On Barriers to Technology Adoption, Appropriate Technology and European Integration ☆

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Abstract

We first estimate, using 2007 data, country- and sector-specific technology frontiers within the EU, and show that in all but a few sectors, countries that joined the Union in 2004-07 clearly stand below the lower envelope frontier of the older members in their use of skilled and unskilled labor. We interpret this as due to past barriers to technology adoption, barriers that are likely to be removed by the integration process, with the technology choice sets of the new counties' eventually shifting to the incumbent members' lower envelope frontier. Could such a tech shock trigger massive enough outflows of capital and firm relocations to be detrimental to the welfare of workers in older EU members? We provide a quantitative exploration of this issue using a calibrated intertemporal multisectoral general equilibrium model of the EU27. The counter factual exploration suggests that, even though for most parameter configurations, workers' real wages in incumbent member countries would not be negatively impacted, this is not the only potential outcome: admittedly only with a specific model structure and under a somewhat extreme but not entirely unlikely parameter configuration, almost all workers of the old member states could experience a fall in the purchasing power of their wages.

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

Keywords: Barriers to technology adoption, appropriate technology, technological upgrading, European integration, calibrated general equilibrium (CGE)

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1. Introduction

The literature on cross-country economic performance has now accumulated ample evidence on existence of large gaps in technology usage between economies. Among the different theories put forward to explain such gaps, two strands of literature single out as particularly appealing. The first acknowledges the existence of barriers to technology adoption, and identifies a large variety of factors that contribute to reduce efficient use of knowledge and innovation 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 et al. (2015) single out the role of labor market regulations, Comin and Hobijn (2004) underline differences in factor endowments and Ferraro (2017) argues that uncertainty in technology diffusion leading to volatility of output 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), Vandenbussche et al. (2006) and Acemoglu (2015). The basic idea in this literature is that it may be optimal for firms in countries with different factor endowments, to choose different technologies. One key implication then, is the existence of an efficiency frontier (rather than a single 'state-of-the-art' production function): with technology choices endogenous, differences in factor endowments will induce countries to pick optimally different technologies on a frontier.

It should be apparent, in view of 20^{th} century history, that the factors highlighted as causing barriers to tech adoption are likely to have contributed to significant lags in technological efficiency in many recent EU member states, prior to their joining the Union. If that were the case, one should expect that the numerous economic, political and institutional reforms implied by integration within the EU will result in the elimination of these barriers, and induce access to higher technology frontiers. 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;[1] adoption of new and higher-productivity technologies in these new member states could trigger some –possibly massive– migration of capital and firms out of the old members, with non trivial indirect effects, in particular on factor prices in these incumbent countries (see e.g. Feenstra, 2007 for a review of current discussions on the link between globalization, offshore outsourcing and labor markets). 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 increasing anti-globalization mobilization, 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. To the best of our knowledge, this has not been previously done. Building on the 'barriers to technology adoption' literature, and drawing on 'appropriate technology', our contribution in this paper is to shed light on those issues, and to provide quantitative estimates by means of counter-factual experiments.

We first apply the cross-section regression methodology of Caselli and Coleman (2006) on EU data for year 2007, and estimate the country and sector specific technology frontiers jointly

[1] 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).

with the optimal location choice on this frontier, conditional on 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 of the incumbent EU members' technology frontiers and compute the distance of each new member to this lower envelope frontier. We interpret these distances, and therefore the gaps in total labor productivity (hereafter TLP), as providing rather conservative measures of the efficiency losses caused by pre-membership barriers to technology adoption. In the absence of these barriers, there is no reason why these countries would not be at least on this lower envelope frontier. Because joining the EU involves a wide range of economic, political and institutional harmonization reforms, we conjecture that these barriers to tech adoption will vanish: integration with the EU is therefore likely to increase the set of technology choices available to these countries, to boost their efficiency position up to the lower envelope frontier of the incumbent-member states. Implementation of such a shock is then straightforward in the form of an upward shift in TLP in a numerical model.

