March 2015

THE NEW NORMAL: A SECTOR-LEVEL PERSPECTIVE ON PRODUCTIVITY TRENDS IN ADVANCED ECONOMIES—TECHNICAL APPENDIX

Prepared by Era Dabla-Norris, Si Guo, Minsuk Kim, and Aleksandra Zdzienicka[1]

CONTENTS

[1] The authors would like to thank Jovana Sljivancanin, Tushara Ekanayake, Xin Guo, Monica Devi, and Ricardo Reinoso for their excellent research and editorial assistance.

1. **This Technical Appendix describes the theoretical model underlying the counterfactual exercise that assesses potential total factor productivity (TFP) gains from reducing resource misallocation across sectors** (Section I). Section II outlines the conceptual framework and data sources used for the empirical analysis and presents detailed findings summarized in the Staff Discussion Note. We first describe the empirical methodology to examine the drivers of industry-level growth, before turning to the dynamic effects of structural reforms on sectoral TFP (Section III). The analysis also investigates the dynamic impact of structural reforms on sectoral employment and output.

I. THEORETICAL FRAMEWORK FOR ASSESSING MISALLOCATION

2. **The model is a revised version of Aoki (2012).** We assume that there are I (i=1,2,…I) sectors in a closed economy. Each sector i produces one kind of good and the price is p_i. Residents consume a basket of I goods and sector shares depends on prices p_i and consumer preferences. Production requires capital and labor as inputs. The aggregate stock of capital and labor is fixed, which implies that the measured aggregate TFP is proportional to output in this economy. There is no capital depreciation or investment, and therefore output equals consumption. There are N kinds of intermediate goods, and one final good. Production of the final good is given by:

$$Y = (\sum \theta_i Y_i^{\frac{\gamma-1}{\gamma}})^{\frac{\gamma}{\gamma-1}}, \quad (1)$$

where $\gamma > 0$ is the elasticity of substitution[2] and $\theta_i > 0$ represents the weight in the production function. Each intermediate goods sector i has a representative firm i with the production function:

$$Y_i = A_i K_i^{\alpha_i} L_i^{1-\alpha_i}. \quad (2)$$

Each sector is competitive, therefore firm i takes output price p_i and input prices w, r as given. Firm i's maximization problem can then be written as

$$Max_{\{K_i,L_i\}} p_i Y_i - (1+\tau_{K,i}) r K_i - (1+\tau_{L,i}) w L_i, \quad (3)$$

where $\tau_{K,i}$ and $\tau_{L,i}$ are capital and labor frictions that influence the effective rental cost of capital and labor in sector i. The market clearing conditions are $\sum_i K_i = K$, $\sum_i L_i = L$.

3. **Firm's optimization problem.** Following Aoki (2012), from firms' optimality conditions we can derive

[2] Aoki (2012) does not specify the form of the final good production function. However, he implicitly assumes that sector shares do not respond changes in frictions, which is equivalent to the special case with unitary elasticity of substitution. In our counterfactual analysis, we allow for a potential change of sector shares.

$$\frac{MRK_i}{MRK_j} = \frac{1+\tau_{K,i}}{1+\tau_{K,j}} \tag{4}$$

$$\frac{MRL_i}{MRL_j} = \frac{1+\tau_{L,i}}{1+\tau_{L,j}} \tag{5}$$

where *MRK (or MRL)* represents the marginal *revenue* of one more unit of capital (or labor). Using the market clear conditions, we can derive

$$K_i = [\frac{\alpha_i s_i}{\overline{\alpha}(1+\tau_{K,i})}]/[\sum_j \frac{\alpha_j s_j}{\overline{\alpha}(1+\tau_{K,j})}]K, \tag{6}$$

$$L_i = [\frac{(1-\alpha_i) s_i}{(1-\overline{\alpha})(1+\tau_{L,i})}]/[\sum_j \frac{(1-\alpha_j) s_j}{(1-\overline{\alpha})(1+\tau_{L,j})}]L, \tag{7}$$

where s_i is the valued-added share of sector i and $\overline{\alpha} = \sum_i \alpha_i s_i$ is the weighted average capital share.

4. **Calculating wedges (distortions).** Defining $\overline{MRK} = 1/[\sum_j \frac{\alpha_j s_j}{\overline{\alpha}} \frac{1}{MRK_j}]$ as the average marginal revenue to capital (and defining $\overline{MRL}$ similarly), we can calculate capital wedges from the observed sectoral capital and value added data:

$$Capital\ Wedge_i \triangleq \frac{\overline{MRK}}{MRK_i} - 1 = \frac{\overline{\alpha}}{\alpha_i s_i}\frac{K_i}{K} - 1 \tag{8}$$

$$Labor\ Wedge_i \triangleq \frac{\overline{MRL}}{MRL_i} - 1 = \frac{(1-\overline{\alpha})}{(1-\alpha_i)s_i}\frac{L_i}{L} - 1 \tag{9}$$

In the Pareto optimal allocation, capital (or labor) frictions should be identical across sectors (i.e., capital and labor wedges are zero). However, deviating from a Pareto optimal allocation, if a sector i is relatively more "favored" in capital markets (i.e., τ_i is relatively smaller compared with other sectors), more capital will be allocated to sector i and the capital wedge of sector i will be positive.

5. **Data and Parameterization.** We measure L_i, K_i, σ_i and α_i from the EUKLEMS dataset. For labor, we first use "total hours worked by persons engaged" in sector i as the relevant measure of labor input L_i. One drawback with using total hours as the measure of labor input is that it puts an even weight on skilled and unskilled labor. Therefore, we also construct an alternate index, which puts a higher weight on high- and medium-skilled labor. The weights of high- and medium-skilled labor are proportional to their hourly wages in 1995. For capital stock, we use "real fixed capital stock, 1995 prices" of "all assets" in sector i as the measure of K_i. For capital share, we use "capital compensation" as a share of total value added. The remaining parameters to be estimated are θ_i (the weight of sector i in final goods production). The first order condition from the maximization problem of the firm that produces the final good is:

$$p\frac{\partial Y}{\partial Y_i} = p_i. \tag{10}$$

This implies

$$p_i = p\theta_i(\frac{Y}{Y_i})^{1/\gamma}. \tag{11}$$

Using data on value added (pY and p_iY_i) and price indices (p and p_i), we can calculate θ_i. Note that we do not have to specify the unit of the price and volume index for each sector. This is because the variable of interest is the real value-added volume Y and its changes in various counterfactual exercises. Changing the units of sectoral prices and volumes will change the measured θ_i but will not change the aggregate value-added volume Y. To see this, suppose we change of a unit of output of sector i by m times. That is, $Y'_i = Y_i/m$ and $p'_i = mp_i$. The measured weight of sector i in the final good production $\theta_i' = m^{1-\frac{1}{\gamma}}\theta_i$ and the aggregate value-added Y calculated from (1) remains unchanged.

6. **Counterfactual exercise.** Suppose that capital and labor frictions are changed to $t_{K,i}$ and $t_{L,i}$. We can then calculate output under this counterfactual set of frictions and examine differences with output observed in the data. Notice that if $t_{K,i} = \overline{t_k}$ and $t_{L,i} = \overline{t_L}$, there is no misallocation across sectors.

