PRODUCTIVITY ANALYSIS

ECONOMICS RESEARCH CENTRE

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UNIVERSITY OF CYPRUS

OUTPUT GROWTH DECOMPOSITION IN CYPRUS

SUMMARY AND POLICY CONCLUSIONS

This bulletin examines the multifactor productivity growth (TFP growth) of Cyprus and assesses the evolution of the production inputs, as well as their growth enhancing performance for the period between 1996 and 2020. Unlike earlier releases of this commentary, the analysis here is not limited to the traditional inputs, (Labor and aggregate capital), but also accounts for human capital and further disaggregates the capital input into its major investment categories: Information and Communication Technology (ICT), Research & Development (R&D), Infrastructure and Other physical capital. This allows estimating each capital's contribution to output growth.

Examining the evolution of the capital inputs in time shows all capital inputs have been increasing until around the year 2010. After 2010, Infrastructure, Other physical capital and Human capital decreased slightly, only to start picking up again in 2016 and eventually reach or even overcome (in the case of Human capital) their pre-crisis levels by the end of 2020. ICT and R&D capital stocks show a different pattern. ICT capital increases up to 2010 and then experiences a fall that is persistent until 2020. It seems that the investment that took place after 2010 was simply not enough to replace the part that had been depreciated. On the other hand, R&D capital kept growing exponentially throughout the sample years.

Productivity growth is estimated using two measures of the capital input: the aggregate capital stock (to assess the updated estimates of productivity growth in Cyprus) and the individual capital stocks. The disaggregation of the capital input diminishes "measurement errors" and results in lower estimates of TFP growth. The estimates show that while the two TFPs move together throughout the sample years, the TFP growth rate that accounts for the aggregate capital stock is higher than its individual capital stocks counterpart.

The analysis shows that the Cyprus economy slowed down by 5.6 percentage points, between the pre-2010 and 2010-2014 periods: average growth fell from 3.67% to -1.95%. This was mostly due to reductions in the Labor, TFP and ICT capital contributions. In fact, during the period of the economic crisis in Cyprus (2010 - 2014), R&D capital, Human capital and Infrastructure capital were the only positive contributing factors of output growth. After 2015 the economy displayed a remarkable improvement: it accelerated by 5.4 percentage points relatively to the 2010-2014 period (almost reaching the pre-2010 growth levels, averaging to a 3.41% growth rate). During these last 5 years, all factors, except ICT capital, positively contributed to growth, with TFP, Labor and R&D capital being the major contributors - contributing around 36%, 35% and 29% to output growth, respectively. For all periods, except the pre-2010 period, the ICT disinvestment had a negative contribution to output growth.

The international literature indicates that R&D and ICT investments are crucial drivers of economic growth. Although in Cyprus R&D investment is constantly rising during the last decade, the R&D expenditure as a percentage of GDP is the lowest among the member states of the European Union. Moreover, the disinvestment in ICT is hampering economic growth. The need for investment in digitalization remained unaddressed for a long time and this could impede Cyprus' growth prospective. Under the Recovery and Resilience Plan (RRP), Cyprus currently addresses these issues by employing measures that will increase investments in ICT as well as in the rest of the capital stocks. Together with the necessary reforms of the public and local administration, the judicial, and the labour market, the RRP will facilitate the path towards improved productivity and significantly affect GDP growth.

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1. Introduction

The aim of this bulletin is to examine the productivity developments in Cyprus and assess the progression of the production inputs, as well as their growth enhancing performance for the period between 1996 and 2020. It adds to previous commentaries in two aspects: firstly, it does not only use the traditional inputs, e.g. Labor and capital, but it also accounts for Human capital. Secondly, it disaggregates the capital input into four investment categories. These are: Information and Communication Technology (ICT), Research & Development (R&D), Infrastructure and Other physical capital. This allows estimating each capital's contribution to output growth.

The observed output growth is associated with changes in factor inputs as well as to productivity changes. Productivity growth, also known as TFP growth, is computed as the difference between output growth and the growth of factor inputs weighted by their output elasticities (growth accounting framework, Solow (1957)). TFP, typically referred to as "technology", reflects advances in production technologies, general knowledge, more efficient use of recourses and generally anything "unexplained" contributing to output growth other than the inputs, which are typically the labour and capital inputs. The construction and use of four distinct capital stocks instead of only a single aggregate capital stock results also in reductions in "measurement errors" in TFP estimation. This means that, the more detailed the input and output measurements, the more negligible the observed growth in the TFP.[1]

The graphs and tables presented in this bulletin describe the economy both for the whole sample period and also for three sub-periods, 1996-2009, 2010-2014, and 2015-2020. The periods chosen are associated with phases of interesting developments for the productivity growth and the various output growth subcomponents.

