ensures that the simulated counterfactual equilibrium allocation remains anchored to its initial geographical distribution. By adopting different values in time (that is at t_1 and t_2) for σ_{E27}^{K} and σ_i^K, we capture the fact that physical capital mobility in the long run exceeds substantially that of the short term, both internationally and intersectorally. Pooling all claims on physical capital into a single European stock also obviously requires pooling investment –a common unit cost of investment is in particular necessary for all capital owners to expect the same rate of return on their physical assets throughout Europe– which imposes some constraints on the modeling of investment: see Appendix B for details.

Each country's aggregate demand for an industry's goods is then converted into a trade matrix (with non-zero diagonal elements) using a CES allocation structure: the assumptions made are therefore, a single-level Armington scheme for CRS sectors, and a standard Dixit-Stiglitz structure for monopolistically competitive sectors.

The model is closed by imposing that supplies and demands balance on all markets. (Alternatively, we make labor supply endogenous by use of a reduced form wage curve.) With budget constraints imposed for all European agents, it is also satisfied for the *RoW* by Walras' law: we check that this is indeed the case. The welfare index we report, ψ_i, is defined as equivalent variation: see Appendix B.

The calibration of the model is made conditional on chosen values for a set of parameters, most of which are substitution/transformation elasticities: the

[13]When reading the results, one should therefore keep in mind that there is no simple link between capital ownership by national households and the amount of capital services in a country's GDP.

values adopted are reported in Appendix C, and are essentially borrowed from Mercenier et al. (2016).

Once the model is calibrated, it can be used to simulate the induced effects of the deep integration shock. This involves computing the new equilibrium allocation and price system consistent with the new exogenous values of the total-labor-productivity shift parameters θ reported in Table 2. Because the technological catch-up will take time to materialize, we impose this exogenous shift in TLP at time t_2 only.

Readers familiar with the new economic geography literature will have noted that we assume no international labor mobility. The reason for this is that we want to limit the risk of equilibrium multiplicity that (as we know from Krugman, 1991; Krugman and Venables, 1995 and others) generically characterize general equilibrium structures with monopolistic competition and endogenous geographical location of firms. Indeed, in absence of a numerical procedure to identify all possible equilibrium configurations, as well as of a theoretically sound mechanism to pick the 'most appropriate' among those possible outcomes, the risk is that the selection be arbitrarily made by a numerical algorithm (see Mercenier, 1995 for such a numerical illustration). By assuming no international mobility of labor we implicitly restrict our numerical search to a neighborhood of the initial (real world) equilibrium configuration on which the model is calibrated, a sound strategy.[14]

4.2 Simulation results

4.2.1 New member states

In the new member states, the mechanisms at work are quite straightforward to anticipate. In addition to boosting the new members' long-term competitiveness, the positive shock on future TLP will cause relative scarcity of capital in these economies, which will push the long-term rental price of capital upwards. This not only will tilt the optimal time profile of private consumption at the expense of short term levels as households substitute intertemporally, but also shift upwards their wealth constraint. Furthermore, attracted by extremely profitable returns, physical capital will flow massively from older to new member states in the long term (t_2) which will contribute to push further up the local household's intertemporal wealth constraint as well as the time profile of its consumption. The wealth effect might be massive enough to overpower the

[14]Also, recent intra-European migration history might seem at odds with our 'no international mobility' assumption. In order to avoid what would be a misunderstanding, it is worth stressing that the purpose of a counterfactual experiment is not to forecast nor to explain what is currently being observed (among other things, some intra-EU migration due to pre-existing absolute wage differences), but rather to evaluate how –and by how much in percentage terms– an exogenous shock is likely to deviate the economy from its initial equilibrium, *everything else equal*. Given that the technological catch-up of which we want to evaluate the effects is likely to improve the wages in the new member states relative to those of the old member states, the shock-induced migration is likely to be from old to new member states, hence contributing to reduce the observed flows due to pre-existing absolute wage differences.

effect of intertemporal substitution on short term consumption with some new member-states' households actually reducing their savings on the whole time horizon. The restructuring of short term aggregate demand will cause intersectoral shifts of activity, possibly in favor of more capital intensive sectors, which could attract some (modest amount of) capital out of old member states also in the short term, and therefore increase GDP also in t_1. All these effects will contribute to increase aggregate welfare, despite the fact that in some countries, capital intensive sectors are on average also more skilled-labor intensive, so that in the short run, low-skilled workers could experience slightly falling real wages.

The above description indeed applies to most new member states, as Table 3 reveals, with aggregate gains that prove quite robust to the type of competition assumed (as well as to changes in important parameter values –unreported to conserve on space).

The only new member countries that make exception to the above narrative are Cyprus and Slovenia. The reason for this is quite obvious: in all but a few sectors, these two countries lie close to or above the EU low-envelope technology frontier –see Table 2– so that they essentially experience only the indirect effects of their neighbor's technology upgrading shocks (as do all the incumbent member states). For Cyprus, even though aggregate welfare only slightly improves in all scenarios, intersectoral adjustments are quite drastic with foreign competition inducing a strong reallocation effect in favor of relatively skilled-labor intensive sectors which quite unambiguously hurts the least skilled workers in the long run. The welfare impact on Slovenia is essentially non-significantly different from zero as it fluctuates by very small amounts around the null with changes in parameter values.

Table 3: Computed effects of 'deep integration' shock on new member states: % deviations w.r.t. initial steady state

ψ = welfare; Con = private consumption; K^{Sup}= capital supplied locally; rw_{sk}, rw_{un} = real wages skilled, unskilled

CRS (σ = 1.3 , σ^{K}_{E27}= 2.0)

	BGR	CYP	CZE	EST	HUN	LTU	LVA	MLT	POL	ROU	SVK	SVN
ψ	18.3	0.3	6.8	13.9	8.2	11.1	17.7	1.9	6.2	11.2	5.6	0.0
Con_{t_1}	9.6	–0.6	3.1	10.3	4.2	6.1	12.4	0.4	1.9	5.8	1.1	–0.8
Con_{t_2}	40.2	2.3	15.8	22.4	17.4	23.0	30.4	5.3	16.4	24.2	16.1	1.7
$K^{Sup}_{t_1}$	0.2	0.0	0.1	0.1	0.1	0.1	0.2	0.0	0.0	0.2	0.0	0.0
$K^{Sup}_{t_2}$	51.8	1.2	15.7	20.5	20.1	29.0	24.8	7.1	21.0	30.6	19.2	0.9
GDP_{t_1}	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0
GDP_{t_2}	138.2	0.8	34.3	42.6	44.6	64.7	49.1	14.0	45.9	72.1	44.5	0.4
rw_{sk,t_1}	1.3	0.0	0.2	0.5	0.3	0.4	0.6	0.1	0.1	0.4	0.1	0.1
rw_{sk,t_2}	101.5	1.3	30.9	38.6	37.5	58.8	48.5	2.9	41.3	57.5	39.6	0.8
rw_{un,t_1}	0.5	0.3	0.0	–0.3	0.1	0.0	–0.3	0.2	0.0	–0.1	0.0	0.2
rw_{un,t_2}	131.4	–1.1	38.2	24.5	58.9	36.3	50.3	23.6	65.1	77.8	69.1	1.2

IRS (σ = 1.3 , σ^{K}_{E27} = 2.0)