II. DRIVERS OF PRODUCTIVITY GROWTH

7. **Conceptual framework.** The analysis in this section follows the conceptual framework of the neo-Schumpeterian growth theory as put forward in Aghion and Howitt (2006, 2009) and Acemoglu, Zilibotti, and Aghion (2006). Economic theory distinguishes between two types of innovation activity: adoption of existing vintage technologies ("imitation") and introduction of new "state-of-the-art" technology ("frontier innovation"). The key intuition is that countries farther away from the global technological frontier tend to grow mainly through imitation, whereas countries closer to the frontier rely more on innovation for growth. From a policy design perspective, an important implication of this theory is that the set of policies and reforms aimed at enhancing productivity can have varying effects depending on each country's relative stage of technological development.

8. **Empirical approach.** Our empirical setup is similar to other recent studies in the literature (e.g., Scarpetta and Tressel 2002; Nicoletti and Scarpetti, 2003; Griffith, Redding, and Van Reenen 2004; Mc Morrow, Werner, and Turrini 2010). Specifically, we model TFP growth using the following baseline specification:

$$\Delta y_{ijt} = \beta_0 + \beta_1 \Delta y_{Ljt} + \beta_2 (y_{ijt-1} - y_{Ljt-1}) + \beta_k \textstyle\sum_k X^k_{ijt-1} + \beta_l \sum_k X^l_{ijt-1} (y_{ijt-1} - y_{Ljt-1})$$
$$+\alpha_1 D_i + \alpha_2 D_j + \alpha_3 D_t + \varepsilon_{ijt}\ ,$$

where subscripts *i, j, t* denote country, industry, and year, respectively. In particular, we use the subscript *L* to denote the "global frontier," the country with the highest level of TFP in industry *j* in a given year *t*. The TFP growth rate (Δy_{ijt}) is the difference in the log-level of TFP between year *t* and *t-1* regressed on the following explanatory variables: (i) the TFP growth rate in the global frontier (Δy_{Ljt}), (ii) the TFP level gap with respect to the global frontier measured as log-difference ($y_{ijt-1} - y_{Ljt-1}$), (iii) a set of structural variables (X^k_{ijt-1}) and the interaction terms with the TFP gap, and (iv) country, industry, and year dummy variables. Conceptually, the TFP growth rate (Δy_{Ljt}) at the global frontier captures potential knowledge spillovers from cutting-edge innovation at the frontier, while the TFP gap represents the distance to the frontier, and hence the potential for "catch-up" for the follower country *i*. The dummy variables control for the effects of unobserved country and industry characteristics, as well as common shocks across time.

9. **Policy and structural variables**. We consider two groups of variables that are widely viewed as boosting productivity. The first group is comprised of measures of product and labor market regulations, which capture the degree of market flexibility and competition in an economy. Stricter regulations in these markets can curb TFP growth by impeding the efficient reallocation of resources across plants, firms, and industries. The second group consists of variables that proxy for the economy's absorptive capacity for innovation and technology diffusion, namely, the intensity of high-skilled labor and ICT capital inputs and R&D expenditures. Beyond their direct contribution to output growth, high-skilled workers and ICT capital can create positive externalities for the overall economy by facilitating adoption of technologies. Similarly, R&D activities can directly contribute to productivity growth through the introduction of new technologies, but also have indirect effects by facilitating the adoption of existing technologies (Griffith, Redding, and Van Reenen 2004).

10. **Data used.** The sample for our analysis covers 23 market industries[3] in 11 advanced economies (Australia, Austria, Denmark, Finland, Germany, Italy, Japan, Netherlands, Sweden, United States, and United Kingdom) over the period 1970–2007. The data definitions and sources for the variables used in the analysis are as follows:

- *Total factor productivity*. TFP growth and level estimates are taken from the EU KLEMS database. The TFP level estimates used for the calculation of TFP gaps are obtained by linking the TFP growth estimates from the EU KLEMS database with the Groningen Growth and Development Centre Productivity Level database, which provides the PPP-adjusted industry TFP levels in 1997 for our sample countries (see Inklaar and Timmer 2008).
- *Product market regulation (PMR)*. We use the Organization for Economic Cooperation and Development's Indicators of Regulation Impact to capture the extent of market regulation at the industry level. These indicators are calculated as the weighted-average of indicators that measure anti-competitive regulation in non-manufacturing upstream sectors (electricity, gas, air, rail, road, road, post and telecommunications, retail trade, professional services, and banking), where the weight for each indicator is the input requirement of these upstream sectors for each downstream industry derived from the OECD input-output tables (for details, see Conway and Nicoletti 2006).
- *Employment protection legislation (EPL)*. We use the OECD's employment protection legislation indicator as a proxy for the degree of overall labor market regulations in an economy. The indicator measures the procedures and costs involved in dismissing individuals or groups of workers and the procedures involved in hiring workers on fixed-term or temporary work agency

[3] Industry coverage includes food, beverage, and tobacco (15t16); textiles, textile products, leather, and footwear (17t19); wood and products of wood and cork (20); pulp, paper, printing and publishing (21t22); chemicals and chemical products (24); rubber and plastics (25); other non-metallic mineral products (26); basic metals and fabricated metal (27t28); machinery, nec (29); electrical and optical equipment (30t33); transport equipment (34t35); manufacturing nec; recycling (36t37); electricity, gas and water supply (E); construction (F); wholesale and retail trade (G); hotels and restaurants (H); transport and storage (60t63); post and telecommunications (64); real estate activities (70); renting of machinery & equipment and other business activities (71t74); financial intermediation (J).

contracts. Unlike the other explanatory variables used in the empirical analysis, this indicator is only available at the aggregate economy level.

- *Share of high-skilled labor*. The EU KLEMS database provides industry-by-industry information on different types of labor inputs classified by age, gender, and skill levels measured by educational attainment (primary, secondary, and tertiary). In our analysis, we use the share of total working hours provided by workers with tertiary education as the relevant measure of high skilled labor.
- *Share of ICT capital*. The EU KLEMS database also provides information on various types of capital inputs (3 ICT – office and computer equipment, communication equipment, software; 4 non-ICT: transport equipment, other machinery and equipment, residential buildings, and non-residential structures) at the industry level. For our analysis, we use the ICT capital share of total capital services as a proxy for the intensity of ICT capital usage in each industry.
- *R&D expenditure*. The R&D expenditure data come from the OECD's Analytical Business Enterprise Research and Development (ANBERD) database, which provides annual industry-level data (ISIC rev. 3). For our analysis, we divide the expenditure estimates by industry value-added.

A. Empirical Findings: Impact of Product and Labor Market Regulations

11. **Baseline results.** Table A1 presents the ordinary least squares (OLS) regression results showing the impact of product and labor market regulations on TFP growth across industries. Column 1 shows that, within each industry, the coefficients for TFP growth in the frontier country of the industry and the TFP gap with respect to the frontier country are both significant and are of the signs expected from neo-Schumpeterian growth theory. In particular, our analysis confirms the existence of significant productivity-enhancing knowledge spillovers from the frontier as well as the notion that the rate of convergence in follower countries increases with the distance to the frontier.[4] The coefficients for product and labor market regulations, however, have unexpected positive signs (i.e., higher regulation is associated with higher TFP growth) but are statistically insignificant.