We provide such a quantitative assessment by means of numerical simulations using a calibrated general equilibrium model of the EU. Because the shock is likely to differ between countries and industries, we want the model to capture international and intersectoral reallocation effects; because adoption of new technologies will take time (and will proceed at an unknown pace) we want such a model to embrace a somewhat long term perspective; however, because individual agents are likely to expect these future effects and will take them into account in building their short term decisions, we need a model that captures intertemporal reallocation effects by also accounting for short run effects. The model we use 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), though our interest here is not on changing trade costs, which we assume negligible.

The paper is organized as follows. In Section 2, we provide estimates of country and sector specific technology frontiers, together with locations on these frontiers in the immediate aftermath of the 5th EU enlargement wave. In Section 3, we argue in favor of a "barriers to tech adoption" interpretation of the estimated efficiency gaps, and report the amplitude of the technology upgrading shock that is implied by the removal of these barriers. This suggests a counter-factual experiment that we perform using the calibrated dynamic GE model described in Section 4. The results of the numerical exploration are presented and discussed in Section 5. The paper closes with a brief conclusion (Section 6).

2. Measuring country specific technology frontiers within the EU

2.1. The econometric methodology

Caselli and Coleman (2006)[2] combine the theories of appropriate technology choice (based on factor endowments) and barriers to technology adoption in a single framework to empirically back-out country-specific technology frontiers and each country's relative position w.r.t. the world technology frontier function. We follow their approach, and assuming a CES technology

[2] Hereafter CC (2006)

that combines skilled and unskilled labor to produce the labor composite input, we write:[3]

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

where, 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 frontier, by firms facing different factor endowments and levels of technology adoption. The efficiency parameters A_{un}, A_{sk} are then computed by combining the above CES technology with the skill premium (w_{sk}/w_{un}) under the assumptions of optimization behavior of the firms and full employment.[4,5] 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.[6] 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; Chemi-

[3]We follow CC (2006), though the notation is ours: the reader is in particular cautioned on the fact that, interpretations of the symbol σ differ.

[4]This is of course, a very strong assumption which precludes using the methodology in periods of severe macroeconomic shocks.

[5]An alternative non-parametric approach proposed by Krüger (2017) uses directional distance functions method that requires no functional form, firm optimization or equilibrium assumptions. The results of Krüger (2017) suggest that the central result of CC is robust to this alternative non-parametric approach, albeit being sensitive to alternative definitions of skilled and unskilled labor. We here follow the CC (2006) approach, in particular because we want to impose the CES functional forms to ensure consistency with the calibrated model to be used in a later section.

[6]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.

cals and Plastics; Basic and Fabricated Metals; Electrical and Optical Equipment; Transport Equipment; Construction; Other Manufacturing; and Services.

