GROUP OF TWENTY

BOOSTING PRODUCTIVITY IN THE AFTERMATH OF COVID-19—ANNEX

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INTERNATIONAL MONETARY FUND*

*Does not necessarily reflect the views of the IMF Executive Board

June 2021

ONLINE ANNEX

This Annex provides underlying details on the empirical exercises in the 2021 G-20 Background Note on Boosting Productivity in the Aftermath of COVID19.[1] *The Annex is structured in four sections, providing background analysis for (i) Figure 9 on intangible investment and productivity; (ii) Figure 10 on reallocation and productivity; (iii) Figure 13 on labor productivity decompositions; and (iv) Figure 16 on structural policies and investment in intangible capital.*

A. Intangible Investment and Productivity

This section describes the analysis shown in Figure 9 of the main text.

Empirical specification

1. The analysis builds on Corrado and others (2009) who estimate the role of intangible capital in US economic growth. Treating intangible capital symmetrically to tangible capital, a production function consistent with the growth equations in Corrado and others (2009) is established:

$$Y_{ijt} = A_{ijt} K_{ijt}^{\alpha} R_{ijt}^{\beta} L_{ijt}^{\gamma}$$

Here, Y_{ijt} is output at the country (i), sector (*j*), and year *(t)* level. A_{ijt} is total factor productivity, K_{ijt} is tangible capital, R_{ijt} is intangible capital, and L_{ijt} labor. Baseline regressions are based on value added output, which allows to ignore intermediate inputs in the production function (gross output is used as an alternative measure in robustness analysis). Labor is measured as hours worked (number of persons employed in robustness analysis).

2. The production function is transformed to consider labor productivity in log terms:

$$\ln\left(\frac{Y_{ijt}}{L_{ijt}}\right) = \ln(A_{ijt}) + \alpha \ln(K_{ijt}) + \beta \ln(R_{ijt}) + \delta \ln(L_{ijt}) + \varepsilon_{ijt}$$

Here, $\gamma = \delta + 1$. As total factor productivity is not directly observed, it is assumed to be in the error term. Hence, the coefficients of interest are α and β. The model is augmented to include country-sector fixed effects, which control for sector-specific characteristics of labor productivity within each country. The results are robust to also including time fixed effects.

[1] This annex, and the G-20 Background Note it supports, was prepared under the supervision of Oya Celasun by a team led by Lone Christiansen and comprising Ashique Habib, Jaden Kim, Margaux MacDonald (principal economist), Davide Malacrino, Menexenia Tsaroucha, and Bryan Zou. Ilse Peirtsegaele provided administrative support. This annex and the G-20 Background Note it supports do not necessarily reflect the views of G-20 members. G-20 notes by the IMF are available on IMF.org.

Data

3. Data on intangible capital are from the INTAN database of Corrado and others (2016). Data on tangible capital, value added output, and labor are from EU KLEMS. The sample includes 17 countries (*Austria*, *Belgium*, *Czech Republic*, *Denmark*, *Finland*, *France*, *Germany*, *Greece*, *Italy*, *Netherlands*, *Portugal*, *Slovak Republic*, *Slovenia*, *Spain*, *Sweden*, *United Kingdom*, *United States*) from 1995 to 2017. The industry classification is from EU KLEMS, aligned with the NACE Rev 2, and covering 13 industries (excluding all non-market sectors and sectors for which data on intangible assets are missing). All variables are in real terms after deflating with the nominal GDP deflator from the World Economic Outlook database.

Results

4. Results are reported in Appendix Table A1. Both tangible and intangible capital are positively and significantly associated with higher labor productivity growth. The baseline specification (column one) is presented in the main text.

Table A1. Association Between intangible investment and productivity

	(1)	(2)	(3)	(4)
Dependent variable:	$\ln\left(\frac{Value\ added}{Hours\ worked}\right)$			$\ln\left(\frac{Gross\ output}{Hours\ worked}\right)$
ln(hours worked)	-0.715***	-0.642***		-0.797***
	(0.0692)	(0.0649)		(0.0666)
ln(tangible capital)	0.312***	0.202***	0.305***	0.331***
	(0.0350)	(0.0346)	(0.0339)	(0.0406)
ln(intangible capita)	0.434***	0.378***	0.434***	0.484***
	(0.0338)	(0.0330)	(0.0334)	(0.0351)
ln(employed persons)			-0.725***	
			(0.0671)	
N	4301	4301	4319	4301
R-sq	0.974	0.978	0.972	0.980
Country-sector FE	YES	YES	YES	YES
Year FE	NO	YES	NO	NO

Clustered standard errors (country-sector) in parentheses
* p<0.1 ** p<0.05 *** p<0.01

B. Reallocation and Productivity

This section describes the analysis of the impact of recessions and reallocation on total factor productivity (TFP) growth shown in Figure 10 of the main text.