12. **Varying impact of product market regulations by sector.** To examine whether PMRs in different sectors have varying productivity effects, we introduce two additional explanatory variables by interacting the PMR index with manufacturing and service sector dummies (Column 2). In this specification, the coefficient for the interaction term between the PMR and the service sector dummy turns out to be negative and significant, indicating that greater product market regulation in the services sector is associated with lower TFP growth. When the interaction terms with TFP gaps are added for these sectors (Column 3), the coefficient of the interaction term for the service sector is negative and significant. This indicates that the negative productivity impact of PMR is more costly for countries closer to the frontier, consistent with findings from other studies (Mc Morrow, Werner, and Turrini 2010; Bourlès and others 2013).

[4] We conducted further robustness checks without industry/country fixed effects, by sector, and for the post-1995 period, all of which confirmed that our results still hold under these different specifications.

13. **Effects across manufacturing and services sectors.** The PMR for the manufacturing sector also turns out to have a negative and significant effect on overall TFP growth, but unlike the services sector, the impact does not vary with the size of the TFP gap. Moreover, the regression results for the manufacturing subsample (Column 4) do not show a significant role of PMR for TFP growth in the manufacturing sector. This could be interpreted as an indication that the PMR in the manufacturing sector affects overall TFP growth mainly through its indirect impact on other nonmanufacturing sectors.

14. **Impact of labor market regulations.** The labor market regulation measure turns out to be insignificant in all the specifications. There could be several reasons for this result. First, it could reflect the fact that the aggregate-level employment protection legislation indicator exhibits little variation across countries and over time, failing to capture diverse industry-level TFP growth dynamics. Second, this is a partial measure of labor market rigidities, focusing only on the formal procedural costs of firing and hiring in an economy. For example, the flexibility of reallocating workers within firms is not captured by these indicators. Similarly, other labor market institutions, such as the degree of centralization in wage bargaining or the extent of labor tax wedges could significantly affect productivity growth. Finally, as is seen in the next section, it is possible that changes in labor market indicators have delayed effects on TFP growth and over a longer horizon.

B. Empirical Findings: Impact of Labor Skills, ICT Capital, and R&D

15. **Baseline estimates.** We next turn to the empirical estimates of the impact of labor skills, ICT capital, and R&D expenditure on TFP growth (Table A2). Columns 1–4 show that more intense use of high-skilled labor and ICT capital inputs, as well as higher spending on R&D activities, all contribute positively and significantly to productivity growth. The channels through which they affect TFP growth differ. In the case of labor skills and ICT capital, TFP growth estimates, by construction, already take into account the direct contribution of skills and ICT capital services to value-added growth. Therefore, positive coefficients for these variables should be viewed as indicating the indirect returns to output beyond their direct contributions. In the case of labor skills, the additional return could be achieved through an improvement in the absorptive capacity for innovation (i.e. a higher share of more educated workers allows for faster acquisition of new technologies). In the case of ICT capital, more intensive use could bring about broader changes in the production process, the organizational structure, and other business practices within firms that lead to unobserved efficiency gains.

16. **TFP growth impact and distance to the frontier.** Column 5 in Table A2 suggests that, within each industry, the productivity impact of high-skilled labor is larger for countries that are closer to the technology frontier. This provides empirical support for policies aimed at boosting higher-level education in countries with already-high productivity levels, and is also in line with recent studies (Mc Morrow, Werner, and Turrini 2010; Vandenbussche, Aghion, and Meghir 2006). Innovation also appears to improve productivity, but the impact does not vary with the TFP gap. As in the case of labor skills, the coefficient estimates should be viewed as capturing the additional returns to productivity growth beyond the direct contribution to output.

17. **Results for industry subsamples.** The results in Columns 6–7 of Table A2 for manufacturing, ICT, and services sector subsamples show that the effects of labor skill, ICT capital service, and R&D are both sector- and country-specific (in terms of the distance to the frontier). The detailed results from sector-level regressions are as follows:

- *Manufacturing.* The coefficient for ICT capital service is positive and significant, suggesting that a more intensive use of ICT capital generates positive returns in addition to directly increasing output (Column 6). Furthermore, this impact is larger as a country gets closer to the global frontier. The effects of labor skills and R&D expenditure, on the other hand, are not statistically significant. While this is somewhat unexpected, one potential explanation could be that many manufacturing industries are relatively "low-tech" in nature, while the use of workers with tertiary education (our definition of "high-skilled" workers) and R&D activities are likely to matter more for "high-tech" industries that require developing and adopting frontier cutting-edge technologies (e.g., in the ICT sector). Another reason could be the potentially long time horizon over which R&D affects TFP growth. Introduction of new innovative products and production processes, for example, may not necessarily lead to immediate productivity gains, requiring time for their technological potential to be sufficiently exploited.
- *Information and communication technologies (ICT).* The coefficient on high-skilled labor for TFP growth in the ICT sector is positive and significant.[5] Furthermore, the coefficient on the interaction terms with the TFP gap variable suggests that the productivity growth gain is larger for countries closer to the frontier. Similarly, the impact of R&D expenditure is also positive and significant, and larger for countries that are closer to the frontier, as indicated by the positive sign for the interaction term with the TFP gap.[6] The result for R&D could, in part, reflect the innovative nature of activities in this sector, which are likely to be more cutting-edge in nature and therefore matter more for countries at higher stages of technological development.
- *Services.* As in the ICT sector, the empirical results indicate that a higher share of high-skilled labor has a significant and positive impact on TFP growth, particularly for countries closer to the frontier. The coefficient for ICT capital is negative, indicating that intense use of ICT capital in the services sector may actually have an unobserved dampening effect on TFP growth. It should be noted, however, that the coefficient on the interaction term with the TFP gap has a negative sign and is significant, implying that the net impact for countries sufficiently farther away from the frontier may actually be positive. Given that the average service sector TFP gap for our sample countries is about 48 percent, the average country is expected to benefit from more intensive use of ICT services (0.002 x 48 – 0.063 = 0.033).

[5] We define the ICT sector as consisting of manufacturing industries that produce ICT goods and service industries that use ICT goods intensively (e.g., telecommunications).

[6] The latter result is in contrast to Griffith, Redding, and Van Reenen (2004), who find an increasing positive impact of R&D spending for countries farther away from the frontier in select manufacturing industries over 1974–90.

Table A1. Regression Results – Product and Labor Market Regulation

Dependent Variable: TFP Growth Rate (Percent, Annual)	All industries			Manufacturing	ICT-related [1]	Service
	1	2	3	4	5	6
C	-5.387	-5.238	-5.081	-4.313	-2.387	-4.306
	[1.641]***	[1.646]***	[1.698]***	[2.429]*	[2.083]	[1.590]***
TFP Growth Rate at the Frontier	0.054	0.053	0.052	0.115	0.025	0.013
	[0.014]***	[0.014]***	[0.014]***	[0.031]***	[0.013]*	[0.011]
TFP Gap w.r.t. the Frontier	-0.113	-0.110	-0.099	-0.093	-0.053	-0.060
	[0.023]***	[0.023]***	[0.027]***	[0.037]**	[0.029]*	[0.026]**
Product Market Regulation	0.385	0.717	0.945	0.892	-0.199	-1.315
	[0.431]	[0.460]	[0.516]*	[0.786]	[0.776]	[0.445]***
Labor Market Regulation	0.828	0.825	0.645	0.895	0.395	0.451
	[0.570]	[0.569]	[0.624]	[0.954]	[0.814]	[0.640]
Product Market Regulation X TFP Gap			0.006	-0.006	-0.010	-0.017
			[0.007]	[0.008]	[0.010]	[0.005]***
Labor Market Regulation X TFP Gap			-0.008	-0.007	-0.014	-0.012
			[0.008]	[0.012]	[0.011]	[0.011]
Product Market Regulation X Manufacturing Dummy		-0.638	-1.255			
		[0.424]	[0.536]**			
Product Market Regulation X Service Dummy		-0.537	-1.461			
		[0.192]***	[0.366]***			
Product Market Regulation X TFP Gap X Manufacturing Dummy			-0.014			
			[0.012]			
Product Market Regulation X TFP Gap X Service Dummy			-0.021			
			[0.007]***			
# of obs.	4,646	4,646	4,646	2,424	1,616	1,414
R2	0.19	0.20	0.20	0.24	0.29	0.21

Source: Organization for Economic Co-Operation and Development; and IMF staff estimates.