	BGR	CYP	CZE	EST	HUN	LTU	LVA	MLT	POL	ROU	SVK	SVN
ψ	22.7	0.6	15.3	20.8	12.9	14.0	22.4	3.0	6.9	16.3	6.0	0.2
Con_{t_1}	14.2	–1.2	15.9	17.5	9.9	8.9	17.4	1.8	4.7	12.9	3.0	–1.2
Con_{t_2}	43.7	4.8	14.0	28.5	19.8	26.2	34.1	5.6	12.1	24.2	13.1	3.2
$K^{Sup}_{t_1}$	0.2	0.0	0.2	0.2	0.1	0.2	0.4	0.0	0.1	0.4	0.1	0.0
$K^{Sup}_{t_2}$	32.8	3.6	18.8	16.9	16.7	19.0	17.5	10.2	19.7	21.5	17.7	3.7
GDP_{t_1}	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.0	0.1	0.2	0.1	0.0
GDP_{t_2}	122.3	2.0	46.6	42.2	44.8	60.1	46.1	16.7	47.1	69.6	45.9	1.7
rw_{sk,t_1}	1.9	0.0	0.6	0.9	0.7	0.6	0.9	0.2	0.3	1.0	0.2	0.1
rw_{sk,t_2}	133.3	2.6	70.4	54.5	58.2	74.2	58.4	6.1	59.3	88.7	59.8	1.8
rw_{un,t_1}	0.7	0.6	–0.4	–0.4	0.2	0.0	–0.3	0.4	–0.1	–0.2	–0.1	0.4
rw_{un,t_2}	174.8	–3.7	106.6	43.4	86.0	51.3	62.6	37.8	91.4	112.9	106.4	1.9

4.2.2 Old member states

Old member states are only indirectly affected by the trade shock, and for this reason, the outcome of the enlargement process on these economies is more difficult to anticipate. Two mechanisms are dominantly at work here, with conflicting implications for workers' welfare. Firstly, the rise in second-period rental price of capital in new member states induces an outflow of that factor from incumbent member countries, which contributes to reduce their second-period GDP and to push local wages down. Secondly –and consequently—the rising expected future return to capital induces local households to substitute future to short term consumption which makes second-period capital endowments higher, hence pushing up GDP and wages. The welfare outcome for workers will therefore crucially depend on the values of two elasticities: the CET parameter σ^K_{E27} that governs how easily physical capital can be relocated internationally in the long run, and the intertemporal CES paremeter σ that determines how responsive the t_2-supply of capital is to future profit opportunities expected in t_1. We shall therefore report in Table 4 results for combinations of high and low values of these two parameters, with σ=1.3 or 0.7; and long-run (t_2) values of σ^K_{E27}=2.0 or 0.5.

Other mechanisms will of course influence these effects. In particular, acknowledging the possibility of imperfect competition in some sectors will affect GDP because endogenous variety (due to exit/entry of competitors) affects the cost to firms of intermediate inputs, as well as the cost of living for consumers. The results reported in Table 5 indeed acknowledge the contribution of these additional mechanisms.[15]

Inspection of Table 4 reveals that, quite robustly w.r.t. changes in parameter values, most –but not all– countries benefit from the EU enlargement shock: in some scenarios, Spain and Sweden could indeed experience extremely modest losses, but the aggregate welfare cost for Denmark is more substantial –ranging between -0.5% and -0.9%– and turns out to be quite robust. The reason behind the deterioration of these countries' intertemporal terms of trade seems to lie essentially in the relatively high share of non-physical assets in their total wealth (with Denmark as the extreme case).

[15] We also explore the possibility for labor supply to be endogenized using a reduced form wage curve, but the contribution of this mechanism turns out to be so minor that we do not report any results for this case.

Table 4: Computed effects of 'deep integration' shock on old member states, CRS: % deviations w.r.t. initial steady state

ψ = welfare; Con = private consumption; K^{Sup}= capital supplied locally; rw_{sk}, rw_{un} = real wages skilled, unskilled

CRS, high international mobility of capital (σ^K_{E27}= 2.0)

	AUT		BEL		DEU		DNK		ESP		FIN		FRA		GBR		GRC		IRL		ITA		LUX		NLD		PRT		SWE	
σ	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**
ψ	0.2	0.3	0.1	0.1	0.4	0.4	−0.9	−0.8	−0.1	0.0	0.1	0.2	0.1	0.1	0.2	0.2	0.5	0.6	0.2	0.3	0.3	0.4	0.4	0.5	0.2	0.3	0.0	0.1	−0.2	−0.1
Con_{t_1}	−0.9	−0.7	−0.8	−0.6	−0.6	−0.5	−1.6	−1.4	−0.7	−0.6	−0.7	−0.6	−0.6	−0.6	−0.6	−0.6	−0.5	−0.5	−0.6	−0.5	−0.6	−0.5	−0.6	−0.5	−0.6	−0.6	−0.6	−0.6	−1.0	−0.8
Con_{t_2}	2.8	2.6	1.9	2.0	2.5	2.6	0.6	0.7	1.2	1.3	2.0	2.0	1.7	1.7	2.0	2.1	2.9	3.0	2.1	2.1	2.4	2.5	2.7	2.7	2.2	2.2	1.5	1.6	1.6	1.6
$K^{Sup}_{t_1}$	6.4	5.1	5.0	4.3	5.1	4.7	10.2	8.8	4.0	3.4	4.9	4.4	4.9	4.6	6.6	6.7	5.7	5.4	3.2	2.7	5.0	4.6	3.4	3.0	4.2	3.8	5.5	5.4	6.7	5.8
$K^{Sup}_{t_2}$	0.6	−0.6	0.8	−0.4	1.0	−0.2	0.8	−0.4	0.9	−0.3	0.8	−0.4	0.9	−0.2	1.0	−0.1	1.1	−0.1	0.8	−0.5	1.1	−0.2	0.5	−0.7	0.8	−0.4	0.9	−0.2	0.7	−0.4
GDP_{t_1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GDP_{t_2}	0.3	−0.3	0.3	−0.2	0.4	−0.1	0.3	−0.1	0.4	−0.1	0.3	−0.2	0.4	−0.1	0.4	−0.1	0.6	−0.1	0.4	−0.3	0.6	−0.1	0.3	−0.4	0.3	−0.2	0.4	−0.1	0.3	−0.2
rw_{sk,t_1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
rw_{sk,t_2}	0.8	0.2	0.6	0.1	0.8	0.2	0.5	0.1	0.6	0.1	0.6	0.1	0.6	0.1	0.6	0.2	1.0	0.3	0.6	0.0	0.8	0.2	0.3	−0.3	0.6	0.1	0.6	0.2	0.6	0.2
rw_{un,t_1}	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.2	0.1	0.4	0.2	0.2	0.1	0.4	0.2	0.1	0.1	0.2	0.1	0.1	0.1
rw_{un,t_2}	1.0	0.4	0.6	0.1	0.7	0.2	0.5	0.1	0.6	−0.1	0.6	0.1	0.5	0.0	0.6	0.1	1.0	0.2	0.8	0.0	0.7	0.0	0.5	−0.2	0.6	0.0	0.5	−0.1	0.6	0.1

CRS, low international mobility of capital (σ^K_{E27}= 0.5)