Empirical specification

5. The analysis is based on a sequence of OLS regressions. They are considered at various horizons (i.e., "local projections", see Jorda, 2005):

$$y_{sc,t+k} - y_{sc,t-1} = \beta_k D_{c,t} + \gamma_k R^D_{sc,t} + \delta_k D_{c,t} * R^D_{sc,t} + \sum_{j\in\{-1,-2\}\cup\{1..k\}} \zeta_k D_{c,t+j} + \phi_{k,cs} + \phi_{k,t} + \varepsilon^k_{sct}$$

Here, k is the forward time horizon and takes values from 0 to 4; s is the sector and c country; and t is quarter. The variables are as follows:

- $y_{sc,t}$ is the log of TFP computed at the firm level and aggregate to the country-sector level. The firm-level TFP measures is from Diez and others (2019), which is based on the De Loecker and Warzynski (2012) definition of firm-level TFP. The measure uses turnover revenue and, as a measure of inputs, materials. Were data on materials is unavailable, cost of goods sold is used. The firm level measure of TFP is then aggregated at the sector level (Nace 2 level) by taking employment weighted averages.

- $D_{c,t}$ is a dummy that takes the value of one in year t if country c experienced a recession (defined as negative real GDP growth) in year t. Following the literature, the regression controls for 2 lags and k forwards of the recession dummy to capture the effect of the recession on impact (such controls are represented by the sum in the equation).

- $R^D_{sc,t}$ is a dummy that takes the value of one if the measure of reallocation in sector-country pair sc (R_{sc}) is above the median of the reallocation distribution in the sample in the year of the shock. Here, we compute R_{sc} across firms and within sector-country pairs as the employment-weighted standard deviation of capital growth:

$$R_{sc} = \sqrt{\sum_{f\in sc} Emp_f * \left(g^k_f - \overline{g_{sc}}\right)^2}$$

  Here, g^k_f is the log change in capital (computed as the sum of tangible and intangible fixed assets), $\overline{g_{sc}}$ is the average growth of capital within each sector-country pair, and Emp_f is the number of employees in the firm.

- $\phi_{k,cs}$ and $\phi_{k,t}$ are country-sector pair and country-year fixed effects, respectively, and ε^k_{sct} is an error term.

6. The coefficients of intertest are β_k and δ_k. The sequence of β_k (for k in 0 to 4) captures the local projection of TFP from a recession (on impact and up to 4 years after the event for country-sector pairs with reallocation index below the median). The sequence of sums $\{\beta_k + \delta_k\}$ represents the same object for pairs with reallocation index above the median.

Data

7. The data combine sector and firm level data.

- *Sector level data are from EU KLEMS*. The sample covers 19 advanced economies (*Austria*, *Belgium*, *Czech Republic*, *Denmark*, *Finland*, *France*, *Germany*, *Greece*, *Hungary*, *Ireland*, *Italy*, *Japan*, *Lithuania*, *Luxembourg*, *Netherlands*, *Spain*, *Sweden*, *United Kingdom*, and *United States*) from 1995 to 2017.

- *Firm level data are from Orbis*. The baseline sample includes data from 13 countries for which it is possible to compute TFP based on De Loeker and Warzynski (2012) using materials as an instrument. Those are *Austria*, *Belgium*, *Czech Republic*, *Finland*, *France*, *Germany*, *Spain*, *Hungary*, *Italy*, *Norway*, *Poland*, *Portugal*, *Slovakia*. In robustness checks, 5 additional countries (*United Kingdom*, *Greece*, *Ireland*, *Japan*, and *United States*), for which it is possible to use only "cost of goods sold" as an instrument to build TFP, are added. The time dimension varies from country to country: most countries have data from 1995 or 1997 to 2015 except for *Japan* (2001–2015) and the *United States* (2007–2015).

Results

8. Results are reported in Figure A1. As highlighted in the main text, the baseline specification shows that TFP falls by more in country-sector pairs with low degree of reallocation. The difference vanishes over time and it is not statistically significant 3 to 4 years after the recession event. Over the analyzed horizon, the cumulative loss in TFP in country-sector pairs with low reallocation stays consistently below country-sector pairs with high degree of reallocation.

9. To check the robustness of the result, the baseline is modified in three ways:

1. *Expanding the sample*. The sample is extended to include those countries for which it is only possible to compute TFP using cost of goods sold as an instrument (panel b).

2. *Alternative reallocation measures*. The specification is altered by using a reallocation measure that enters continuously rather than as a dummy (panel c). In this case the "high" and "low" reallocation IRFs are computed by picking values of the reallocation index at the 90th and 10th percentiles of the distribution respectively.