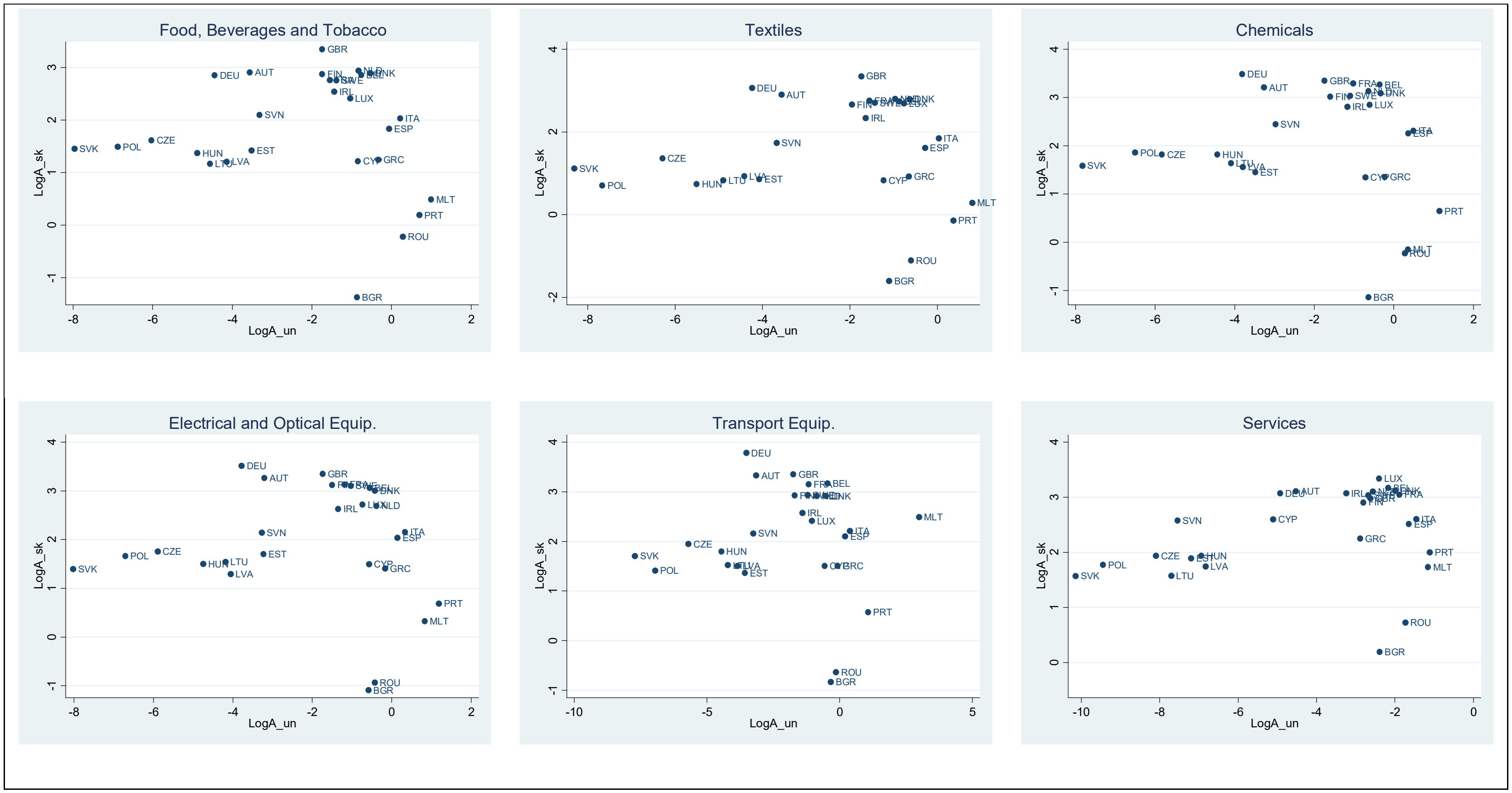
2.2. Estimation results

Underlying theoretical assumptions preclude utilizing the CC methodology for periods of severe macroeconomic shocks: years posterior to 2008, therefore clearly disqualify and we choose year 2007 as the most recent best candidate. The econometric methodology requires that we first 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 are consistent with the output and skill-premium in each country/sector.[7] Though numbers do differ across sectors –in some cases significantly– a common pattern clearly emerges as Figure 1 illustrates, to conserve on space, for a subset of sectors. For all sectors, 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.

[7]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).

Figure 1: Efficiency of skilled and unskilled workers, selected sectors, 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 technology 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 generally adopted as a reasonable benchmark value.[8] The resulting parameter values that define the country and sector specific technology frontiers are reported in Table 1.[9] 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}) are also comparable. The (relative) variabilities of the Bs and of the efficiency ratios, are much higher for the new members.

[8]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.

[9]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			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	$log(A_{sk}/A_{un})$	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	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	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	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	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	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	1.07	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	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	-0.20	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	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	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	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	1.20	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	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	2.16	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	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	-0.47	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	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	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	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	0.35	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	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	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	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	1.30	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	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	-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	-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	1.17	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	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	-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	-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	0.31	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	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	3.14	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	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	2.77	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	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	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	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	2.05	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	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	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	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	-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	-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	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	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	-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	-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	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	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	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	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	0.3965			0.4101			0.4101			0.4101			0.4101			0.4100			0.4101			0.4054			0.4101			0.4027		

It is illuminating to compute, for each sector, the upper and lower envelopes of the technology frontiers of the old member states: we display in Figure 2 the resulting graphs for the same set of selected sectors as in Figure 1. 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 textile 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) 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 compute the distances to the lower envelope frontier of the incumbent EU members, hence the amount of shift in TLP (represented by parameter θ in equation (1)) that would be required, everything else equal, to give the new member states access to the lower envelope in each sector. The distance to frontier values are reported in Table 2.