	AUT		BEL		DEU		DNK		ESP		FIN		FRA		GBR		GRC		IRL		ITA		LUX		NLD		PRT		SWE	
σ	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**
ψ	0.3	0.4	0.1	0.2	0.4	0.4	−0.7	−0.5	0.0	0.1	0.2	0.2	0.1	0.2	0.2	0.3	0.5	0.6	0.4	0.4	0.3	0.4	0.5	0.6	0.3	0.4	0.1	0.1	−0.1	0.0
Con_{t_1}	−0.8	−0.6	−0.7	−0.5	−0.5	−0.5	−1.4	−1.1	−0.6	−0.4	−0.6	−0.5	−0.6	−0.5	−0.6	−0.6	−0.5	−0.4	−0.5	−0.3	−0.6	−0.5	−0.5	−0.4	−0.6	−0.5	−0.5	−0.5	−0.8	−0.7
Con_{t_2}	2.8	2.6	2.0	2.0	2.6	2.6	0.8	0.9	1.4	1.4	2.0	2.1	1.8	1.8	2.1	2.2	2.9	2.9	2.2	2.2	2.4	2.5	2.7	2.8	2.3	2.3	1.6	1.6	1.6	1.7
$K^{Sup}_{t_1}$	5.6	4.3	4.3	3.6	4.6	4.1	8.6	7.3	3.4	2.7	4.2	3.7	4.4	4.0	6.0	6.0	5.3	5.0	2.5	1.9	4.6	4.2	2.7	2.3	3.6	3.1	5.0	4.7	5.8	4.9
$K^{Sup}_{t_2}$	1.7	0.5	1.8	0.6	1.9	0.7	1.8	0.6	1.8	0.6	1.8	0.6	1.8	0.6	1.8	0.7	1.9	0.7	1.8	0.6	1.9	0.7	1.7	0.5	1.8	0.6	1.8	0.7	1.8	0.6
GDP_{t_1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GDP_{t_2}	0.8	0.2	0.7	0.2	0.8	0.3	0.6	0.2	0.8	0.3	0.8	0.3	0.7	0.3	0.7	0.3	1.1	0.4	0.9	0.3	1.0	0.4	0.8	0.2	0.8	0.3	0.7	0.3	0.6	0.2
rw_{sk,t_1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
rw_{sk,t_2}	1.2	0.7	1.0	0.5	1.1	0.6	0.8	0.4	1.0	0.4	1.0	0.5	0.9	0.4	0.9	0.5	1.4	0.7	1.0	0.4	1.2	0.6	0.8	0.2	0.9	0.4	0.9	0.5	0.9	0.5
rw_{un,t_1}	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.3	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.2	0.1	0.3	0.2	0.2	0.1	0.4	0.2	0.1	0.1	0.2	0.1	0.1	0.1
rw_{un,t_2}	1.4	0.8	1.0	0.5	1.1	0.5	0.8	0.4	0.9	0.3	1.0	0.4	0.9	0.4	0.9	0.4	1.4	0.6	1.2	0.4	1.1	0.4	1.0	0.2	0.9	0.4	0.8	0.2	0.9	0.4

The time profile of aggregate consumption adjusts, as expected, with households quite robustly accumulating more capital: second-period physical assets $K_{t_2}^{Hou}$ rise by some approximate 5% in all countries. The first-period outflow of capital is negligible so that short term production capacities, and therefore GDP_{t_1}, are essentially unaffected; real wages (expressed in terms of the price of the aggregate consumption basket) of both skilled and unskilled workers (rw_{sk} and rw_{un} respectively) either increase (mildly) or remain unaffected in all countries for all parameter configurations. In the second period, as we know, the amount of capital locally available for production ($K_{t_2}^{Sup}$) depends on the balance between induced accumulation and geographic relocation. When the value of σ is set to 1.3, the first effect systematically outperforms the second: $K_{t_2}^{Sup}$ unambiguously increases in all the old EU-member states, and so do aggregate output and real wages of both skilled and unskilled workers. Reducing the value of σ below unity breaks this robustness result: the signs of the changes in long-run production capacities, as well as that of GDP growth, now depend on how easily production capacities can be relocated within the EU. Quite remarkably, however, the down-push of goods' prices induced by the positive productivity shock of deep integration lowers the consumer price index, at least as much, if not more, than the wages for both skills in most countries, so that for all parameter configurations the large majority of workers in the old-member states see their purchasing power at worst unaffected, but in most cases improved, by the EU enlargement shock. The strongest exception to this claim is Luxembourg, where real wages could be eroded by less than half a percent depending on the parameter configuration used.

The numbers reported in Table 5 have been computed under the assumption that monopolistic competition prevails in a large subset of sectors.[16] We learn from this table that the aggregate welfare conclusions remain qualitatively the same as in the case of perfect competition, though quantitatively significantly amplified, confirming among other things, the possibility of a deterioration of the intertemporal terms of trade for Denmark, and, to a lesser extent, for Sweden and Spain, especially under high international mobility of capital (σ_{E27}^{K}=2.0). Intertemporal consumption smoothing behavior is of course unaffected, and forward looking households quite vigorously accumulate physical assets, and indeed more so than under overall perfect competition. The only short term effects are induced by demand restructuring (the demand for investment goods rising at the expense of private consumption), with real wages remaining essentially unaffected, the heaviest loss of -0.1% being for Portuguese skilled workers. The sign of the long term effects on GDP again depends on the balance between the households' willingness to smooth their consumption through time, and the second period speed of international capital mobility: it is not affected by the change in the competitive game assumption on product markets. Assuming IRS technologies and imperfect competition only amplifies the magnitude of the effects. The 'best case' scenario –with strong response of saving (high σ)

[16] Food, Beverages and Tobacco; Textiles and Textile Production; Chemicals and Plastics; Basic and Fabricated Metals; Electrical and Optical Equipment; Transport Equipment; and Construction.

and not too highly mobile physical capital between countries (σ^K_{E27} low)– is characterized by a widespread boost of aggregate activity, with GDP growth rates between 1.1% (Denmark) and 2.3% (Greece), against 0.6% and 1.1% for the same countries when perfect competition prevails. Real wages unambiguously increase for all workers, at a pace included between 1.2% and 2.9% for the skilled and between 1.0% and 3.0% for the unskilled. The 'worst case' scenario, on the other hand, suggests the possibility of a bleaker outcome for workers: when intertemporal substitution in consumption is not strong enough (σ=0.5) and physical capital displaces easily across national borders (σ^K_{E27}=2.0). The outflow of capital is in this case large enough to reduce physical capital available to firms in older EU member countries; wages are unambiguously pushed downward. All workers are negatively impacted with unskilled workers generally suffering the heaviest losses in most countries; real wages fall by percent amounts between -0.2 and -1.2 for the skilled workers, between -0.2 and -1.6 for unskilled workers. Though these unpleasant results are associated with a somewhat extreme parameter configuration, such a configuration is not completely unlikely. The results should therefore raise concern, in particular in view of the fact that improving education alone, which is often thought as a cure-all policy, is unlikely to be enough.

Table 5: Computed effects of ‘deep integration’ shock on old member states, IRS: % deviations w.r.t. initial steady state

ψ = welfare; Con = private consumption; K^{Sup}= capital supplied locally; rw_{sk}, rw_{un} = real wages skilled, unskilled

IRS, high international mobility of capital (σ_{E27}^{K}=2.0)

	AUT		BEL		DEU		DNK		ESP		FIN		FRA		GBR		GRC		IRL		ITA		LUX		NLD		PRT		SWE	
σ	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**
ψ	0.4	0.4	0.0	0.1	0.7	0.6	−2.1	−1.6	−0.3	−0.1	0.1	0.2	−0.1	0.0	0.3	0.3	1.1	0.9	0.4	0.2	0.7	0.7	0.9	0.9	0.5	0.5	0.1	0.1	−0.7	−0.4
Con_{t_1}	−1.5	−1.1	−1.8	−1.3	−1.4	−1.0	−3.5	−2.6	−1.5	−1.1	−1.6	−1.2	−1.8	−1.2	−1.5	−1.2	−1.0	−0.8	−1.3	−1.1	−1.4	−1.0	−1.1	−0.8	−1.3	−0.9	−1.3	−1.0	−2.3	−1.7
Con_{t_2}	4.8	4.0	4.1	3.3	5.7	4.5	0.9	0.8	2.6	2.3	4.1	3.4	3.7	3.0	4.3	3.7	5.9	5.1	4.2	3.3	5.6	4.5	5.7	4.8	4.6	3.8	3.2	2.8	3.0	2.6
$K_{t_1}^{Sup}$	10.8	8.5	12.3	9.0	12.4	9.2	22.1	16.9	9.1	6.5	11.4	8.8	14.3	10.2	15.7	12.8	11.4	9.0	7.4	6.3	11.7	8.2	7.0	4.9	8.9	6.5	12.2	9.9	16.1	11.9
$K_{t_2}^{Sup}$	1.7	−0.9	1.4	−1.0	1.8	−0.6	1.3	−0.9	1.6	−0.7	1.2	−1.3	1.1	−1.0	1.8	−0.5	2.7	−0.1	0.9	−2.3	2.2	−0.3	1.1	−1.2	1.5	−0.9	1.7	−0.7	1.0	−1.3
GDP_{t_1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GDP_{t_2}	0.8	−0.4	0.6	−0.4	0.8	−0.3	0.4	−0.3	0.7	−0.3	0.5	−0.6	0.5	−0.4	0.7	−0.2	1.5	0.0	0.5	−1.1	1.2	−0.2	0.5	−0.6	0.6	−0.4	0.7	−0.3	0.4	−0.4
rw_{sk,t_1}	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.2	0.2	0.1	0.0	−0.1	−0.1	0.0	0.0
rw_{sk,t_2}	1.1	−0.3	0.5	−0.6	1.1	−0.2	0.5	−0.3	0.9	−0.2	0.7	−0.4	0.0	−0.8	0.6	−0.3	2.2	0.6	0.7	−1.2	1.5	0.2	0.6	−0.5	1.0	0.0	1.0	0.0	0.4	−0.4
rw_{un,t_1}	0.1	0.0	0.3	0.1	0.2	0.1	0.1	0.0	0.6	0.3	0.3	0.1	0.2	0.1	0.1	0.0	0.4	0.2	0.7	0.4	0.3	0.2	0.9	0.5	0.3	0.1	0.5	0.3	0.2	0.1
rw_{un,t_2}	0.8	−0.6	0.2	−1.1	0.9	−0.4	0.3	−0.5	1.1	−0.3	0.6	−0.6	0.1	−0.8	0.5	−0.5	2.3	0.5	0.8	−1.6	1.3	−0.1	1.3	−0.2	0.9	−0.2	0.8	−0.4	0.1	−0.8

