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Population instability and EU-production function anomaly[2]

Introduction

This paper focuses on the European production function as an analytical framework for studying economic growth. This particular method should be employed with caution. It has been widely recognised in the literature that modeling economic growth based on just two factors of production is a far-reaching simplification of the underlying processes. Mankiw, Romer, and Weil (1992) introduced human capital into their model and achieved excellent results, explaining about 80% of the international variation of income per capita in this way. This particular approach to capturing output dynamics may bear a significant bias and misrepresent crucial underlying relationships due to sudden qualitative and negative quantitative changes to one of the two exogenous variables, namely: population *(POP)*.

Studies of output in the European Union have been a challenge due to the dynamic changes in the underlying social, legal and institutional frameworks. Not only have socio-economic relationships been subject to substantial developments, but the composition of the working population at the national level has also been transformed since 2004. These dynamic alterations in the economic mechanisms are the result of a guided integration process as well as being external to political decisions and the common EU policies (Młodkowski, 2018). Similar reasons may disrupt any growth studies that cover former periods in European history.

Explaining the deficiency in the production function in growth studies must begin with a diligent historical review of European population developments. The

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purpose is to indicate one of Europe's population characteristics: instability of the qualitative and quantitative features. This instability is clearly visible in comparison to much more hermetic countries, like China or Japan (Masui, Młodkowski, 2019). The time series analysis delivers an image of a very stable population growth in Europe, with not much variation over the last millennium. However, even a brief review of the deaths due to wars, diseases and, relatively recently, genocide, prove that European countries have suffered frequent substantial losses in the accumulated knowledge and skills. Would a production function estimated on such records deliver consistent results and credible projections? It would hardly seem so, which this empirical exercise demonstrates.

The results suggest that accession to the European Union has resulted in substantial alterations to the population characteristics at a country-level, reassembling those historically observed. Due to the Common Market, and one of the associated three freedoms, there have been qualitative and quantitative changes to the working populations of all Member States. The narrative on these changes is based on a systematic review of the country-level production functions estimated for all 27 EU Members, over the period 2004–2016. It may be concluded that attempts to project the economic growth trajectory with the production function estimated at the country-level may fail. The reason is in the altered mechanism of the transformation of labour (L) into output. When production functions are estimated based on historical data, then the associated structural parameters reflect the characteristics of the underlying working population. Any sudden negative or positive developments in the number of citizens, or in the structure of the population, along with its productivity, invalidates the production function transformation. Prospective analysis seems to lack viability.

The paper is organised as follows: The initial section offers a historical review of population-affecting events in European history, starting as early as the late Middle Ages. It departs from the discussion on arguments about the production function, with a focus on sudden changes in population, its growth rate and composition. A diligent review of population-decreasing events from the historical perspective represents a substantial part of the paper. The narration is, however, prospective, and aimed at associating historically observed instability of β in the production function with post-2004 intra-EU migration, and recent inflow of refugees from the Middle-East. The information about wars, diseases, and genocides comes from multiple sources. It should be noted that in spite of a great effort to reflect lives lost as precisely as possible, the presented numbers are still greatly underestimated. The other argument in the production function, the fixed capital formation in Europe, is also addressed, but to a much lesser extent as it is not the main "issue" in the analysed framework.

This paper contributes to empirical evidence concerning the EU economy, with estimated production functions for all 27 EU Member States. Extensive data mining resulted in the compilation of a consistent set of time series that capture the EU's

population, and fixed capital formation in the EU, as two arguments in the classical production function. Various sources have been used, including the International Financial Statistics by the IMF (for private investment spending) and the World Development Indicators by the World Bank (for population and the real GDP). The estimation was based on records covering the period from 2004 to 2016, as the most closely matching mechanics that may be expected over a mid-term projection horizon.

The contribution of this paper to the discussion is twofold. First, it estimates production functions at the country level for all EU Member States. Structural parameters allow output analysis and economic policy discussion on economies of scale. Estimated production functions for the European countries show which of them are characterised by the highest and most positive economies of scale. This information may be used to aid resource allocation in the most productive manner, for the sake of the whole EU society.

Second, there are very special population-output mechanics recognised in several EU Member States. These anomalies are inconsistent with the production function framework assumptions and call for further investigation. Investigations into the "misbehaving" cases uncover several factors that are potentially responsible. Recognizing anomalies is highly important, because the EU witnesses fierce discussions about and faces decisions on managing refugees, addressing the problem of aging societies in the EU, and handling migration in the most productive manner. The empirical results presented in this paper may allow much better-informed political decisions for the sake of the whole EU-27.