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

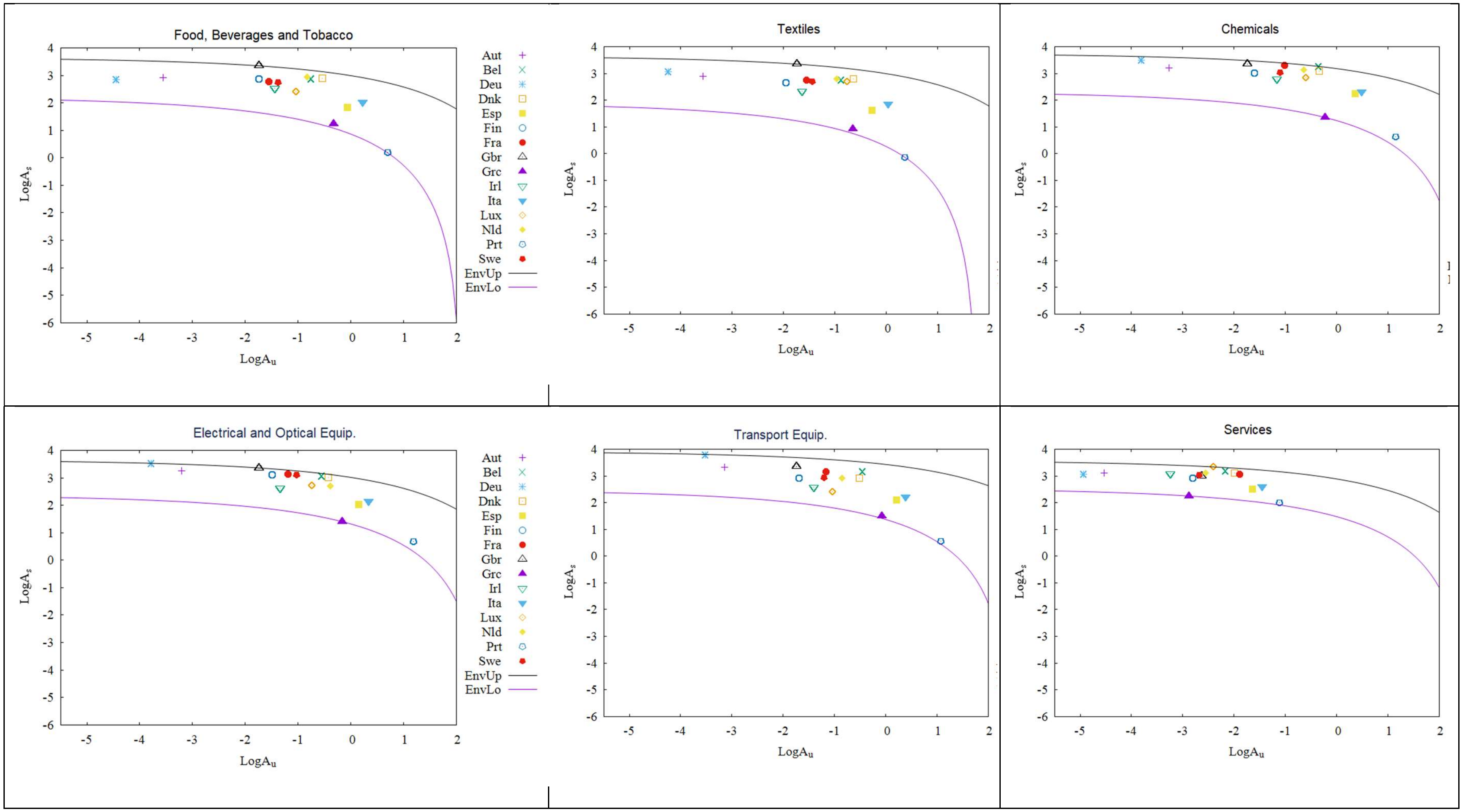


Figure 3: Technology gap between new members and lower envelope of old members, selected sectors, 2007