IRS, low international mobility of capital (σ_{E27}^{K}= 0.5)

	AUT		BEL		DEU		DNK		ESP		FIN		FRA		GBR		GRC		IRL		ITA		LUX		NLD		PRT		SWE	
σ	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**	**1.3**	**0.7**
ψ	0.6	0.5	0.3	0.3	0.9	0.7	−1.6	−1.0	0.0	0.2	0.4	0.3	0.2	0.2	0.4	0.4	1.1	0.9	0.6	0.6	0.8	0.7	1.2	1.0	0.7	0.6	0.2	0.2	−0.3	−0.1
Con_{t_1}	−1.3	−0.9	−1.5	−1.0	−1.2	−0.8	−2.9	−2.0	−1.2	−0.7	−1.3	−0.9	−1.4	−1.0	−1.4	−1.0	−1.0	−0.7	−1.1	−0.6	−1.3	−0.8	−0.9	−0.5	−0.9	−0.7	−1.2	−0.8	−1.9	−1.3
Con_{t_2}	4.9	3.8	4.2	3.2	5.7	4.2	1.4	1.2	2.9	2.3	4.3	3.3	3.9	3.0	4.7	3.5	6.1	4.7	4.6	3.4	5.6	4.3	6.0	4.6	4.6	3.6	3.5	2.7	3.4	2.6
$K_{t_1}^{Sup}$	9.5	6.7	9.8	6.7	10.8	7.5	18.6	12.8	7.4	4.5	9.4	6.6	11.4	7.9	15.1	10.8	11.3	7.8	6.1	3.8	11.0	6.9	5.8	3.4	6.3	4.9	11.1	7.8	12.9	9.2
$K_{t_2}^{Sup}$	3.7	0.9	3.5	0.8	3.6	0.9	3.3	0.8	3.5	0.9	3.4	0.7	3.4	0.8	3.5	1.0	4.0	1.2	3.3	0.6	3.7	1.1	3.4	0.8	3.6	0.9	3.5	0.9	3.3	0.7
GDP_{t_1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GDP_{t_2}	1.7	0.4	1.5	0.3	1.6	0.4	1.1	0.3	1.6	0.4	1.4	0.3	1.4	0.3	1.4	0.4	2.3	0.7	1.7	0.3	2.0	0.6	1.7	0.4	1.5	0.4	1.4	0.4	1.2	0.3
rw_{sk,t_1}	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.2	0.1	0.1	0.0	−0.1	−0.1	0.0	0.0
rw_{sk,t_2}	1.9	0.5	1.7	0.3	2.0	0.5	1.2	0.3	1.9	0.6	1.9	0.5	1.4	0.2	1.3	0.3	2.9	1.2	1.7	0.3	2.3	1.0	1.7	0.5	2.2	0.7	1.8	0.7	1.6	0.3
rw_{un,t_1}	0.1	0.0	0.2	0.1	0.1	0.1	0.1	0.0	0.5	0.2	0.2	0.1	0.2	0.1	0.1	0.0	0.3	0.1	0.6	0.3	0.3	0.1	0.8	0.4	0.2	0.1	0.4	0.2	0.2	0.1
rw_{un,t_2}	1.6	0.3	1.4	0.0	1.8	0.4	1.0	0.1	2.0	0.6	1.8	0.3	1.4	0.2	1.2	0.2	3.0	1.1	1.7	−0.1	2.0	0.7	2.5	0.7	2.2	0.5	1.5	0.4	1.3	0.1

5 Conclusion

In this paper, we have explored the relative degree of technological efficiency characterizing the new and the incumbent member states of the EU in their use of skilled and unskilled labor in year 2007, at the time of the fifth enlargement wave. Our industry level econometric analysis indicates clear and systematic patterns of efficiency gaps for labor productivity between the two groups of countries. One most likely explanation, is that these relative inefficiencies are caused by barriers to technology adoption responsible for reducing international technology diffusion. 20^{th} century history and the fact that most of the new member states were part of the Soviet bloc give considerable credit to such explanations emphasizing the role of trade restrictions, institutions and policies, in the build-up of these barriers. For new member states therefore, joining the EU is likely to eliminate most of these impediments. Indeed, the disciplines required to reduce such technology adoption barriers are essentially the same as those discussed as necessary to achieve 'deep integration' within the EU, a concept that is widely used in trade policy discussions but defined somewhat informally. Bridging the literatures on 'barriers to technology adoption' and on 'deep integration', we have proposed a reinterpretation of the concept of 'deep integration' that can easily be implemented as a reduced form shock in numerical policy evaluation exercises.

Our appraisal of 'deep integration' takes the form of a technological upgrading of total labor productivity in new member states. The amplitude of this upgrading is inferred, rather naturally, from econometric estimation results as the TLP up-shift required to place these countries on the lower-envelope tech frontier of incumbent EU members. The resulting measure of the technological shock that is associated with 'deep integration' is arguably conservative since it is not unlikely that in a span of thirty years, some of these new member states could outperform some older member economies.

Though particularly relevant to the EU enlargement experience, our definition of deep integration is clearly not specific to that context. It can be implemented to evaluate any deep integration efforts, and in particular, in any single-country calibrated GE model for quantitative evaluation. One thing that makes the 2004-7 EU enlargement episode so special, is its size. Indeed, experienced simultaneously by ten new EU members, such a shock is likely to have non trivial, indirect general equilibrium effects, also on incumbent member states. A proper quantitative evaluation of these effects calls for a full country-disaggregated model of production and trade within the EU27. We have provided such a quantitative exploration by use of a numerical intertemporal GE model of the EU27, calibrated on 2007 data.

From a policy perspective, the main conclusion we reach, is that, for most parameter configurations, workers' welfare in incumbent member countries is not negatively impacted, despite the rather drastic improvement in competitiveness experienced by new members. In the current context of rising populism and widespread anti-EU resentment, this outcome is rather reassuring. However welcome as this conclusion may be, it should not over-shade the finding that, admittedly only with a specific model structure (most sectors subject to increasing returns to scale, with monopolistic competition and costless entry/exit of firms) and under a somewhat extreme but not entirely unlikely parameter configuration (low intertemporal substitution in consumption and high international mobility of physical capital), almost all workers of the old member states could experience a fall in the purchasing power of their wages. In this scenario, improving education alone, which often serves as a cure-all policy for European policy makers, is unlikely to be enough given that real wages of both skilled and unskilled workers fall alike.