Note: The symbols *, **, *** denote statistical significance at 10, 5, and 1 percent, respectively. The figures in brackets are panel-corrected standard errors robust to heteroskedasticity and possible contemporaneous cross-section correlation. *TFP growth at the frontier* is the annual TFP growth rate of the country with the highest TFP level in industry j. *TFP gap with respect to the frontier* is defined as the percent deviation of the TFP level in country i from the frontier country in year t-1 (with minus sign). *Product market regulation* is an indicator measuring the potential costs of anti-competitive regulation in select non-manufacturing sectors (electricity, gas, air, rail, road transport, post and telecommunications, retail, and professional services) on the industries that use the outputs of these sectors as intermediate inputs, normalized to have mean zero and unit standard deviation for this analysis. *Labor market regulation* is the employment protection legislation index, which we use as a proxy for labor market regulations.

[1] Industries that produce ICT goods or employ ICT goods intensively (ISIC3 code: 21t22, 29, 30t33, 36t37, G, 64, J, 71t74).

Table A2. Regression Results – ICT, Human Capital, R&D

Dependent Variable: TFP Growth Rate (Percent, Annual)	All industries 1	2	3	4	5	Manufacturing 6	ICT-related [1] 7	Service 8
C	-0.579	-1.759	1.68	-0.89	-1.59	-0.905	-6.921	-4.205
	[0.508]*	[0.760]**	[0.606]***	[1.101]	[0.691]**	[1.005]	[1.875]***	[1.719]**
TFP Growth Rate at the Frontier	0.019	0.018	0.043	0.043	0.046	0.089	0.028	0.005
	[0.005]***	[0.005]***	[0.013]***	[0.013]***	[0.013]***	[0.030]***	[0.016]*	[0.012]
TFP Gap w.r.t. the Frontier	-0.019	-0.021	-0.009	-0.008	-0.026	-0.043	-0.076	-0.038
	[0.004]***	[0.005]***	[0.005]*	[0.005]	[0.007]***	[0.010]***	[0.016]***	[0.014]***
ICT Capital	0.025			0.024	0.023	0.146	0.000	-0.063
	[0.007]***			[0.014]**	[0.022]	[0.053]***	[0.037]	[0.037]*
High-skilled Labor		0.055		0.047	0.12	0.077	0.183	0.236
		[0.020]***		[0.024]*	[0.028]***	[0.053]	[0.041]***	[0.057]***
R&D Expenditure			0.118	0.084	0.195	0.100	0.480	0.387
			[0.045]***	[0.048]*	[0.056]***	[0.082]	[0.119]***	[0.731]
ICT Capital X TFP Gap					0.000	0.002	0.000	-0.002
					[0.000]	[0.001]**	[0.001]	[0.001]**
High-skilled Labor X TFP Gap					0.002	0.002	0.003	0.003
					[0.001]***	[0.001]	[0.001]***	[0.001]***
R&D Expenditure X TFP Gap					0.002	0.001	0.006	0.013
					[0.001]	[0.001]	[0.002]***	[0.013]
# of obs.	6,923	6,402	2,950	2,685	2,685	1,707	849	487
R2	0.11	0.11	0.11	0.11	0.11	0.15	0.21	0.24

Source: Organization for Economic Co-Operation and Development; and IMF staff estimates.

Note: The symbols *, **, *** denote statistical significance at 10, 5, and 1 percent, respectively. The figures in brackets are panel-corrected standard errors robust to heteroskedasticity and possible contemporaneous cross-section correlation. TFP growth at the frontier is the annual TFP growth rate of the country with the highest TFP level in industry j. TFP gap with respect to the frontier is defined as the percent deviation of the TFP level in country i from the frontier country in year t-1 (with minus sign). ICT capital and high-skilled labor are the ICT capital share of total capital compensation and the hours worked by workers with tertiary education, respectively, all from the EU KLEMS. R&D expenditure is the R&D expenditure as percent of each industry's value-added.

[1] Industries that produce ICT goods or employ ICT goods intensively (ISIC3 code: 21t22, 29, 30t33, 36t37, G, 64, J, 71t74).

18. **Robustness checks**. The results presented in Tables A1 and A2 are broadly robust under alternative specifications, sample periods, and the inclusion of other control variables that capture macroeconomic conditions, such as the output gap and the systemic banking crisis dummy variable. First, to control for possible country-specific developments, we used a joint time-country fixed effect in Table A2 instead of considering country and time fixed effects separately.[7] In this case, both the significance and the signs of the coefficients remain the same as in the baseline specification in the full sample (Column 5), but the interaction term between the R&D and the TFP gap becomes significant and positive, implying greater productivity gains for countries closer to the frontier. Second, we also obtained broadly similar results when using the post-1995 subsamples. Notably we find that while the coefficient of the interaction term for manufacturing PMR becomes significant and negative in the all-industry sample, the coefficients for R&D expenditure and its interaction term with the TFP gap become significant and positive in the manufacturing subsample. Finally, the main baseline results remain unchanged even after controlling for macroeconomic conditions, which are captured using the output gap and the systemic banking crisis dummies.

III. DYNAMIC EFFECT OF REFORMS

This section describes the framework to assess the dynamic effects of structural reforms on sectoral TFP, employment, and output, then discusses the main findings. We also investigate how the effects of reform depend on the distance from the frontier, initial structural and institutional settings, and prevailing economic conditions.

19. **Identification of reforms.** Reforms are identified using the same set of policy and structural indicators described in the previous section. We also include a measure of the level of infrastructure and the labor tax wedge. The infrastructure measure is the principal component of roads, phones lines, and electricity generation capacity (IMF 2014). the labor tax wedge is taken from the OECD's Taxing Wages database and measured as a percentage of taxes and transfers paid in the share of total labor costs. An increase (in absolute terms) of a structural indicator above a certain threshold is assumed to signal a reform, while any other change—including in the opposite direction—is not. This definition is directional in the sense that large changes in indicators in the opposite direction (e.g., an increase in product and labor market rigidities) are ignored. The threshold is constructed by industry, country, and year to capture the catch-up effect to the best performers. More specifically, a reform variable is equal to 1 if the change in R&D, ICT capital, and high-skilled labor is above (or below for labor tax wedge) two standard deviations of the average annual change in the indicator, and 0 otherwise. Given little variation in some structural indicators over time, a reform variable takes the value of 1 if it is below (product and labor market regulations) or above (infrastructure) one standard deviation of the average annual change in the indicator, and 0 otherwise. Table A3 presents the descriptive statistics underlying the analysis.