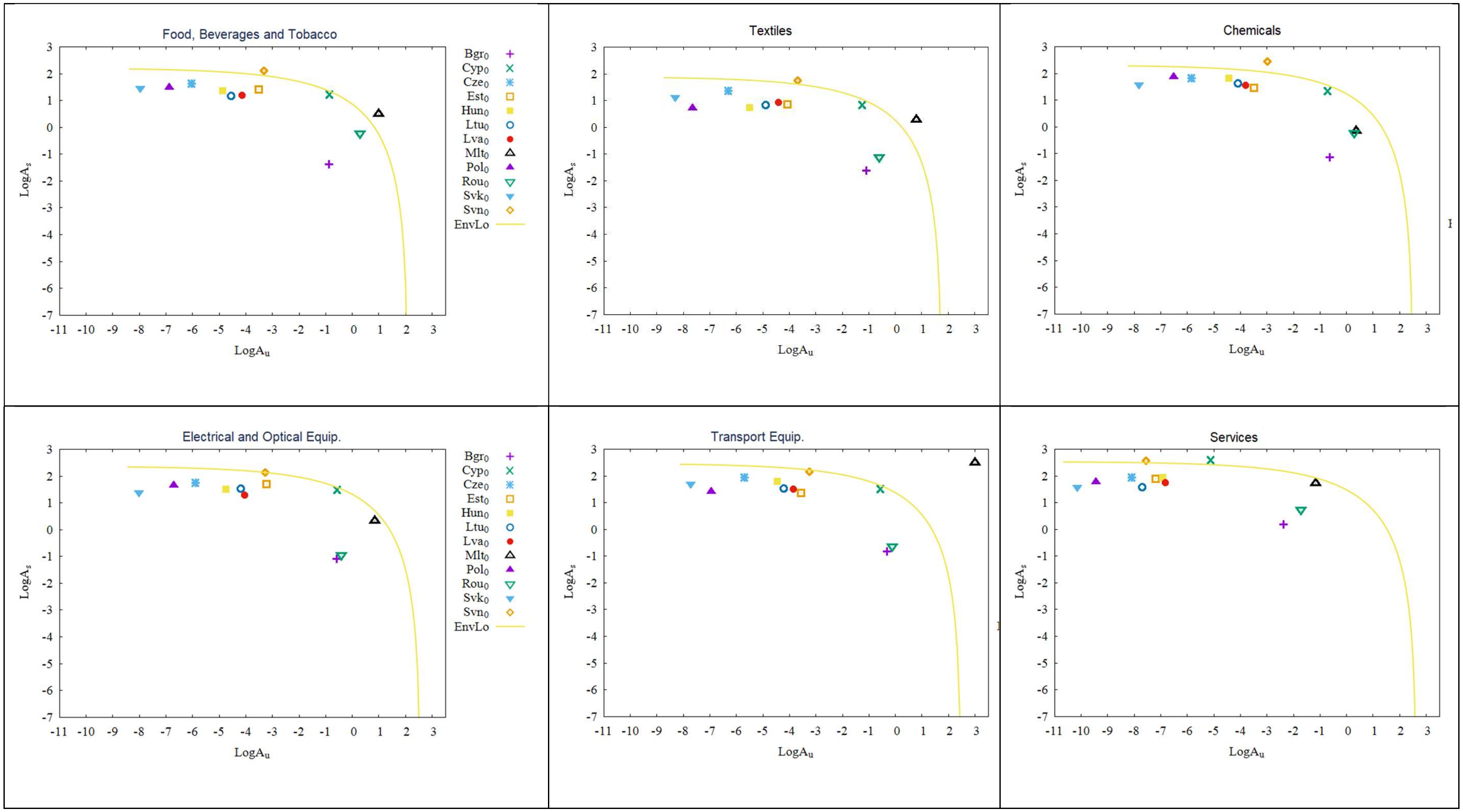


Table 2: Computed distances for new members to reach the lower envelope technology frontier of incumbent members, 2007

	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. Apprehending efficiency losses due to pre-integration barriers-to-technology-adoption