Data

We associate the output growth of the economy to changes in Labor, Human capital, capital inputs and productivity growth. Data for the construction of the aforementioned indicators and variables are collected annually and are sourced from Eurostat, the Statistical Service of Cyprus, as well as from the relevant literature.

The quantity of output is measured as value added in constant 2010 prices, the Labor input is measured in man hours and the level of Human capital is measured as the population average of the accumulated education and health expenditures in constant 2010 prices. In addition, we constructed investment quantities in constant 2010 prices for the following capital inputs: Information and Communication Technology (ICT), Research and Development (R&D), Infrastructure and Other physical capital. The sum of the investment series used for the construction of the capital stocks gives the aggregate investment (used for the measurement of the aggregate capital stock). To construct the capital stocks, we use the perpetual inventory method assuming a constant deprecation rate δ_i for each capital stock: 0.019 for Infrastructure, 0.083 for Other physical capital, 0.265 for Information and Communication Technology (ICT), 0.246 for Research & development (R&D) and 0.039 for Human capital.[2]

To obtain estimates of the output growth associated with changes in factor inputs we further need to specify the output elasticities of the relevant inputs. The values of the output elasticities for each capital input are based on the average estimates of elasticities provided in the literature.[3] The resulting output elasticities are: 0.1 for Infrastructure capital, 0.108 for Other physical capital, 0.05 for ICT capital, 0.109 for R&D capital and 0.06 for Human capital. The output elasticity of Labor is calculated from the data and it is equal to 0.573.[4]

[1] Jorgenson & Griliches (1967) were the first to test this hypothesis. (Jorgenson, D.W., Griliches, Z. (1967). The Explanation of Productivity Change, *The Review of Economic Studies*, 34(3), 249-283).

[2] For details on the depreciation rates, see Table 2.2 and the relevant discussion in Andreou et al., (2021). Report on the Assessment of the Recovery and Resilience Plan of Cyprus. Economic Policy Papers, and references therein. https://www.ucy.ac.cy/erc/en/publications/economic-policy-analysis-papers

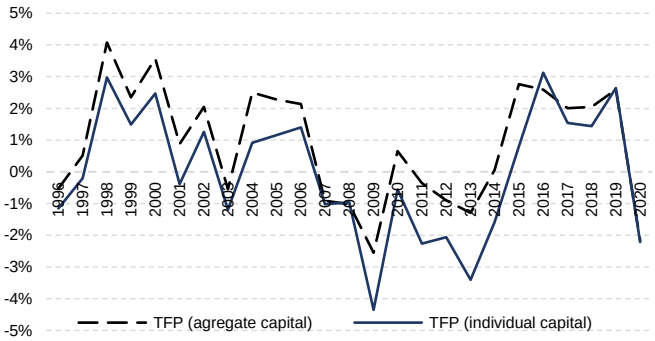
[3] For details on the output elasticities, see Tables 2.3 and 2.4 in Andreou et al., (2021), and references therein.

[4] The output elasticities of the inputs all sum to unity. Note also that, under certain assumptions the output elasticity of each input is equal to its revenue share observed in the data.

2. Productivity growth

Figure 1 presents the productivity (TFP) growth for the Cyprus economy for the period between 1996 and 2020. It is estimated using two different measures of the capital input. Firstly, we use the aggregate capital stock in order to assess the updated estimates of productivity growth in Cyprus[5]. Secondly, we use the disaggregate individual capital stocks. This allows us to measure each capital input's contribution to output growth (presented in the next section). Figure 1, shows that the pattern of the two TFPs throughout the years between 1996 and 2020, is similar. The TFP growth rate using the aggregate capital stock is higher than the TFP using the individual capital stocks. This confirms the hypothesis that, the more detailed the measurement of output and inputs, the smaller the observed growth in TFP.[6]

Figure 1: Productivity (TFP) growth



Source: Statistical Service of Cyprus, Eurostat and authors' calculations.