[7] In Table A1, the labor market regulation measure is a country-level index and hence including the joint fixed effect leads to perfect collinearity.

Table A3. Descriptive Statistics

Policy/ Structural Indicators	Mean	Standard Deviation	Number of Reform Shocks per Country	Average Cumulative 5-year Change in TFP Following the Shocks	Percent of Shocks and Average Cumulative 5-year TFP Change	
					during upturns	during downturns
Product Market Regulation	2.77	1.16	136	6%	55%	45%
Job Protection Legislation	1.78	0.96	15	5%	3%	67%
Labor Tax Wedge	0.07	1.14	11	10%	82%	18%
Infrastructure	0.33	1.91	35	3%	91%	9%
R&D	2.99	5.16	75	18%	56%	44%
ICT capital	0.13	0.16	197	14%	71%	32%
High-Skill Labor	8.94	8.77	329	6%	40%	60%
Memorandum Items: Average Cumulative 5-year Changes						
TFP level in the sample	4%	19%				
Employment level in the sample	-1%	16%				
Output (value added) level in the sample	11%	18%				

Source: EU KLEMS database; World KLEMS database; OECD and IMF databases; and IMF staff estimates.

20. **Empirical specification.** A dynamic version of the empirical specification outlined in the previous section is used to assess the temporal effects of reform shocks on changes in the TFP level. In particular, the following equation is estimated for each of the three or five years after the reform episode:[8]

$$\mathrm{tfp}_{i,j,t+k}-\mathrm{tfp}_{i,j,t} = \beta_0 + \beta_1 S_{i,j,t} + \beta_2 S_{i,j,t}\mathrm{tfpgap}_{i,j,t} + \beta_3 \mathrm{tfpgap}_{i,j,t} + \beta_4 \Delta\mathrm{tfp}_{L,j,t} + \beta_5' X_{it} + \alpha_1 D_i + \alpha_2 D_j + \alpha_3 D_t + \varepsilon_{i,j,t},$$

where tfp_{ijt} is the log of real TFP in country i, industry j, and year t and $S_{i,j,t}$ denotes reform dummies (equal to 1 in case a reform has been identified and zero otherwise). The log of real TFP at the frontier industry j and technological gap from the frontier are indicated by $tfp_{L,j,t}$ and $tfpgap_{i,j,t}$, respectively. X_{it} is a set of controls and D_i, D_j, and D_k are country, industry and time dummies, respectively.[9] As economic crises can facilitate the introduction of reforms, controls include recession and financial crises dummies. GDP growth is also included to further control for the procyclical nature of TFP measures. The estimated coefficients β_1 and β_2 capture the unconditional and conditional (taking into account the technological gap) effect of reforms at horizon k and yield the impulse response function. In the baseline specification, the impact of a reform is assessed at the average technological gap: $\beta_1 + \beta_2\overline{tfpgap}$.

[8] Robust standard errors are clustered at country and industry levels. The empirical setup consists of derivate impulse response functions from *local projections* (Jorda, 2005; Teulings and Zubanov 2014) by estimating a set of *k* (with *k*=1…3 or *k*=1…5) independent equations. This approach has been applied, for instance, by Ahrend, Arnold, and Moeser (2011) and Bouis and others (2012).

[9] To minimize potential omitted variable bias resulting, for instance, from country-wide developments, an alternative specification includes a country-time dummy. The results remain qualitatively similar.

21. **Impact on TFP across all industries.** Figure A1 presents the effect of reforms on the cumulative short-term (three years) and medium-term (five years) changes in the TFP level. It indicates that PMR reforms, a large decline in the labor tax wedge, and significant increases in R&D, ICT capital, and infrastructure generally have a positive impact on TFP growth. A reduction in employment protection legislation, however, tends to be associated with a short-term reduction in aggregate TFP level.[10] More specifically, Figure A1 shows that an average product market regulation shock, on average, increases the TFP level across all industries by about 1 percent after five years (i.e., 0.05 standard deviation of the average cumulative five-year TFP change in the sample). Further, a 10-percent increase in R&D spending, on average, increases the TFP level across all industries by about 2 percent in the medium term (0.1 standard deviation of the average cumulative five-year TFP change in the sample). The results appear to confirm previous findings,[11] particularly those that find that deregulation of network industries is positively associated with higher efficiency in sectors that more intensively use these industries as intermediate inputs (Bourlès and others, 2013; IMF 2014b).

22. **Reform impact tends to vary across different industries.** PMR reforms increase TFP in manufacturing and distribution both in the short and medium term, and over the medium term in ICT and personal services. Large infrastructure shocks have a positive and increasing impact on productivity in ICT, finance-business, and other production.[12] R&D shocks steadily boost TFP in manufacturing and ICT, and, over the medium term, in distribution services. ICT shocks have a positive permanent impact on manufacturing and personal services, while a large increase in high-skilled labor affects medium-term TFP growth in ICT and other production sectors (e.g., agriculture, mining, and utilities). Some adjustment costs can be discerned in the ICT, finance-business, and personal services sectors following product and market liberalization.

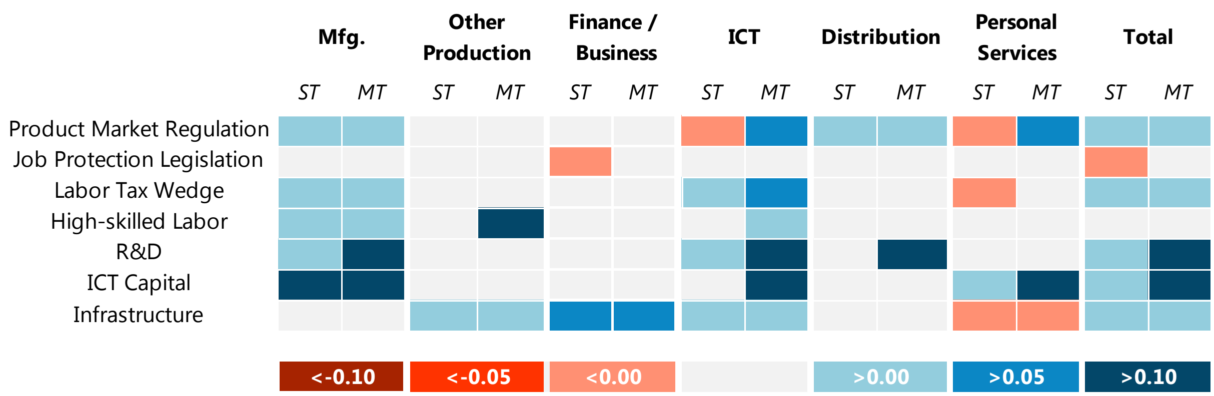
[10] Partial labor protection reforms have been associated with lower GDP, consumption, and investment growth in the short term (Bouis and others 2012). However, the cross-country productivity effects of labor market reforms are less clear-cut in the literature (OECD 2007).

[11] The results are qualitatively similar when all reforms and structural change shocks are jointly estimated. In particular, the coefficients associated with product market reforms, R&D, and ICT shocks remain statistically significant. In addition, while the coefficients associated with infrastructure and high-skilled labor shocks become statistically insignificant due to multicollinearity between the various reform variables, a test of joint significance validates the inclusion of these variables in the model.