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 indeed reflect heterogeneity in factor endowments, as suggested by the 'appropriate-technology' literature. However, other complementary explanations have to be provided to justify such efficiency differences: the results clearly suggest existence of barriers to technology adoption in the recent past. Though the causes of such barriers may be numerous and country specific, with each individual cause's contribution to technological lags accordingly difficult to apprehend, the joint efficiency cost of these barriers is likely to be a function of the distance between the technology frontier position of new and old member states, prior to the integration of the former into the Union. To make this "barriers-to-technology-adoption induced efficiency gap" a useful concept requires, however, defining a reference efficiency frontier for the incumbent member states as a group. 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. Putting this differently, we suggest attributing to pre-integration barriers to technology adoption the responsibility for the new members' position below the lower envelope technology frontier of incumbent member states. The amplitude of the tech lag that is attributed to barriers to tech adoption is therefore the one reported in Table 2 (in the form of a multiplicative factor). Hence, if –as we conjecture– joining the EU should result in the elimination of these barriers, integration within the EU will induce a shift of the TLP parameters θ so as to place the new member states on this lower envelope. We want to explore the consequences on the EU27 of such a technological shock using a numerical model which we describe in the next section.

4. The numerical set-up

We now provide a rather non-technical presentation of our set-up, and in order to conserve on space, refer to Mercenier et al. (2016) for a formal presentation of the features that are common with RHOMOLO, the spatial calibrated GE model of the European Commission.

The two models differ substantially on many grounds, however; we first highlight these differences. In contrast with the model of the European Commission, we are not constrained by short-run policy considerations, so we select a different base year for calibration, more on the basis of its adequacy with our assumption of stationary equilibrium, rather than because "it is the most recent available social accounting matrix". Secondly, we are not interested in specifically regional issues: we substantially reduce the dimension of the numerical system by working with national rather than with regional units; this size downscaling makes it possible for us, on the one hand, to adopt a finer sectoral disaggregation, and on the other, in line with modern macroeconomic and growth theory, to introduce more sophisticated dynamics based on explicit optimal intertemporal decision making by households endowed with forward-looking expectations. RHOMOLO also includes a very ad hoc R&D bloc, which we do not retain.

The year we choose for model calibration purposes is of course the same as the one used in our econometric estimations, 2007.[10] In this kind of exercise, the choice of an appropriate base year is both important and difficult, particularly so, when the model is dynamic and calibration assumes the economy in a steady state. We choose year 2007 for the following reasons. 2007 is

[10] 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.

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 are likely to have 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 of severe recession, any year of which would clearly fail to qualify as a proper candidate for an approximate steady state equilibrium.[11] For these reasons, year 2007 appears to be the most recent best compromise for our purpose.

The model structure is of the infinite horizon optimal growth type, 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 (hereafter $E27$); all countries have identical structures; the model is closed by a 'rest-of-the-world' (hereafter 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. This agent is 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 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.[13] The intertemporal preferences assume constant inter-period substitution elasticity:

$$\sum_{t}^{\infty} \Psi^t \frac{[C_{i,t}]^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \tag{4}$$

where i is the country index, σ the elasticity of intertemporal substitution and Ψ^t a discount factor. Dynamic optimization, performed assuming forward-looking expectations, yields the following intertemporal consumption smoothing scheme:

$$\left[\frac{C_{i,t+1}}{C_{i,t}}\right]^{1/\sigma} = \frac{p^C_{i,t}}{p^C_{i,t+1}} \frac{\left[1 + r^K_{t+1} - \frac{p^I_{t+1}}{p^I_t}\right]}{\rho} \tag{5}$$

where $p^C_{i,t}$ is the consumption price index, p^I_t is the unit cost of investment goods, ρ is the rate of time preference, and r^K_{t+1} is the rate of return expected at time t to be reaped on physical capital at time $t+1$:

$$1 + r^K_{t+1} = \frac{p^K_{t+1} + (1-\delta)p^I_{t+1}}{p^I_t} \tag{6}$$

[11] The reader will remember that, for the same reason, the econometric method used to estimate the country-specific technology frontiers in the previous section precluded using years posterior to 2008.

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

[13] Bonds include debt issued by $E27$ governments and by the RoW. These bonds are included for base year accounting reasons only: the dynamic budget constraints are formulated to ensure that these stocks, supplied and held, remain constant through time.

with p_t^K the rental price of a unit of capital, and δ the depreciation rate assumed constant.[14] Observe that p_t^K and p_t^I are written without the i index: both prices are common to all countries for reasons that is explained below.