Up to 2007 TFP grew at an average annual rate of 1.53% when using the aggregate capital stock and 0.64% when using the individual capital stocks (average TFP for the period 1996-2007). Over the years from 2008 to 2014, which is roughly the period of the European economic crisis, productivity growth was at its worse, -0.77% and-2.17% on average, for each of the TFP measurements. As shown in Figure 1, this was followed by a period during which Cyprus' performance greatly improved in terms of productivity growth: during the years between 2015 and 2020, productivity in Cyprus grew on average at an annual rate of 1.64% per year (1.22% when using the individual capital). This was mainly due to Labor market and public sector reforms that have taken place since the beginning of the crisis.

Using the individual capital stocks in the model helps in explaining a larger part of output growth relatively to the aggregate capital stock. The next section analyzes their behavior in time.

3. The capital inputs

The evolution of the capital inputs for the years 1995 to 2020 is presented in Figure 2. Infrastructure, Other physical capital, ICT and R&D capital stock are presented in Panel A through Panel D, while Human capital is presented in Panel E. Infrastructure and Other physical capital follow a similar pattern in time (Panel A and B respectively). They both increase until around the year 2010 and then decrease slightly until the year 2016, only to increase again and reach their pre-crisis levels by the end of 2020. This is more evident in the case for Other physical capital (Panel B). As far as Infrastructure is concerned, it seems that the investment that took place during this period was just enough to replace what was depreciated (replacement investment).

A different picture is presented for ICT and R&D capital stocks, in panels C and D respectively. Panel C shows that ICT capital increases up to 2010 and then experiences a fall that is persistent until the last year of the sample, the year 2020. The data on the investment in ICT show that the fall starts in 2009. This, together with the fact that ICT has one of the highest depreciation rates, results in the fall of ICT capital stock after 2010. That is, the investment that took place during this period was simply not enough to replace the part that had been depreciated. In fact, as seen in Panel C, given the depreciation rate, the ICT disinvestment has reached its pre-2000 levels.

On the other hand, R&D capital grows exponentially (Panel D): the increase in R&D investment was more than enough to replace its depreciated part. Despite its increasing course, R&D investment in Cyprus is well below the EU average, in fact it is the lowest among the EU member states. The EU R&D intensity (R&D expenditure as a percentage of GDP) was 2.3% in 2020. The highest R&D intensity took place in Belgium and Sweden (3.5% of GDP), whereas the lowest was recorded in Cyprus, Bulgaria and Slovakia (all 0.9%).

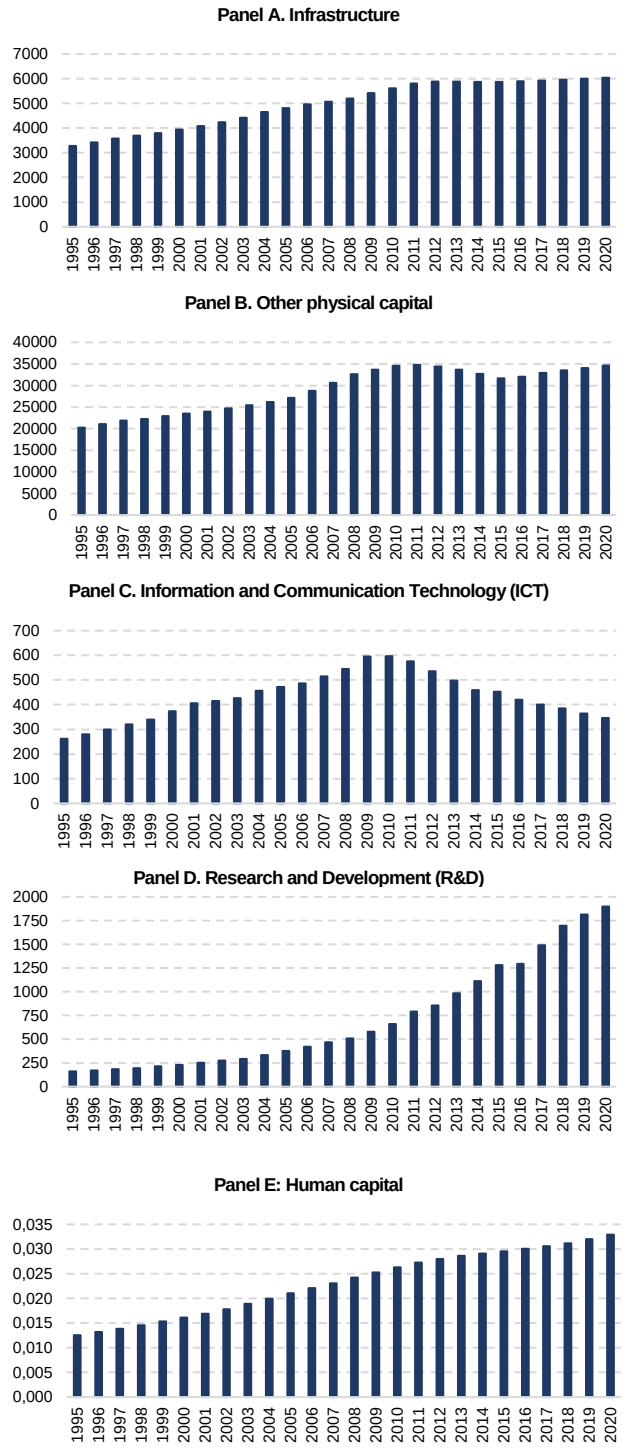
Lastly, Human capital stock (Panel E) follows a similar path to that of Infrastructure and Other physical capital. According to the data, investment in Human capital was