The framework we have used in this paper could be extended, in several directions. First, it would obviously be worth investigating how the inclusion of physical capital endowments affects the relative position of countries' technology frontiers. This is far from being a trivial extension, however: it requires extending the estimation method to a three dimensional technology frontier, presumably assuming two-level nested CES technology structures.

Another short-coming of our analysis is that it is based on a cross-section estimation and therefore only builds on a snapshot; it is likely to miss potentially important dynamic forces actively at work, that could affect each country's relative technological position with respect to an evolving minimal "state-of-the-art" technical envelope. A dynamic approach to the estimation of the technology frontiers by use of panel-data techniques could provide more nuanced evaluations of the amplitude of the implicit barriers to technologies that existed prior to 2004-7.

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A Data

In following the procedure of backing out the sectorial technology frontiers of the E27 countries, we rely on the data from the World Input Output Database (WIOD) along with the data compiled by Álverez-Martinez and López-Cobo (2016). WIOD's Socio-Economic Accounts contain data on employment (in terms of number of workers, number of hours worked and respective shares w.r.t. educational attainment). Hence it is possible to construct, for each country and sector the skilled (L_{sk}) and unskilled (L_{un}) labor, associated wage rates (p^L_{sk} and p^L_{un}), skill-premium (p^L_{sk}/p^L_{un}) and the efficiency parameters (A_{sk} and A_{un}) of the model. The data on gross output and value added components as well as taxes on each type of labor are from the social accounting matrices by Álvarez-Martínez and López-Cobo (2016). Sectoral aggregation of the data is conducted under International Standard Industrial Classification (ISIC) Rev.3.

WIOD aggregates the seven International Standard Classification of Education (ISCED) levels of education into low, medium and high skill categories. In order to further aggregate the labor input into skilled and unskilled labor classes, we assume that the unskilled labor category in the model corresponds to low skilled labor, and the skilled labor category corresponds to medium and high skilled classifications of WIOD. Hence, it becomes possible to calculate the hourly wage rates of skilled and unskilled labor in each country/sector, making use of the data on labor compensation at the skill level and of the total number of hours worked by each skill category. Following the standard convention as in

CC (2006) that relative wages are equal to relative efficiency units, we construct the skilled labor by making use of the wage ratio of the high skilled labor to medium-skilled labor along with their respective shares in the hours worked.[17]

B Formal description of the calibrated GE Model

Endogenous countries belong to the set $E27$ which includes the 27 member states of the European Union in 2007, our base year; the model is closed by a 'rest-of-the-world' (here after RoW) that is kept exogenous except for the volume of its trade which is price responsive. The prices of the RoW serve as numeraire. Countries are indexed by $i, i' \in E27 \cup RoW$. All European countries have identical structures; in the description of the individual national economy that follows, we therefore drop the country subscript where no confusion can arise. The model is infinite horizon intertemporal, time-aggregated into two periods, a short term and a long term, separated by a span of 30 years after which steady-state is assumed. We drop the time subscript where no confusion can arise.

B.1. Households and assets

We aggregate all national households into a single representative agent. This agent is endowed with two types of labor, skilled and unskilled, indexed $l \in \{sk, un\}$, in amount $\overline{L_l^{Hou}}$ which she endogenously allocates to different sectors of activity:[18] $L_{l,s}^{sup}$ denotes the supply of labor type l to sector s. We model the household's allocation of labor across sectors as price-responsive resulting from labor income maximization subject to a constant elasticity of transformation (hereafter CET) frontier: a rising relative wage in one sector will therefore induce an inflow of labor to the sector, the size of which will depend on the value of an elasticity of transformation $\sigma_l^{L^{sup}}$; intersectoral mobility of labor is typically higher in the long than in the short run, and we therefore choose significantly higher values for $\sigma_l^{L^{sup}}$ in the second period. Solving the household's optimal labor allocation problem immediately yields the following supply

[17] An alternative method for calculating the skilled and unskilled labor categories would rely on the estimated *Mincerian* coefficients as in Caselli and Coleman (2006). Utilizing the estimated coefficients of Mincer equations from Roszkowska (2014) for years 2002 and 2010, we have calculated alternative indicators of L_{sk} and L_{un}. The results are comparable with difference in estimated coefficients around 1%.

[18] Upper-lining a variable indicates that it is assumed exogenous, fixed to its base year level.

system derived from first order conditions:

$$L^{sup}_{l,s} = \alpha^{L^{sup}}_{l,s} \left[\frac{p^{L^{sup}}_{l,s}}{p^{L^{Hou}}_{l}}\right]^{\sigma^{L^{sup}}_{l}} [1 - UR_l] \; \overline{L^{Hou}_{l}} \qquad l \in \{sk, un\} \tag{B.1}$$

$$\left[p^{L^{Hou}}_{l}\right]^{1+\sigma^{L^{sup}}_{l}} = \sum_{s} \alpha^{L^{sup}}_{l,s} \left[p^{L^{sup}}_{l,s}\right]^{1+\sigma^{L^{sup}}_{l}} \qquad l \in \{sk, un\} \tag{B.2}$$

where $p^{L^{sup}}_{l,s}$ is the price of labor type l earned by workers in sector s, $p^{L^{Hou}}_{l}$ is the ideal price aggregator over sectors for labor type l, and the αs are (simple transforms of) the CET share parameters;[19] observe that we have multiplied labor endowments by a factor $[1 - UR_l]$ that reflects the possible existence of unemployment at rate UR_l.

Households also own assets which they accumulate by endogenous savings decisions. We formally identify three types of assets:[20] claims on physical capital, local government bonds and bonds issued by the *RoW*, though we make the unrealistic –albeit innocuous– assumption that the two types of bonds are valued in the same price, the *RoW* price, and that they both carry the same nominal interest rate, the *RoW* interest rate.[21] We then write the national household's budget constraint as follows:

$$\begin{aligned} p^{Inv^{Hou}}_{t} \frac{K^{Hou}_{t+1}}{\kappa} + p^{RoW}_{t} \left[B^{Gov}_{t+1} + B^{RoW}_{t+1}\right] = Sav^{Hou}_{t} + p^{RoW}_{t-1} \left[B^{Gov}_{t} + B^{RoW}_{t}\right] \\ + p^{Inv^{Hou}}_{t} (1 - \delta) \frac{K^{Hou}_{t}}{\kappa} \end{aligned} \tag{B.3}$$

where $p^{Inv^{Hou}}$ is the unit price of new equipments, κ is a parameter that converts annual flow services of private capital (K^{Hou}) into a stock, Sav^{Hou} is private flow savings, δ is a depreciation rate assumed constant.[22] Private savings is flow income (Inc^{Hou}) minus income taxes ($Tx^{Inc^{Hou}}$), net transfers abroad

[19] Throughout this paper, the σs will refer to transformation (substitution) elasticity parameters from the CET (CES) functional form constraints from which optimal supplies (demands) are derived. Also, the αs will refer throughout the paper to (the same simple transforms of) the share parameters of the CET (CES) functions.

[20] For base year accounting reasons, we actually identify a fourth type of bond, one bought from other European governments. This stock is held constant, and therefore justified for base year accounting reasons only. We neglect writing this term in the equations to ease the reading of the model.

[21] As will be emphasized later, we shall further assume that they are in constant supply.

[22] Note that older vintages of capital net of depreciation are assumed valued as new equipments.