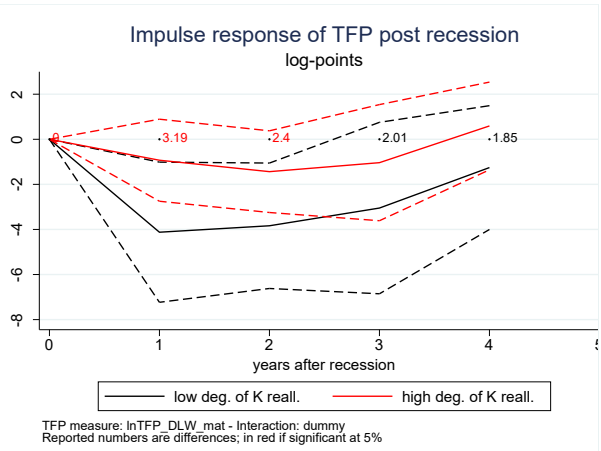
3. *Combining modifications in 1 and 2*. The results are shown in panel d.

10. Results from the robustness check are in line with the baseline results. The results from robustness check 1 confirm those in the baseline although the difference between the two groups is

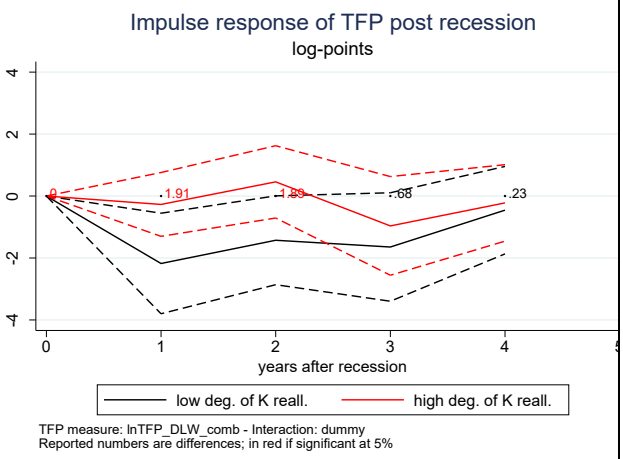
now smaller. The results from robustness checks 2 and 3 confirm qualitatively the baseline findings insofar as the local projects among country-sector pairs with high degree of reallocation lie systematically above those computed for pairs with low degree of reallocation—though responses are statistically indistinguishable.

Figure A1. Impulse Responses of TFP to Recessions for given levels of Capital Reallocation

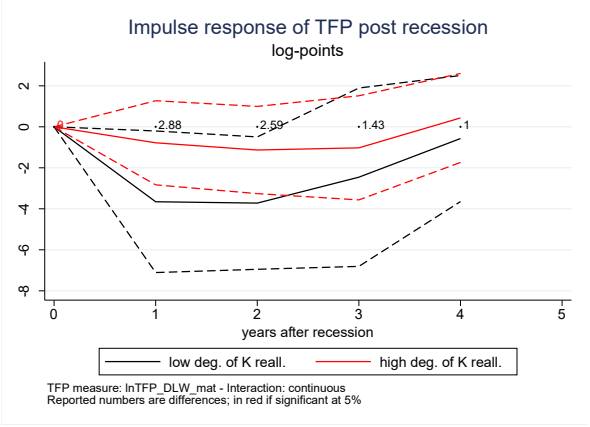
1. Baseline



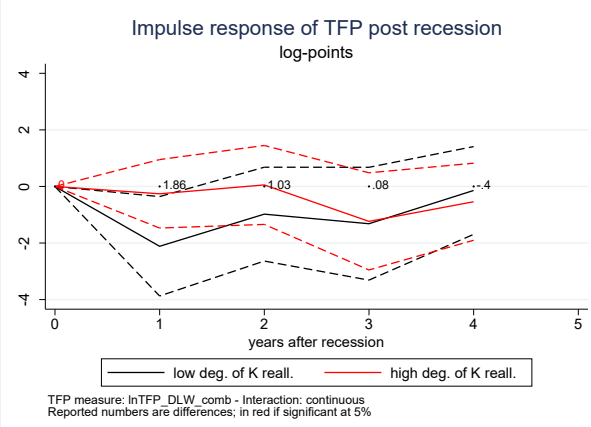
2. Robustness: extended sample



3. Robustness: continuous specification



4. Robustness: continuous specification and extended sample



Source: Orbis; EU KLEMS; and IMF staff estimates.

C. Decomposition of Labor Productivity

This section describes the analysis shown in Figure 13 of the main text.

Empirical specification

11. The labor productivity decomposition is based on McMillan and Rodrik (2011). This method decomposes labor productivity growth in an economy into two sources:

- *With sectors*. Labor productivity growth *within* sectors through capital accumulation, technological change, or reduction of misallocation across firms.
- *Between sectors*. Labor can move *across* sectors, from sectors with low output per worker to those with high output per worker, increasing overall labor productivity in the economy.