[5] You can find the previous bulletins on "Productivity Analysis" on the Economics Research Website: http://ucy.ac.cy/erc/en/publications/productivity-analysis.

[6] Jorgenson & Griliches (1967).

increasing up to 2010, fell during the economic crisis in Cyprus (2010 – 2014), only to increase again in 2015 and even overcome its pre-crisis levels by the end of 2020.

Figure 2: Capital stock (million euros)



Source: Statistical Service of Cyprus, Eurostat and authors' calculations.

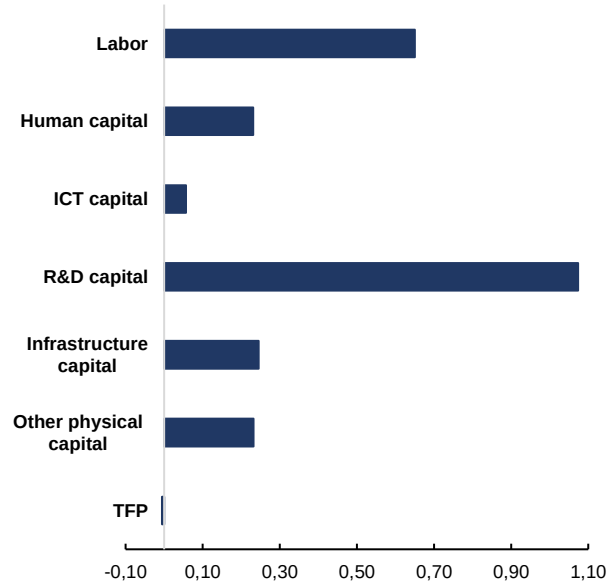
Next section analyzes the contribution of Labor, Human, ICT, R&D, Infrastructure and Other physical capital, as well as TFP, to the growth of the Cyprus economy.

4. Output growth decomposition

Changes in the inputs, together with their output elasticities as well as productivity growth, are associated with the observed output growth of the economy.

Figure 3 presents the breakdown of the average output growth to its contributors over the entire sample period. The average output growth during this period was 2.48%. R&D capital and Labor contributed the most: 1.07 and 0.65 of the 2.48 output growth rate, respectively, whereas the lowest contribution came from ICT capital and TFP (close to zero).

Figure 3: Output growth decomposition*
(average annual percent changes, 1996–2020)