Arguments for the European (Union) Production Function

A production function is an elegant instrument to handle economic growth studies. It greatly simplifies the problem at hand by reducing the number of factors of production to only two, i.e. labour (*POP*) and capital (*CAP*). In this paper, the focus is on the role that unstable population characteristics play in the production function analytical framework.

$$F(CAP, POP) = aCAP^{\alpha}POP^{\beta}; CAP, POP \geq 0 \quad (1)$$

Population is just a plain number that does not reflect any qualitative changes in the underlying output driver. When it declines (actually it is the population growth rate that declines), the production function framework becomes less useful. This is due to the negative assessment of parameter β. It is a common feature for the numerous countries that have joined the EU since 2004. Their respective populations have effectively declined as a result of intra-union migration to richer EU countries. However, due to other factors, the real GDP has continued to grow.

Economic expansion of the lower-income countries in the EU has been driven by a wide variety of EU-accession-related factors. Growth has been fueled by access to the Common Market, common EU policies, and a multitude of transfers from the European Commission budget. Therefore, an empirical investigation of economic growth in the EU after 2004 shows a strange situation that invalidates a production function-based study.

The EU population has changed its composition at national levels, and it continues to grow. As a consequence, there have been significant changes in the composition of the labour force in each of the Member States. These developments have not resulted from former mechanisms and endowments (on education and training). However, such an instability in the characteristics of the working population is not anything new in Europe. When studying economic history over the last millennium or so, one can observe that there have been numerous cases of substantial declines in the total population, along with drastic changes to the qualitative features, including skill composition of the labour force. As such, population-declining events seem to invalidate the parameters of any production function, estimated over such periods.

Europe has undergone numerous such transformations that have made growth-focused studies challenging. Over the last millennium, the continuity of European states has been a unique feature. However, this is not the only reason for the difficulties faced when investigating economic growth in Europe. The geographical coverage of each state has also differed greatly over the past centuries. A good example in this regard is the records from the period of colonial expansion. These records reflect unusual growth fueled by unprecedented factors. They belong to categories of non-replicable, one-time events, and unique policy-associated actions. These changes to a set of actual growth factors mean any studies featuring extensive coverage lack a point of reference.

Fluctuations in European population (*POP*), when cast against output, tell a straight story (Figure 1), one that clearly explains growth in Europe. When it comes to endowment of capital (*CAP*), the picture is also clear (Figure 2). There should be no doubt that private investment spending stimulates GDP growth. There is a clear positive relationship between the rates of change of both arguments of the production function and the output. However, one should be aware that gross capital formation is just a fraction of the GDP, and such a straight positive correlation results from strong collinearity.

The European population had expanded to almost 600 million by 2020. There were, however, episodes when particular countries or the whole continent experienced significant, as well as sharp, declines in the number of citizens. All estimates for population and total fatalities per conflict are rough. The assessment of losses compiled by Brecke (2009; 2012) is still incomplete and understates losses to many of European nations. Output-related effects resulting from the skills and knowledge that have been lost could be captured by a new β, reflecting the features of a new underlying working population.

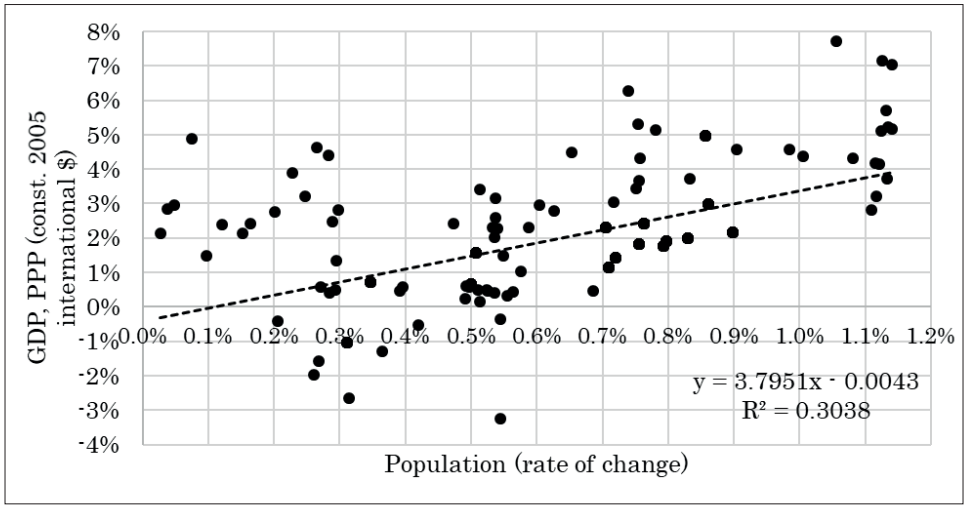

Figure 1. Growth rate for GDP and population in Europe, 1800–2017 with a linear trend

Source: own study based on the Eurostat and World Development Indicators database.