$(p^{Con^{Hou}}\overline{Tr^{Hou\rightarrow RoW}})$[23] and consumption expenditures $(p^{Con^{Hou}}Con^{Hou})$[24]:

$$Sav^{Hou} = Inc^{Hou} - T^{Inc^{Hou}} - p^{Con^{Hou}}\overline{Tr^{Hou\rightarrow RoW}} - p^{Con^{Hou}}Con^{Hou} \quad \text{(B.4)}$$

with taxes on income collected at fixed rates $\tau^{Inc^{Hou}}$:

$$T^{Inc^{Hou}} = \tau^{Inc^{Hou}} Inc^{Hou} \quad \text{(B.5)}$$

The household earns income by supplying production factor services, possibly earns unexpected super-natural profits from firms ($Prof^{Hou}$) in the short run, benefits from government transfers (a flow assumed constant in real terms though valued at public consumption deflator: $p^{Con^{Gov}}\overline{Tr^{Gov\rightarrow Hou}}$), and earns interests (at rate r^{RoW}) on its holding of bonds:

$$\begin{aligned} Inc^{Hou} = & \sum_{l} p_l^{L^{Hou}} \left[1 - UR_l\right] \overline{L_l^{Hou}} + p^{K^{Hou}} K^{Hou} + Prof^{Hou} \\ & + p^{Con^{Gov}} \overline{Tr^{Gov\rightarrow Hou}} + r^{RoW} p^{RoW} \left[B^{Gov} + B^{RoW}\right] \end{aligned} \quad \text{(B.6)}$$

The household makes its consumption decisions by maximizing its intertemporal utility subject to its budget constraint (B.3). Assuming CES intertemporal preferences (with substitution elasticity σ), perfect foresight and imposing steady state restrictions in the long run, the first order conditions yield

$$\left[\frac{Con_{t+1}^{Hou}}{Con_t^{Hou}}\right]^{1/\sigma} = \frac{p_t^{Con^{Hou}}}{p_{t+1}^{Con^{Hou}}} \frac{\left[1 + r_{t+1}^{K^{Hou}} - \frac{p_{t+1}^{Inv^{Hou}}}{p_t^{Inv^{Hou}}}\right]}{\rho} \quad \text{(B.7)}$$

where $p_t^{Inv^{Hou}}$ is the unit cost of investment goods, ρ is the rate of time preference, and $r_{t+1}^{K^{Hou}}$ is the rate of return expected at time t to be reaped on physical capital at time $t+1$:

$$1 + r_{t+1}^{K^{Hou}} = \frac{p_{t+1}^{K^{Hou}} \kappa + (1-\delta) p_{t+1}^{Inv^{Hou}}}{p_t^{Inv^{Hou}}} \quad \text{(B.8)}$$

The optimal composition of the aggregate consumption basket Con^{Hou}, as well as the ideal cost of living index $p^{Con^{Hou}}$ are jointly determined from intra-period utility maximization assuming CES preferences; from rearranging first

[23] There are also some transfers between EU households; these flows are kept constant and we drop them from the expressions to ease reading.

[24] It should be mentioned that in some sectors, inventory accumulation flows may be significantly different from zero; to limit spurious effects, we treat this residual component of demand as a constant term in the private sector's expenditures. We drop this term from the equation to ease reading.

order conditions, we obtain:

$$c_s^{Hou} = \alpha_s^{c^{Hou}} \left[\frac{p^{Con^{Hou}}}{p_s} \right]^{\sigma^{Con^{Hou}}} Con^{Hou} \tag{B.9}$$

$$\left[p^{Con^{Hou}} \right]^{1-\sigma^{Con^{Hou}}} = \sum_s \alpha_s^{c^{Hou}} \; [\, p_s]^{1-\sigma^{Con^{Hou}}} \tag{B.10}$$

where $\sigma^{Con^{Hou}}$ is the substitution elasticity, and the αs are (simple transforms of) the CES share parameters. This completes our description of the household.

B.2. Producers

Production sectors are indexed s or $s\prime$. Some of these industries are perfectly competitive with firms making use of constant returns to scale (hereafter CRS) production functions, others operate increasing returns to scale (hereafter IRS) technologies within an imperfectly competitive market structure. These two subsets of industries are identified respectively as S^{CRS} and S^{IRS}.

In sectors $s \in S^{IRS}$, firms are assumed symmetric within national boundaries. We describe the individual producer's behavior so that all variables refer to a single firm. A firm faces a fixed production cost which we assume in the form of a real amount of foregone output denoted by Fx_s; we then write the firms total production as $Z_s + Fx_s$ where Z_s represents the volume of sales. The presence of fixed costs introduces a wedge between average and marginal costs, respectively noted Av_s^{cost} and Ma_s^{cost}, which we formalize with the following relation:

$$Av_s^{cost} Z_s = Ma_s^{cost} \left[Z_s + Fx_s \right] \qquad s \in S^{IRS} \tag{B.11}$$

Large group monopolistic competition (i.e., competition in the form of a Nash game in prices) prevails so that firms' optimal pricing strategy is to mark-up price p_s^Z over marginal production costs:

$$\frac{p_s^Z - Ma_s^{cost}}{p_s^Z} = \frac{1}{\sigma_s^A} \qquad s \in S^{IRS} \tag{B.12}$$

where σ_s^A is the price elasticity of the demand curve that the firm faces. The definition of super-natural profits then immediately follows:

$$Prof_s = \left[p_s^Z - Av_s^{cost} \right] Z_s \qquad s \in S^{IRS} \tag{B.13}$$

In the other industries, those that belong to S^{CRS}, we set $Fx_s = 0$; perfect competition prevails and profit maximization imposes to firms to price their output at marginal cost:

$$p_s^Z = Ma_s^{cost} \qquad s \in S^{CRS} \tag{B.14}$$

In these industries, because of CRS, the scale of firms and their number are immaterial so we may set $N_s = 1$ for $s \in S^{CRS}$ without loss of generality: this will prove convenient as many equations below will then be written identically for all sectors.

Marginal costs result from choosing optimal bundles of various variable inputs conditional on multilevel CES technical constraints that have common architecture for all $s \in S^{IRS} \cup S^{CRS}$; we therefore drop the sector subscript s in what follows to lighten expressions. At the upper level of this nested structure, a material input aggregate is combined with value added to produce output $Z + Fx$. Cost minimization yields the following optimal choice system:

$$X = \alpha^X \left[\frac{Ma^{cost}}{p^X}\right]^{\sigma^Z} [Z + Fx] \tag{B.15}$$

$$Q = \alpha^Q \left[\frac{Ma^{cost}}{p^Q}\right]^{\sigma^Z} [Z + Fx] \tag{B.16}$$

$$\left[Ma_s^{cost}\right]^{1-\sigma^Z} = \alpha^X \left[p^X\right]^{1-\sigma^Z} + \alpha^Q \left[p^Q\right]^{1-\sigma^Z} \tag{B.17}$$

where X and Q denote respectively volumes of material and value-added input aggregates, p^X and p^Q their associated prices, σ^Z the substitution elasticity, and the αs are (simple transforms of) CES share parameters as usual. Aggregate material inputs are themselves CES bundles of goods from sectors $s\prime$ available locally at market prices $p_{s'}$; cost minimization yields the firm's intermediate demands:

$$XX_{s'} = \alpha_{s'}^{XX} \left[\frac{p^X}{p_{s'}}\right]^{\sigma^X} X \tag{B.18}$$

$$\left[p^X\right]^{1-\sigma^X} = \sum_{s'} \alpha_{s'}^{XX} \left[p_{s'}\right]^{1-\sigma^X} \tag{B.19}$$

with $XX_{s\prime}$ the firm's demand for goods from industry $s\prime$, σ^X a substitution elasticity parameter and αs the share parameters. Value added results from combining services from an aggregate capital (Kap) and an aggregate labor (Lab) intrants, respectively priced p^{Kap} and p^{Lab}; these are imperfect substitutes with the technology imposing constant substitution elasticity; under cost minimization the optimal amount of services used for production is determined by:

$$Kap = \alpha^{Kap} \left[\frac{p^Q}{p^{Kap}}\right]^{\sigma^Q} Q \tag{B.20}$$

$$Lab = \alpha^{Lab} \left[\frac{p^Q}{p^{Lab}}\right]^{\sigma^Q} Q \tag{B.21}$$

$$\left[p^Q\right]^{1-\sigma^Q} = \alpha^{Kap} \left[p^{Kap}\right]^{1-\sigma^Q} + \alpha^{Lab} \left[p^{Lab}\right]^{1-\sigma^Q} \tag{B.22}$$