[12] While the large gains in TFP associated with infrastructure shocks are likely to be driven by the fact that our measure of TFP embodies public infrastructure capital, the results are also indicative of complementarities between private and public capital (Dabla-Norris and others 2013).

Figure A1. Dynamic Impact of Reforms on Total Factor Productivity

(Percent)



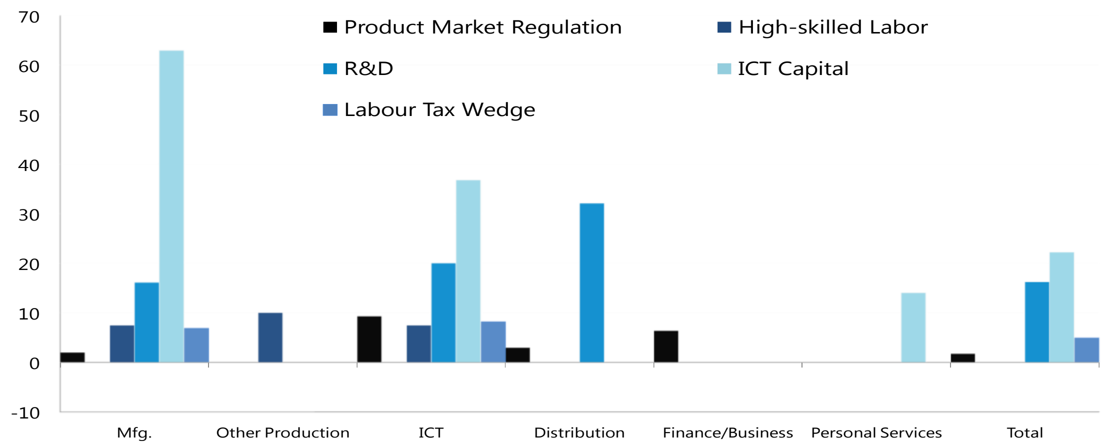
Sources: EU KLEMS database; World KLEMS database; OECD and IMF databases; and IMF staff estimates.

Note: The results show cumulative three-year (ST) and five-year (MT) level gains in TFP. Brown and shades of red indicate a negative statistically significant impact of the reform; shades of blue indicate a positive statistically significant one. For instance, following an average reform shock in ICT capital, the cumulative increase in the TFP level in ICT-related industries is about 30 percent after five years (i.e., about two standard deviations of an average cumulative five-year change in the TFP level in the sample). "Other production" includes agriculture, forestry, fishing, mining, quarrying, electricity, gas, and water-related industries.

23. **Reforms and distance to the frontier.** As the impact of structural reforms may depend on the degree of technological advancement, we extend the baseline analysis by focusing on technological gaps with the frontier. In particular, we estimate how the effect of reforms varies between an industry with a lower technological gap (75th percentile of the distribution) and an industry with a higher technological gap (25th percentile of the distribution) with respect to the frontier. Consistent with the results presented in the previous section, we find that the impact of product market liberalization, R&D, ICT, and human capital is larger the closer a country is to the frontier (Figure A2). In particular, the TFP increase in industries with a lower technological gap, on average, is about 2 percent higher following PMR and infrastructure reforms, and about 10 percent higher following R&D and ICT shocks, than for industries farther away from the frontier. A significant increase in high-skilled labor raises the TFP level by about 7–10 percent more in the distribution and ICT-related industries that are closer to the frontier. The positive productivity impact of infrastructure, however, does not appear to be affected by the distance to the technological frontier.

Figure A2. Dynamic Impact of Reforms on TFP: Conditional on the TFP Gap

(Percent)



Sources: EU KLEMS database: World KLEMS database; OECD and IMF databases; and IMF staff estimates.

Note: The results show cumulative five-year level gains in TFP as a function of the distance to the technological frontier. For instance, following an average R&D shock, the cumulative five-year increase in the aggregate TFP level is about 15 percent higher (i.e., about one standard deviation of an average cumulative five-year change in TFP level in the sample) for industries closer to the technological frontier (75th percentile of the distribution) than farther from it (25th percentile). "Other production" includes agriculture, forestry, fishing, mining, quarrying, electricity, gas, and water-related industries.

24. **Pre-reform policy and structural settings.** The impact of reforms may also differ depending on initial structural and policy settings. Therefore, the baseline specification is extended as follows:

$$\mathrm{tfp}_{i,j,t+k} - \mathrm{tfp}_{i,j,t} = \delta_0 + \delta_1^{<Xt} S_{i,j,t} + +\delta_1^{>Xt} S_{i,j,t} + \delta_2^{<Xt} S_{i,j,t}\mathrm{tfpgap}_{i,j,t} + \delta_2^{>Xt} S_{i,j,t}\mathrm{tfpgap}_{i,j,t} + \delta_3 \mathrm{tfpgap}_{i,j,t} + \delta_4 \Delta\mathrm{tfp}_{L,j,t} + \delta_5' X_{it} + \gamma_1 D_i + \gamma_2 D_j + \gamma_3 D_t + \epsilon_{i,j,t},$$

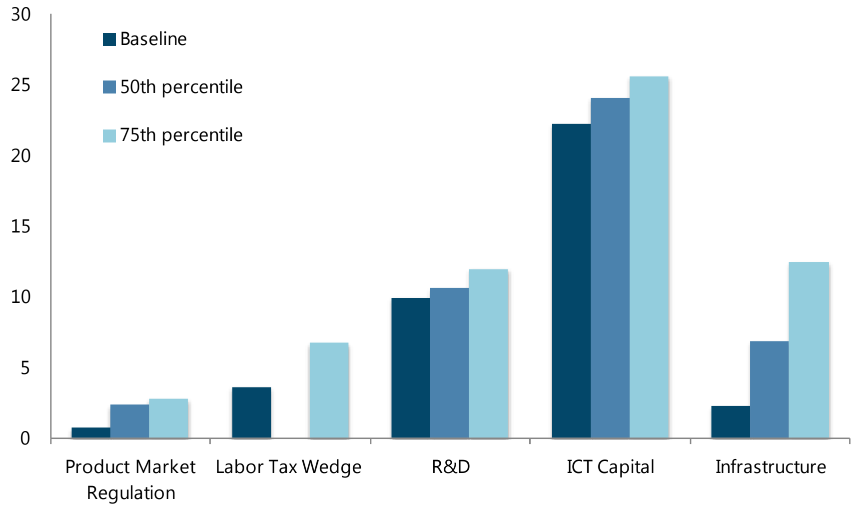
where the estimated coefficients $\delta_1^{<Xth}$and $\delta_2^{<Xth}$ capture the impact of reforms for industries with initial policy and structural settings below the 25th, 50th, and 75th percentile of the distribution. Conversely, $\delta_1^{>Xth}$and $\delta_2^{>Xth}$ denote the average reform effects for industries with initial settings above the 75th, 50th, and 25th percentile of the distribution. The results (reported in Figure A3) appear broadly in line with previous findings.[13] In particular, a large decline in PMR, on average, results in the highest productivity gains for industries with initially higher regulatory burdens, while the impact is not statistically significant for industries with the lowest regulations. Similarly, the impact of R&D, ICT, and infrastructure shocks on TFP, on average, is higher for industries with higher initial levels of innovation and infrastructure. The impact of labor tax wedge shocks is higher for industries in countries with an initial level of the tax wedge above the 75th percentile and not significant for industries in countries with lower tax wedges. Some differences, however, can be

[13] For instance, Bourlès and others (2013) find that the highest productivity gains accrue from adopting best practices in terms of PMR regulations in highly-regulated sectors with lower gains resulting when best practices are adopted in sectors with initially low regulatory burdens.

gleaned across industries, especially in ICT and personal services, where productivity gains tend to be higher the lower are initial levels of R&D and ICT capital use.