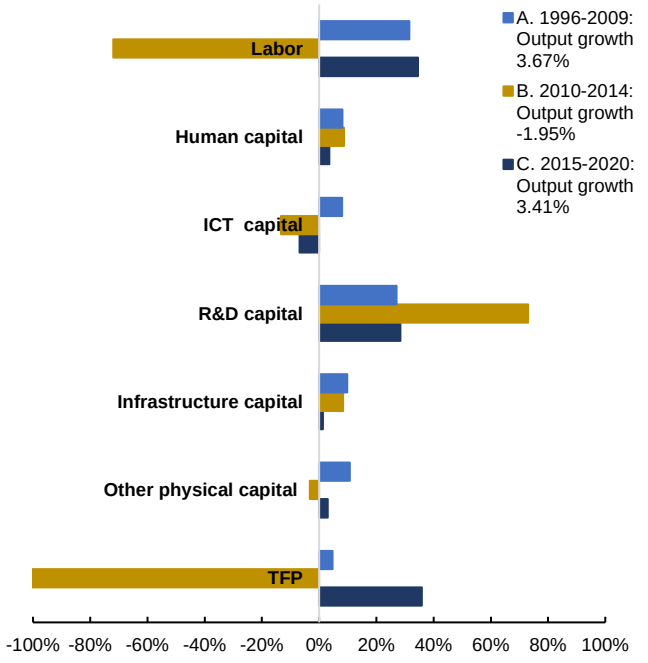


Source: Statistical Service of Cyprus, Eurostat and authors' calculations.
*The input contribution is calculated as: Output elasticity of input x Input Growth.

Figure 4 presents the *percentage* contribution to output growth for three periods: Period A. 1996–2009, Period B. 2010–2014 and Period C. 2015–2020. In period A, all inputs and TFP positively contributed to output growth, with the highest contribution that of Labor. During period B (economic crisis in Cyprus), R&D capital, Human capital and Infrastructure capital were the only positive contributing factors to output growth, with R&D capital contributing as much as 73%. This was due to the high growth rate of investment in R&D capital throughout all periods. On the other hand, during the same period, TFP, Labor, ICT capital and Other physical capital negatively contributed to output

growth, with TFP and Labor being the greatest negative contributing factors. During the last 5 years of the sample almost all factors positively contributed to output growth, with TFP, Labor and R&D capital being the major contributors (36%, 35% and 29% contribution respectively). The only exception was ICT capital: the disinvestment in ICT that took place during this period negatively affected output growth.

Figure 4: Output growth decomposition, % Contribution* (average annual percent changes)



Source: Statistical Service of Cyprus, Eurostat and authors' calculations.
*The percentage contribution is calculated as: (Output elasticity of input x average Input Growth) / average Output growth. For TFP this is calculate as: (average TFP growth / average Output growth).

5. Acceleration/deceleration of the Cyprus economy

Table 1 presents the acceleration/deceleration of the Cyprus economy by comparing the developments that took place in the three successive periods (A.1996–2009, B.2010–2014 and C.2015–2020). Its top part depicts the output growth together with its contributing components. The lower part calculates their differences between the three successive periods.

Between periods A and B, that is between the pre–2010 period and the economic crisis period (2010–2014), the economy slowed down by 5.61 percentage points, most of which is due to the reduction in Labor, TFP and ICT capital contribution. R&D capital is the only input whose contribution to output growth has increased between the two periods (0.43 percentage points increase). By itself this was not enough to counterbalance the major negative contribution that Labor, TFP and the disinvestment in ICT brought about to output growth.

In the last 5 years Cyprus' performance showed a remarkable improvement in terms of output growth as well as for most of its subcomponents (comparison between periods B and C). Output growth increased by 5.36 percentage points relatively to the 2010–2014 period, most of which coming from the increased contribution of TFP and Labor. Labor market as well as public sector reforms implemented during the crisis played a major role towards the post–2015 acceleration of the economy.

Table 1: Acceleration/Deceleration of the economy

Period	Output growth	Contribution to output growth (average annual percent changes)*						
		Labor	Capital					TFP
			Human	ICT	R&D	Infr.	Other ph.	
A.1996-2009	3.67	1.16	0.30	0.29	0.99	0.36	0.39	0.17
B.2010-2014	-1.95	-1.40	0.17	-0.26	1.42	0.16	-0.06	-1.98
C.2015-2020	3.41	1.18	0.12	-0.23	0.97	0.05	0.10	1.22
	Difference between periods							
A to B	-5.61	-2.56	-0.13	-0.55	0.43	-0.20	-0.45	-2.15
B to C	5.36	2.58	-0.05	0.03	-0.45	-0.12	0.17	3.20

Source: Statistical Service of Cyprus, Eurostat and authors' calculations.
*Contribution to output growth is calculated as: Output elasticity of input x Input Growth.