Relative abundance of public infrastructure is likely to affect the local producer's competitive position; one way to capture this is to assume that private and public capital enter the production process as imperfect substitutes so that low public infrastructure tend to force local firms to compensate this scarcity by renting more private capital. Private and public capital services are therefore combined assuming a CES constraint with low substitution elasticity parameter σ^{Kap}, with demand for private and public capital services (respectively K^{dem} and KG^{dem}) determined from first order cost minimization conditions:

$$K^{dem} = \alpha^K \left[\frac{p^{Kap}}{(1+\tau^K)\ p^K}\right]^{\sigma^{Kap}} Kap \tag{B.23}$$

$$KG^{dem} = \alpha^{KG} \left[\frac{p^{Kap}}{(1+\tau^{KG})\ p^{KG}}\right]^{\sigma^{Kap}} Kap \tag{B.24}$$

$$\left[\ p^{Kap}\right]^{1-\sigma^{Kap}} = \alpha^K \left[(1+\tau^K)\ p^K\right]^{1-\sigma^{Kap}} + \alpha^{KG} \left[(1+\tau^{KG})\ p^{KG}\right]^{1-\sigma^{Kap}} \tag{B.25}$$

where p^K and p^{KG} are the rental prices of private and public capital, τ^K and τ^{KG} are (possibly negative) tax rate parameters affecting the use of these capital inputs. Producers also hire imperfectly substitutable skilled and unskilled labor services from local workers; the CES demand system for these services again immediately follows from cost minimization; we write:

$$L_l^{dem} = \theta^{\sigma^{Lab}-1} \alpha_l^{L^{dem}} \left[\frac{p^{Lab}}{(1+\tau_l^L)\ p_l^L}\right]^{\sigma^{Lab}} Lab \tag{B.26}$$

$$\left[\ p^{Lab}\right]^{1-\sigma^{Lab}} = \theta^{\sigma^{Lab}-1} \sum_l \alpha_l^{L^{dem}} \left[(1+\tau_l^L)\ p_l^L\right]^{1-\sigma^{Lab}} \tag{B.27}$$

where τ_l^L are (possibly negative) fixed tax rates affecting the cost of labor services to firms; θ is a shift parameter affecting total labor productivity: this is of course the parameter that will be affected by our technological upgrading experiment.

We close the description of the production sector by collecting for future use the taxes paid by the firm on inputs:

$$T^K = \tau^K \ \ p^K K^{dem} \tag{B.28}$$

$$T^{KG} = \tau^{KG} \ \ p^{KG} KG^{dem} \tag{B.29}$$

$$T_l^L = \tau_l^L \ \ p_l^L L_l^{dem} \tag{B.30}$$

and acknowledge existence of indirect taxes at fixed rates levied by national governments on local firms' sales:

$$T^Z = \tau^Z\ p^Z Z \tag{B.31}$$

B.3. The government

Government income (Inc^{Gov}) includes capital rental revenues, income taxes payed by households, taxes payed on primary inputs by firms, as well as indirect taxes on products; formally:

$$Inc^{Gov} = p^{KG}\ \overline{KG^{sup}} + T^{Inc^{Gov}} + \sum_s N_s\ \left[T_s^K + T_s^{KG} + \sum_l T_{s,l}^L + T_s^Z \right] \tag{B.32}$$

where all notations have been previously introduced except $\overline{KG^{sup}}$ which denotes the country's endowment in public infrastructure.

Our interest in this paper is not on public policies, and we therefore make assumptions so as to keep the public sector as neutral as possible. For this reason, we assume that domestic bonds are valued at price p^{RoW}, and carry the same constant interest rate r^{RoW} as foreign bonds; furthermore, the stock of domestic bonds is constant, so that the government's intertemporal budget constraint can be written as:

$$Inc^{Gov} = r^{RoW}\overline{B^{Gov}} + p^{Con^{Gov}} Con^{Gov} + p^{Con^{Gov}}\overline{Tr^{Gov \to Hou}} \tag{B.33}$$

which defines public aggregate consumption Con^{Gov}residually. The sectorial composition of public consumption c_s^{Gov} is then determined by minimizing a CES cost function with low substitution elasticity $\sigma^{Con^{Gov}}$, which yields the following demand system

$$c_s^{Gov} = \alpha_s^{c^{Gov}}\ \left[\frac{p^{Con^{Gov}}}{p_s} \right]^{\sigma^{Con^{Gov}}} Con^{Gov} \tag{B.34}$$

$$\left[p^{Con^{Gov}} \right]^{1-\sigma^{Con^{Gov}}} = \sum_s \alpha_s^{c^{Gov}}\ [\ p_s]^{1-\sigma^{Con^{Gov}}} \tag{B.35}$$

B.4. European private capital market

All the physical capital of European households is pooled into a single European capital stock; this aggregate EU stock, denoted K_{E27}, is then optimally allocated to each country within the Union, and to each sector within each country, so as to maximize the rental revenues of the pooled capital subject to a two-level nested CET constraint. Formally, the optimal allocation of private physical capital services within the European Union is determined by the following set of nested CET supply equations derived from first order conditions:

$$K_i^{sup} = \alpha_i^{K^{sup}}\ \left[\frac{p_i^K}{p_{E27}^K} \right]^{\sigma_{E27}^K} K_{E27} \qquad i \in E27 \tag{B.36}$$

$$\left[p_{E27}^K \right]^{1+\sigma_{E27}^K} = \sum_{i \in E27} \alpha_i^{K^{sup}}\ \left[\ p_i^K \right]^{1+\sigma_{E27}^K} \tag{B.37}$$

$$K_{i,s}^{sup} = \alpha_{i,s}^{K^{sup}} \left[\frac{p_{i,s}^K}{p_i^K}\right]^{\sigma_i^K} K_i^{sup} \qquad i \in E27 \tag{B.38}$$

$$\left[p_i^K\right]^{1+\sigma_i^K} = \sum_s \alpha_{i,s}^{K^{sup}} \left[\, p_{i,s}^K\right]^{1+\sigma_i^K} \qquad i \in E27 \tag{B.39}$$

The first equation determines the supply of private capital services to each national economy K_i^{sup} as a share of Europe's aggregate stock K_{E27}; the share adjusts endogenously to changes in relative rental prices within the E27. The second equation defines the ideal service price index of K_{E27}, a function of country specific capital rental prices p_i^K. These two equations are the FOCs associated with the upper level CET. The next two equations characterize the optimal supply of physical capital across sectors within each country, conditional on the second level CET constraint. Here, $p_{i,s}^K$ is the rental price of private capital services payed by firms in sector s country i, and $K_{i,s}^{sup}$ is the amount of these services made available on that specific factor market. Both transformation elasticities σ_{E27}^K and σ_i^K are set to significantly higher values in the second period than in the first to capture higher mobility in the long term.