Aggregate household consumption is –as are all other components of the demands for goods, final and intermediate– 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 Products", "Chemicals and Plastics", "Basic and Fabricated Metals", "Electrical and Optical Equipments", "Transport Equipments" and "Construction") will, depending on the model version used, 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.[15] Individual monopolistically competitive firms face fixed production costs –which we assume in the form of a real amounts of foregone output– which add to variable costs determined from nested-CES structures identical to the ones 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 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 held constant and public consumption roughly proportional to GDP by being defined residually.

Importantly, the model has to capture two characteristic features of modern capital: first, low transaction costs and efficient banking make financial capital extremely mobile; under perfect foresight, this implies that in equilibrium, no systematic differences should exist between expected rates of returns on capital within the EU: $r_{i,t+1}^K = r_{t+1}^K$. Second, in spite of this, the capital rental cost for firms is far from being equalized across sectors and countries due to inertia in physical capital relocation. We capture these features by pooling all the physical capital of $E27$ 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.[16] 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

[14] Older vintages of capital net of depreciation are assumed valued as new equipments.

[15] The decision regarding which industry is likely or not to be characterized by IRS technologies and monopolistic competition is difficult, and admittedly bears some arbitrariness. Our choice is based, among other things, on industry concentration statistics (more specifically, on Herfindahl indices), on how roughly homogeneous an industry is ("Services", for instance, include such different sub-sectors as retail trade, restoration, and banking...), on how internationally comparable are the national symmetric firms that would emerge from the (inverse of the) Herfindahl indexes, and on how realistic it is to assume that individual firms' products are differentiated from their competitors (it is, for instance, hard to justify that agriculture goods that constitute a large part of "Primary" are differentiated enough to confer some monopoly power to individual farmers).

[16] 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.

data ensures that the simulated counterfactual equilibrium allocation remains anchored to its initial geographical distribution.[17] By adopting different values in time (that is at t_1 and t_2) for σ^K_{E27} and σ^K_i, 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 –so that $p^I_{i,t} = p^I_t$ consistently with the assumption that capital owners expect the same rate of return on their physical assets throughout Europe– which imposes some constraints on the modeling of the composition of the investment good: see Mercenier et al. (2016) for details on this rather technical and innocuous aspect of the modeling of the composition of the investment good.

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. On labor markets, in some scenarios, we make labor supply endogenous by use of a reduced form wage curve. In IRS sectors, the geographic location of firms is endogenous in the long run: the equilibrium number of producers is determined by entry or exit of firms such that zero super-natural profits result. In the short run, it is assumed costly for firms to enter or exit the market: the geographic location of activity is held fixed at t_1 (determined from base year Herfindahl concentration indexes); in case of unexpected shocks, non-zero profits exist in the short run, which are redistributed to capital owners in proportion to their contribution to the $E27$ aggregate capital stock. 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:

$$\sum_t^\infty \Psi^t \frac{[\psi_i \; C_{i,0}]^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} = \sum_t^\infty \Psi^t \frac{[C_{i,t}]^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \tag{7}$$

where $C_{i,0}$ is initial steady-state (base-year) value of aggregate consumption.

The calibration of the model is made conditional on chosen values for a set of parameters, most of which are substitution/transformation elasticities: the values adopted are reported in Appendix B, 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 tech upgrading shock. This involves computing the equilibrium allocation and price system consistent with the new exogenous values of the total-labor-productivity shift parameters θ reported in Table 2.[18] 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 our set-up is a dynamic highly sophisticated version of the so-called 'footloose capital with vertical linkages' model (see e.g. Baldwin et al., 2003). In particular, we assume no international labor mobility, which might seem at odds with recent intra-European migration history. The reason for this is twofold. First, 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

[17] This mechanism can obviously be interpreted as a reduced form representation of the role of financial markets and banking sector activities.

[18] Remember that initial positions on the technology frontiers reflect the appropriate technology choices conditional on factor endowments. With fixed factor endowments, these choices are unaffected by the integration shock: the induced change is the movement on the same A_{sk}/A_{un} ray, as captured by a shift in θ. In the general equilibrium setup, however, because of the intersectoral mobility of labor, this is no longer exactly the case: as sector endowments change, optimizing firms adjust their appropriate technology choice, so that the shift in θ is accompanied by an endogenously determined movement on the sector-specific frontier. We of course, do take this effect into account in our simulations.