6. Conclusion and Policy Implications

This bulletin examines the productivity growth in Cyprus and assesses the evolution of the production inputs, as well as their growth enhancing performance for the period between 1996 and 2020. Unlike earlier releases of this commentary, the analysis here does not only use the traditional inputs, e.g. Labor and capital, but also accounts for Human capital. Furthermore, it disaggregates the capital input into four investment categories: Information and Communication Technology (ICT), Research & Development (R&D), Infrastructure and Other physical capital. This has two important advantages: firstly, it diminishes "measurement errors" in the estimation of TFP growth, and secondly, it allows estimating each capital's contribution to output growth.

Productivity growth is estimated using two different measures of the capital input: the aggregate capital stock (in order to assess the updated estimates of productivity growth

in Cyprus) and the individual capital stocks. The analysis shows that while the two TFPs move together throughout the sample years, the TFP growth estimated using the aggregate capital stock is higher than its individual capital stocks counterpart. This confirms the hypothesis that, the more detailed the measurement of the variables, the smaller the observed growth in TFP. Over the years between 2008 and 2014, which is roughly the period of the European economic crisis, productivity growth was at its worse, for both TFP estimates. It then picked up again in the subsequent years up to 2020: it grew at an average annual rate of 1.22% using the individual capital stocks and 1.64% per year at the aggregate level.

Employing the individual capital stocks in the model helps explaining a larger part of output growth relatively to the aggregate capital stock. Their evolution in time is thus central in explaining output growth. All capital inputs were increasing until around the year 2010. After 2010, Infrastructure, Other physical capital and Human capital decreased slightly, only to start increasing again in 2016 and eventually reach or even overcome (in the case of Human capital) their pre-crisis levels by the end of 2020. ICT and R&D capital stocks show a different pattern. The fall in ICT capital after 2010 is persistent until 2020. It seems that the investment that took place in that period was simply not enough to replace the part that had been depreciated. In fact, by 2020, the ICT disinvestment had reached its low pre-2000 levels. On the other hand, R&D capital kept growing exponentially throughout the sample years with an average growth rate as high as 10%.

The analysis shows that the Cyprus economy slowed down by 5.6 percentage points, between the pre-2010 and 2010-2014 periods: average growth fell from 3.67% to -1.95%. This was mostly due to reductions in the Labor, TFP and ICT capital contributions. In fact, during the period of the economic crisis in Cyprus (2010 – 2014), R&D, Human and Infrastructure capital were the only positive contributing factors of output growth, with the highest contribution that of R&D capital (73%). The following period (2015 – 2020) and as a result of the reforms that took place in the Labor market and in the public sector during the crisis, the economy displayed a remarkable improvement: it accelerated by 5.4 percentage points relatively to the previous period (output growth almost reached the pre-2010 growth levels, averaging to a 3.41% growth rate). During these last 5 years, almost all factors positively contributed to growth, with TFP, Labor and R&D capital being the major contributors (contributing around 36%, 35% and 29% respectively). The only exception was ICT capital: the disinvestment in ICT that took place during this period negatively affected output growth.

The international literature on the factors that drive economic growth suggests that countries should encourage investment in ICT, R&D and Human capital. The analysis performed in this bulletin indicates that in Cyprus, the need for investment in digitalization, an important part of ICT, remained unaddressed for a long time and this could impede Cyprus' growth prospective. Moreover, although R&D investment is constantly rising during the last decade, the R&D expenditure as a percentage of GDP is well below the EU average, in fact it is the lowest among the EU member states. According to Demetriades et al., (2020), the weak link between the university and the business sector causes reduced diffusion of innovation and commercialization of research results.[7]

Under the Recovery and Resilience Plan (RRP), Cyprus currently addresses these issues by working towards implementing measures that will increase investments in ICT as well as in the rest of the capital stocks.[8] Equally important are the reforms of the public and local administration, the judicial, and the labour market that will facilitate the path towards improved productivity and significantly affect GDP growth.

[7] Demetriades M., and Robledo-Bottcher N. (2020), RIO Country Report 2019: Cyprus, Joint Research Centre, European Commission, Publications Office of the European Union, Luxembourg.

[8] The Economics research center of Cyprus contacted the economic impact assessment of the Cypriot RRP and provided estimates of the Plan's impact on future output growth. For a more in-depth discussion, see Andreou et al., (2021).

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