We still have to define the aggregation process that determines K_{E27}; we formalize this as follows:

$$K_{E27} = \sum_i^{E27} K_i^{Hou} \tag{B.40}$$

Observe that with such a definition of the aggregate European capital stock, we have to reward each national household for its capital ownership at the same unit price p_{E27}^K so that:

$$p_i^{K^{Hou}} = p_{E27}^K, \qquad i \in E27 \tag{B.41}$$

Consistently we allocate supernatural profits to national households in proportion to the ownership share they hold on K_{E27}, so that:

$$Prof^{Hou} = \left[\sum_j \sum_s Prof_{js}\right] \frac{K^{Hou}}{K_{E27}} \tag{B.42}$$

Pooling capital as we did also requires pooling savings, and clearly imposes some restrictions on our modeling of investment. We impose that

$$p_i^{Inv^{Hou}} = p_{E27}^{Inv} \qquad i \in E27 \tag{B.43}$$

where p_{E27}^{Inv} is the unit price of European aggregate investment, and therefore write pooled European real gross capital formation as:

$$Inv_{E27,t} = \sum_{i \in E27} \left[\frac{K_{i,t+1}^{Hou}}{\kappa} - \frac{K_{i,t}^{Hou}}{\kappa}\right] \tag{B.44}$$

To determine the composition of this investment good, we assume a two-level CES technology, and write its cost-minimizing input structure as:

$$Inv_i = \alpha_i^{Inv} \left[\frac{p_{E27}^{Inv}}{p_i^{Inv}}\right]^{\sigma_{E27}^{Inv}} Inv_{E27} \tag{B.45}$$

$$\left[p_{E27}^{Inv}\right]^{1-\sigma_{E27}^{Inv}} = \sum_{i\in E27} \alpha_i^{Inv} \left[\, p_i^{Inv}\right]^{1-\sigma_{E27}^{Inv}} \tag{B.46}$$

$$I_{i,s} = \alpha_{i,s}^{I} \left[\frac{p_i^{Inv}}{p_{i,s}}\right]^{\sigma^{Inv}} Inv_i \tag{B.47}$$

$$\left[p_i^{Inv}\right]^{1-\sigma^{Inv}} = \sum_s \alpha_{i,s}^{I} \left[\, p_{i,s}\right]^{1-\sigma^{Inv}} \tag{B.48}$$

The upper level defines the composition of the European aggregate Inv_{E27} in terms of national sub-aggregate flows Inv_i, and the lower level the composition of the latter in terms of local goods from different sectors $I_{i,s}$ associated to each are the ideal price indices respectively p_{E27}^{Inv} and p_i^{Inv} as usual, the σs and the αs are the substitution elasticities and share parameters respectively. Observe that this is a very flexible structure; for instance, one could set σ^{Inv} to zero which would impose constant shares in terms of country sub-aggregates.

B.5. Trade

We collect all the EU country demands for a market good s into a real variable $A_{i,s}$, an acronym reminiscent of country i's absorption:

$$A_{i,s} = \sum_{s'} N_{i,s'}\ XX_{i,s,s'} + c_{i,s}^{Hou} + c_{i,s}^{Gov} + I_{i,s} \qquad i \in E27 \tag{B.49}$$

We make this good a cost minimizing CES aggregate of goods produced in the same industry by firms worldwide, and write the first order conditions as follow:

$$Exp_{i',i,s} = \alpha_{i',i,s}^{Exp} \left[\frac{p_{i,s}}{(1+\tau_{i',s}^{Z})p_{i',s}^{Z}}\right]^{\sigma_s^A} A_{i,s} \quad i', i \in E27 \cup RoW \tag{B.50}$$

$$\left[\, p_{i,s}\right]^{1-\sigma_s^A} = \sum_{i'} N_{i',s}\ \alpha_{i',i,s}^{Exp} \left[\, (1+\tau_{i',s}^{Z})p_{i',s}^{Z}\right]^{1-\sigma_s^A} \tag{B.51}$$

Here, $Exp_{i',i;s}$ is the total demand by country i for goods produced by an individual producer of sector s in country $i\prime$; the good is sold at price $(1+\tau_{i',s}^{Z})p_{i',s}^{Z}$. In this system, if $i \in RoW$, $p_{i,s} = p_{i,s}^{Z} = 1$ and $A_{i,s} = \overline{A_{i,s}}$ for all s, because the rest of the world is assumed exogenous. Observe that these equations also apply if $i = i'$, defining therefore for each endogenous country the domestic demand functions for the domestically produced goods.[25] Observe also that, in perfectly competitive industries where there is a single aggregate producer ($N_{i\prime,s} = 1,\ s \in S^{CRS}$) this is a specification that captures the Armington assumption; in imperfectly competitive industries we have a form of Dixit-Stiglitz specification.

B.6. Equilibrium conditions

Goods

On each market for good s, equilibrium requires that supplies equal demands:

$$Z_{i',s} = \sum_i Exp_{i',i,s} \tag{B.52}$$

Labor

Sector specific wages ensure that supply and demand balance in each sector for each type of labor:

$$L^{sup}_{l,s} = N_s\ L^{dem}_{l,s} \tag{B.53}$$

The short term unemployment rate is either assumed fixed to its base year level, or endogenized by use of a reduced form wage curve specific o each type:

$$\text{Ln}\left[\frac{p_l^{L^{Hou}}}{p^{Con^{Hou}}}\right] = -\varepsilon_l\ \ \text{Ln}\left[\frac{UR_l}{UR_{0l}}\right] \tag{B.54}$$

where ε_l is a constant elasticity.

For the long term, we assume that labor supply remains at its short term endogenously determined level.

Capital

Equilibrium country and sector specific rental price of private capital services is determined so that,

$$K^{sup}_{i,s} = N_{i,s} K^{dem}_{i,s} \tag{B.55}$$

National public infrastructure is unlikely to be sector specific; we compute p^{KG} by imposing that:

$$\overline{KG^{sup}_i} = \sum_s N_{i,s} KG^{dem}_{i,s} \tag{B.56}$$

[25] The parameters $\alpha^{Exp}_{i',i,s} = 0$ for $i\prime, i \in RoW$ by calibration to base year data.

Geographic location of firms

In the short run, it is costly for firms to enter or exit the market: the geographic location of activity is therefore held fixed at t_1 (determined from base year Herfindahl concentration indices) and unexpected shocks will induce non-zero super-natural profits which are redistributed to capital owners (see equation (B.42)). With time, however, these non-zero profits will induce entry or exit so that the total number of firms and their geographic distribution become endogenous. The long run equilibrium number of competitors $N_{t_2,s}$ ($s \in S^{IRS}$) is determined by imposing zero profits at t_2:

$$p_s^Z = Av_s^{cost} \quad s \in S^{IRS} \tag{B.57}$$

Walras' law

All European agents satisfy their budget constraints, and equilibrium is imposed on each market, therefore we know from Walras' law that the *RoW* budget constraint is redundant and should automatically be satisfied; we check that this is indeed the case:

$$\begin{aligned} &\sum_{i\, \in E27} \left\{ p_i^{Con^{Hou}} \overline{Tr_i^{Hou\rightarrow RoW}} + \sum_s p_{RoW,s}^Z \ Exp_{RoW,i,s} \right\} \\ &= \sum_{i \in E27} \left\{ \sum_s (1+\tau_{i,s}^Z) p_{i,s}^Z \ Exp_{i,RoW,s} \right\} + r^{RoW} B^{RoW} \end{aligned} \tag{B.58}$$

B.7. Welfare

We evaluate country i's welfare using the equivalent variation index ψ_i determined as follows:

$$\sum_t^{\infty} \Psi^t \frac{\left[\psi_i \ Con_{i,0}^{Hou}\right]^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} = \sum_t^{\infty} \Psi^t \frac{\left[Con_{i,t}^{Hou}\right]^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \tag{B.59}$$

where $Con_{i,0}^{Hou}$ is initial steady-state (base-year) value of aggregate consumption, and Ψ^t is the discount factor.

C Base Case Parameter Values

Households and assets:		
	$\sigma_l^{L^{sup}}$	0.30 / 5.0 (Short / long run)
	σ	1.3
	$\sigma^{Con^{Hou}}$	1.2
Producers:		
	σ_s^Z	0.20
	σ_s^X	0.25
	σ_s^Q	1.0
	σ_s^{Kap}	2.0
	σ_s^{Lab}	1.4
Government:		
	$\sigma^{Con^{Gov}}$	0.30
European private capital market:		
	σ_{E27}^K	0.10 / 2.0 (Short / long run)
	σ^K	0.30 / 3.0 (Short / long run)
	σ_{E27}^{Inv}	3.0
	σ^{Inv}	1.3
	δ	0.10
Trade:		
	σ_s^A	6.0
Equilibrium (labor markets):		
	ε_l	0.10