12. This is expressed, for each individual country *i*, as:

$$\Delta Y_{it} = \sum_{s=n} \theta_{si,t-k}\, \Delta y_{sit} + \sum_{s=n} y_{sit} \Delta \theta_{sit}$$

Here, Y_{it} and y_{sit} are economy-wide and sectoral labor productivity levels, and θ_{sit} is the share of employment in sector *s*. The data is quarterly and *k=4,* and Δ denotes the year-on-year change in labor productivity or employment shares. The first term $\sum_{s=n} \theta_{sit-k}\, \Delta y_{sit}$ (the "within" component) is the employment-weighted sum of labor productivity growth within sectors. The second term $\sum_{s=n} y_{sit} \Delta \theta_{sit}$ (the "between" component) captures the productivity effect of labor reallocation across different sectors. The within and between components of changes in aggregate labor productivity (measured as total value added over hours worked) are then calculated in each country in the sample. To reach at an overall measure, the aggregate value-added weighted average across countries is then computed for each within and between sector component.

Data

13. The data are from Eurostat. The data cover 28 countries (*Austria*, *Belgium*, *Cyprus*, *Czech Republic*, *Germany*, *Denmark*, *Spain*, *Estonia*, *Finland*, *France*, *United Kingdom*, *Greece*, *Croatia*, *Hungary*, *Ireland*, *Italy*, *Lithuania*, *Luxembourg*, *Latvia*, *Netherlands*, *Norway*, *Poland*, *Portugal*, *Romania*, *Slovakia*, *Slovenia*, and *Sweden*) from 2018Q1 to 2020Q4.

D. Structural Policies and Intangible Investment

This section describes the analysis shown in Figure 16 of the main text.

Empirical specification

14. The analysis of policy determinants of intangible investment follows the methodology in Corrado and others (2016). This approach uses the ratio of intangible to tangible investment, rather than intangible investment in levels, in order to control for any common effects affecting investment that are difficult to model (e.g., the observation that investment tends to be cyclical in ways that are difficult to capture with prices or adjustment costs). In addition, the specification controls for the relative price level of intangible to tangible capital and the share of employment in the manufacturing sector (since countries with more services might be more intensive in intangible capital). The specification also includes country-specific fixed effects, which control for country-specific characteristics that do not vary over time.

15. In addition, the specification includes reform indices. The method in Corrado and others (2016) is augmented to include reform indices for the strictness of policies related to competition (state control, barriers to entry, and barriers to trade) and labor market flexibility (strictness of employment protection legislation)—with reform indices entering the regressions one at a time. As the underlying reform indices are interpreted as being stricter for a larger value of the index, the regressions are run using the negative of the indices in order to reach the reverse interpretation: a higher value of the indices in the specification here is associated with less strictness of the policy.

16. The following regression specification is estimated:

$$\ln\left(\frac{K_{it}^{intangible}}{K_{it}^{tangible}}\right) = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{P_{it}^{intangible}}{P_{it}^{tangible}}\right) + \beta_2 Emp_{it}^{manuf} + \beta_3 Policy_{it} + e_{it}$$

Here, $K_{it}^{intangible}$ is intangible capital in country i and year t, $K_{it}^{tangible}$ is tangible capital, P_{it} variables are price levels, Emp_{it}^{manuf} is the share of manufacturing in the economy, α_i and γ_t are country and time fixed effects, and $Policy_{it}$ is the policy variable of interest. Results are reported in Table A2.

Data

17. Data on intangible capital are from the INTAN database of Corrado and others (2016). Data on tangible capital, price levels, and employment shares are from EU KLEMS. Data on policy restrictiveness is from the OECD.

Table A2. Policy Stringency and Intangible Investment

	(1)	(2)	(3)	(4)
Dependent variable:	*ln(Intangible/Tangible)*			
ln(P^intan/P^tan)	-0.364***	-0.318***	-0.114	-0.245**
	(0.123)	(0.103)	(0.106)	(0.0959)
Employment in manuf	0.00275	-0.00244	-0.00277	-0.0165**
	(0.00771)	(0.00775)	(0.00811)	(0.00772)
Employment protection legislation	0.229***			
	(0.0512)			
State controls		0.155***		
		(0.0281)		
Barriers to entry			-0.0612	
			(0.0507)	
Barriers to trade				0.337***
				(0.0461)
Constant	5.390***	5.113***	4.611***	5.306***
	(0.220)	(0.220)	(0.248)	(0.217)
N	276	359	359	359
R-sq	0.928	0.921	0.914	0.926
Country FE	Yes	Yes	Yes	Yes

Clustered standard errors (country level) in parentheses
* p<0.1, ** p<0.05 *** p<0.01