Figure A3. Dynamic Impact of Reforms on TFP: Conditional on Initial Settings

(Percent)



Sources: EU KLEMS database; World KLEMS database; OECD and IMF databases; and IMF staff estimates.
Note: The results show the cumulative five-year level gains in TFP as a function of initial policy and structural settings. "Other production" includes agriculture, forestry, fishing, mining, quarrying, electricity, gas, and water-related industries.

25. **Reform impact across the business cycle.** The impact of structural reforms may also depend on the business cycle position, in particular on how changes in institutional and structural settings affect supply and demand factors. In particular, the impact of reforms may be stronger if they increase demand more than supply during a downturn. To capture the importance of economic conditions, the baseline specification is extended as follows:[14]

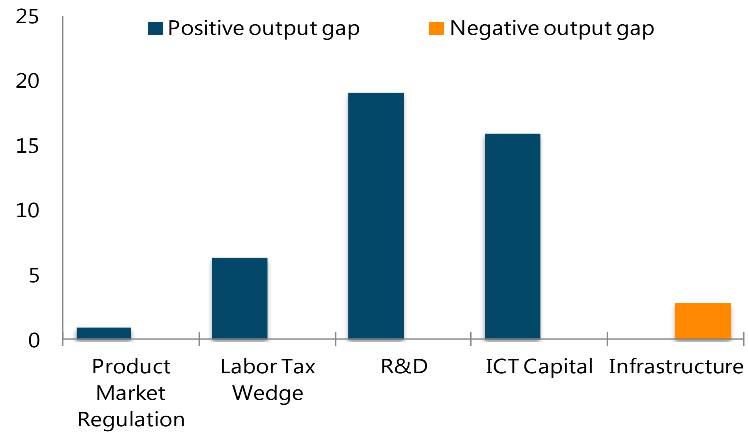
$$tfp_{i,j,t+k} - tfp_{i,j,t} = \beta_0 + \gamma_1 F(Z_{i,t})S_{i,j,t} + +\gamma_2 F(1 - Z_{i,t})S_{i,j,t} + \theta_1 F(Z_{i,t})S_{i,j,t}tfpgap_{i,j,t} + \theta_2 F(1 - Z_{i,t})S_{i,j,t}tfpgap_{i,j,t} + \beta_3 tfpgap_{i,j,t} + \beta_4 \Delta tfp_{L,j,t} + \beta_5^{'} X_{it} + \alpha_1 D_i + \alpha_2 D_j + \alpha_3 D_t + \varepsilon_{i,j,t},$$

where the coefficients γ_1 and θ_1 capture the impact of reforms during downturns and γ_2 and θ_2 during upturns.[15] The results (Figure A4) confirm that infrastructure shocks are associated with significantly higher productivity gains during downturns (Abiad, Furceri, and Topalova, forthcoming), while product market liberalization and innovation shocks have a more significant impact during upturns.

[14] Reform shocks are broadly equally distributed between periods of economic upturns and downturns. As economic crises can facilitate the introduction of reforms (Duval 2008), recession and crises dummies are included in the model specification.

[15] Overall economic conditions are identified using the output gap and, alternatively, downturn and expansion normalized indicators (IMF 2014a).

Figure A4. Dynamic Impact of Reforms on TFP across the Business Cycle
(Percent)



Source: EU KLEMS database; World KLEMS database; OECD and IMF databases; and IMF staff estimates.
Note: The results show the cumulative five-year level gains in TFP across overall economic conditions. For instance, following an average reform shock in ICT capital during upturns, the cumulative five-year increase in the average TFP across all industries increases by about 15 percent (i.e., 0.8 standard deviation of the average cumulative five-year TFP level change in the sample). "Other production" includes agriculture, forestry, fishing, mining, quarrying, electricity, gas, and water-related industries.

A. Dynamic Impact on Employment and Output Growth

26. **Empirical approach.** Previous analyses have shown that although structural reforms can have substantial medium-term benefits, there could be short-term costs associated, for instance, with adjustment, reallocation, or loss of physical and human capital (Blanchard and Giavazzi, 2003). To shed more light on this issue, this section extends the dynamic analysis of sectoral productivity on employment and output. In particular, the baseline specification is modified as follows:

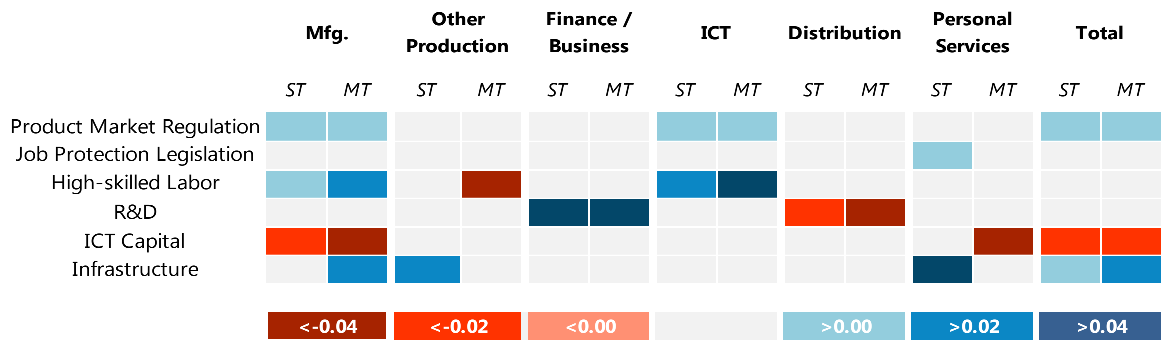
$$\mathrm{va}_{i,j,t+k} - \mathrm{va}_{i,j,t} = \beta_0 + \beta_1 S_{i,j,t} + \sum_{\tau=1}^{\tau=3} \beta_2 \mathrm{va}_{i,j,t-\tau} + \beta_3' X_{it} + \alpha_1 D_i + \alpha_2 D_j + \alpha_3 D_t + \varepsilon_{i,j,t},$$

where va_{ijt} is the log of real value added or employment in country i, industry j, and year t. $S_{i,j,t}$ denotes the reform variables. X_{it} is a set of controls and D_i, D_j, and D_k are country, industry, and time dummies, respectively. As the analysis focuses on the overall (i.e., unconditional) impact of reform shocks, no transition channel is specified.

27. **Impact on employment.** The results (reported in Figure A5) suggest that product market liberalization and infrastructure shocks have a positive and persistent impact on employment, while ICT capital shocks seem to reduce it, likely reflecting the effect of automation on labor shedding. More intensive use of high-skilled labor has a positive effect on employment in manufacturing and ICT industries, but negatively affects employment in other production sectors. Labor market liberalization, proxied here by employment protection legislation, boosts employment in personal services in the short term.