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 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. Secondly, we are performing a counter-factual experiment: the purpose 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*. What the counter-factual experiment will tell us is if the specific shock is likely to improve relative wages in the new member states, and therefore if it will contribute to reduce rather than to increase the flows due to pre-existing absolute wage differences.

We now turn, to the results of our numerical counter-factual exploration.

5. Measuring EU enlargement: the contribution of elimination of barriers-to-technology-adoption

5.1. 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 induced 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 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 neighbors' increase in technological efficiency (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; C = private consumption; K^{Sup}= capital supplied locally; rw_{sk}, rw_{un} = real wages skilled, unskilled

CRS (σ = 1.3 , σ_{E27}^{K}= 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
C_{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
C_{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
$K_{t_1}^{Sup}$	0.2	0.0	0.1	0.1	0.1	0.1	0.2	0.0	0.0	0.2	0.0	0.0
$K_{t_2}^{Sup}$	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_{E27}^{K} = 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
C_{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
C_{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
$K_{t_1}^{Sup}$	0.2	0.0	0.2	0.2	0.1	0.2	0.4	0.0	0.1	0.4	0.1	0.0
$K_{t_2}^{Sup}$	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

5.2. Old member states

Old member states are only indirectly affected by the shock –through trade in goods and factor mobility– 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.[19]

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).

[19] 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; C = private consumption; K^{Sup}= capital supplied locally; rw_{sk}, rw_{un} = real wages skilled, unskilled

CRS, 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	0.2	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
C_{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
C_{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
$K_{t_1}^{Sup}$	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
$K_{t_2}^{Sup}$	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_{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	0.3	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
C_{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
C_{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
$K_{t_1}^{Sup}$	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
$K_{t_2}^{Sup}$	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 turns out to be quite negligible as a share of the initial stock, 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 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.[20] 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) and not too highly mobile physical capital between countries (σ_{E27}^{K} low)– is characterized by a widespread boost of aggregate activity, with GDP higher by a factor 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, by a factor 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_{E27}^{K}=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 work-

[20]Namely: "Food", "Beverages and Tobacco", "Textiles and Textile Products", "Chemicals and Plastics", "Basic and Fabricated Metals", "Electrical and Optical Equipments", "Transport Equipments" and "Construction".

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

IRS, 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	0.4	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
C_{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
C_{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
$K^{Sup}_{t_1}$	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
$K^{Sup}_{t_2}$	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^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	0.6	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
C_{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
C_{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
$K^{Sup}_{t_1}$	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
$K^{Sup}_{t_2}$	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

6. 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. Our first contribution in this paper is to suggest a methodology for assessing the size of the efficiency loss that can be attributed to barriers to tech adoption in an economy. As a by-product, we show how this directly translates into a workable technological shock that can be implemented in a calibrated GE model to evaluate the welfare gains a country can potentially generate by erasing restrictions to knowledge diffusion.

For a non-member country joining the EU, integration within the Union is likely to eliminate most of these impediments that limit the ability of local firms to adopt more advanced technologies. Indeed, the disciplines required to eliminate these impediments are essentially the same as those discussed as necessary to achieve 'deep integration' within the EU. We therefore also contribute to the literature that aims to evaluate the costs and benefits of EU integration: to the best of our knowledge, the contribution of barrier-to-tech-adoption elimination to these costs and benefits has never been previously assessed (except possibly using very aggregate single country models).

Though particularly relevant to the EU enlargement experience, our methodology is clearly not specific to that context: it can be implemented to evaluate any serious integration effort from a single-country perspective. One thing that makes the 5th EU enlargement episode so special, however, 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 in particular because of physical capital mobility. 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 significant outflows of physical capital attracted by more profitable opportunities in the new member states. 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; it might miss dynamic forces 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 adopting methodologies such as the one proposed by Krüger (2017) in the estimation of the technology frontiers could provide more nuanced evaluations of the amplitude of the implicit barriers to technologies that existed prior to 2004-7.

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Appendices

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 Álvarez-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.[21]

[21] An alternative method for calculating the skilled and unskilled labor categories would rely on the estimated

B. Base Case Parameter Values

Households and assets:		
	$\sigma_l^{L^{sup}}$	0.30 / 5.0 (Short / long run)
	σ	1.3
	σ^C	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:		
	σ^G	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

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%.