Figure A5. Dynamic Impact of Reforms on the Sectoral Employment Level

(Percent)



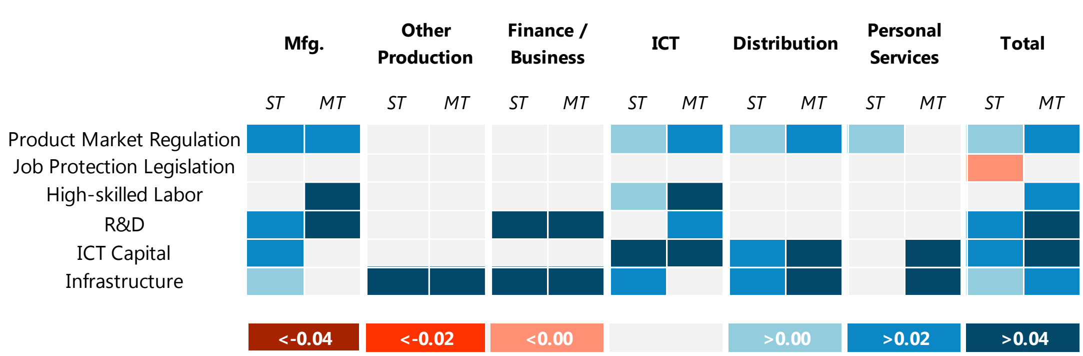
Source: EU KLEMS database; World KLEMS database; OECD and IMF databases; and IMF staff estimates

Note: The results show cumulative three-year (ST) and five-year (MT) level gains in employment. Brown and shades of red indicate a negative and statistically significant impact of the reform; shades of blue indicate a positive and statistically significant one. For instance, following an average R&D shock, the cumulative increase in the employment level in finance/business-related industries is about 10 percent after five years (i.e., about 0.7 standard deviations of the average cumulative five-year change in employment level in the sample). "Other production" includes agriculture, forestry, fishing, mining, quarrying, electricity, gas, and water-related industries.

28. **Impact on output**. In general, structural reforms have positive and increasing effects on output (Figure A6). In particular, product market liberalization and more intensive use of high-skilled labor increase overall industrial value added by about 2 percent over the medium term. Effects of infrastructure and innovation shocks are even larger, boosting output, on average, by around 3 and 5 percent, respectively. Labor market liberalization has a short-term negative impact on output, similar to that on TFP. Some differences can be noticed across industries. For instance, high-skilled labor and R&D shocks have larger positive effects on manufacturing and ICT-related industries. ICT shocks increase output in ICT, distribution and personal services. Infrastructure shocks have a positive short-term impact on almost all sectors.

Figure A6. Impact of Reform Shocks on Sectoral Output

(Percent)



Sources: EU KLEMS database; World KLEMS database; OECD and IMF databases; and IMF staff estimates.

Note: The results show cumulative three-year (ST) and five-year (MT) level gains in output. Brown and shades of red indicate a negative impact of the reform; shades of blue indicate a positive one. For instance, following an average shock in high-skilled labor, a cumulative increase in output level in manufacturing-related industries is about 6 percent after five years (i.e., about 0.3 standard deviations of an average cumulative five-year change in output level in the sample). "Other production" includes agriculture, forestry, fishing, mining, quarrying, electricity, gas, and water-related industries.

REFERENCES

Abiad, A., D. Furceri, and P. Topalova. Forthcoming. "Macroeconomic Effects of Public Investment: Evidence from Advanced Economies." IMF Working Paper.

Acemoglu, D., F. Zilibotti, and P. Aghion. 2006. "Distance to Frontier, Selection and Economic Growth." *Journal of the European Economic Association* 4 (1): 37–74.

Aghion P., and P. Howitt. 2006. "Joseph Schumpeter Lecture Appropriate Growth Policy: A Unifying Framework." *Journal of the European Economic Association* 4 (2-3): 269–314.

———. 2009. *The Economics of Growth*. Cambridge, Massachusetts: MIT Press.

Ahrend R., J. Arnold, and C. Moeser. 2011. "The Sharing of Macroeconomic Risk: Who Loses (and Gains) from Macroeconomic Shocks." OECD Economics Department Working Paper No. 877, Organization for Economic Cooperation and Development, Paris.

Aoki, S. 2012. "A Simple Accounting Framework for the Effect of Resource Misallocation on Aggregate Productivity." *Journal of the Japanese and International Economies* 26 (4): 473–94.

Blanchard, O., and F. Giavazzi. 2003. "Macroeconomic Effects Of Regulation And Deregulation In Goods And Labor Markets." *The Quarterly Journal of Economics* 118 (3): 879–907.

Bouis R., O. Causa, L. Demmou, R. Duval, and A. Zdzienicka. 2012. "The Short-Term Effects of Structural Reforms: An Empirical Analysis." OECD Economics Department Working Paper No. 949, Organization for Economic Cooperation and Development, Paris.

Bourlès, R., G. Cette, J. Lopez, J. Mairesse, and G. Nicoletti. 2013. "Do Product Market Regulations In Upstream Sectors Curb Productivity Growth? Panel Data Evidence for OECD Countries." *The Review of Economics and Statistics* 95(5): 1750–768.

Conway, P., and G. Nicoletti. 2006. "Product Market Regulation in the Non-Manufacturing Sectors of OECD Countries: Measurement and Highlights." OECD Economics Department Working Paper No. 530, Organization for Economic Cooperation and Development, Paris.

Dabla-Norris, E., and others. 2013. "Anchoring Growth: The Importance of Productivity-Enhancing Reforms in Emerging Market and Developing Economies." Staff Discussion Note 13/08, International Monetary Fund, Washington.

Duval, R. 2008. "Is There a Role for Macroeconomic Policy in Fostering Structural Reforms? Panel Evidence from OECD Countries over the Past Two Decades." *European Journal of Political Economy* 24 (2): 491–502.

Griffith R., S. Redding, and J. Van Reenen. 2004. "Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries." *The Review of Economics and Statistics* 86 (4): 883–95.

International Monetary Fund (IMF). 2014a. *World Economic Outlook,* Washington, October.

———. 2014b. "Macroeconomic and Reform Priorities." Paper presented at the meeting of G-20 Finance Ministers and Central Bank Governors, 22-23 February, Sydney, Australia.

Inklaar, R., and M. P. Timmer. 2008. "GGDC Productivity Level Database: International Comparisons of Output, Inputs and Productivity at the Industry Level." GGDC Research Memorandum GD-104, Groningen Growth and Development Centre, University of Groningen.

Jorda, O. 2005. "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review* 95 (1): 161–82.

Mc Morrow, K., R. Werner, and A. Turrini. 2010. "Determinants of TFP Growth: A Close Look at Industries Driving the EU-US TFP Gap." *Structural Change and Economic Dynamics* 21 (3): 165–80.

Nicoletti, G., and S. Scarpetta. 2003. "Regulation, Productivity and Growth: OECD Evidence." *Economic Policy* 18 (36): 9–72.

Organization for Economic Cooperation and Development (OECD). 2007. *OECD Employment Outlook*. Paris: Organization for Economic Cooperation and Development.

Teulings, C., and N. Zubanov. 2014. "Is Economic Recovery A Myth? Robust Estimation Of Impulse Responses." *Journal of Applied Econometrics* 29(3): 497–514.

Vandenbussche, J., P. Aghion, and C. Meghir. 2006. "Growth, Distance to Frontier and Composition of Human Capital." *Journal of Economic Growth* 11 (2): 97–127.