However, this makes the production function framework less useful. Potential recovery of work force quality may be achieved in many ways, but some unique, valuable, and productive skills may still be lost forever (if a genocide is systematic enough to kill all bearers of particular skills, for example). The timing of population declining events, geographical coverage, and associated fatalities are presented in Tables 1, 2 and 3.

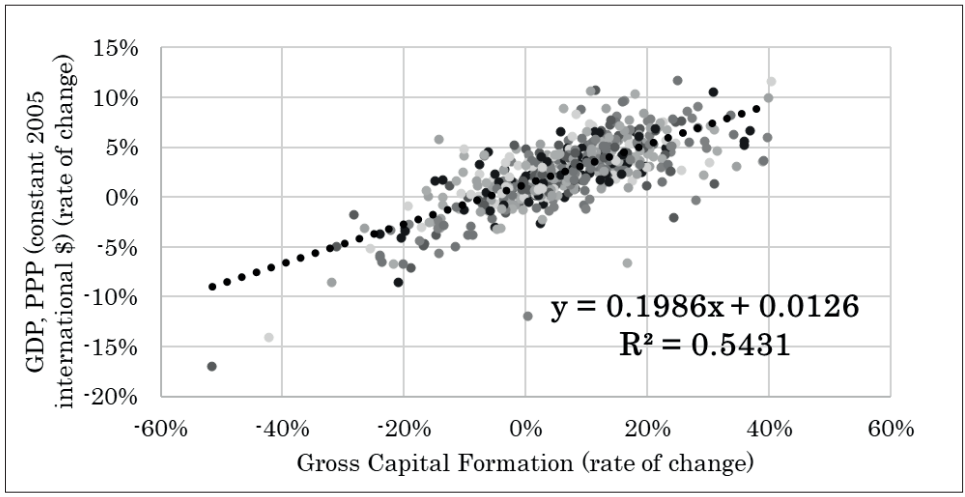

Figure 2. GDP growth rate and Gross Capital Formation in European countries, 1948–2016

Source: own study based on International Financial Statistics, by the IMF.

Even the basic statistics accessed from Conflict Database are informative. There have been 1,167 conflicts in Europe since the year 1400, with estimated fatalities due to interstate and sub-state conflicts of 106,734,335 citizens (both military personnel and civilians). In reality, as credible estimates are missing for most of the conflicts, the European population suffered much more serious losses over that period. The picture of the relationship between population and economic growth becomes clear when the rates of growth are cast against each other (Figure 1). The consequences of the fatalities mentioned above for the production function become straightforward.

Table 1. Summary review of conflicts in Europe, since the Middle Ages

Century	Number of conflicts	Lives lost (underestimated)
15th	304	436 700
16th	248	1 736 420
17th	238	12 126 620
18th	95	7 160 420
19th	152	9 262 554
20th	130	76 011 621
Total	**1167**	**106 734 335**

Source: own study based on Brecke (2012).

Population growth is lower during the 1800–2016 period, and the production function framework has the potential to shed some light on the scale of such effects. However, the estimated β parameters for times of peace and of war, and other population-reducing developments, may differ. Following the original idea by Wicksell, empirical tests by Douglas and Cobb (Douglas, 1976) showed that since 1928 there has been relative stability of the structural parameters in the production function. Results obtained for the USA and British Commonwealth countries (Daly, Douglas, 1943; Browne, 1943; Williams, Douglas, 1945; Lomax, 1950; Leser, 1955), with time series covering the 1930s and 1940s, confirmed low variability of the structural parameters. However, the empirical investigations in the 1950s and 1960s revealed a stable decline in the contribution of labour to output (Douglas, 1976, p. 912). There was a slow yet systematic change in the underlying economic system and in the way production processes were organised. The significance of both variables (*POP* and *CAP*) in the production function has evolved to match the contemporary economic system and qualitative characteristics of the labour force.

Currently, national economic systems seem to be even more unstable than they were in the times of an estimated labour-related parameter of between 0.6 and 0.75, as reported by Douglas (1976, p. 904). However, in the former periods there were changes in the manner in which production was organised. This no

longer seems to be primarily about improvements in technology, management, and intensity of the capital employed. It is still possible to gain from innovation, but such technology-driven gains are restricted to one, or just a few industries. When it comes to analysis based on aggregated records, covering the whole national economy, the driving force seems to be of a different nature. This is because the previously prominent growth drivers tend to be depleted these days. In particular, economic integration in Europe and the Common Market freedoms have allowed an unprecedented realignment of the production factors on an international scale. Capital has been relocated mostly to China and other Asian countries, while the labour force flows between EU-27 countries create an unprecedented production-affecting phenomenon. This makes the production function framework much less suitable for growth studies.

Due to intra EU-27 migration, one can observe substantial alterations in the qualitative characteristics of the labour force employed in each national economy. In general, part of the workforce of the new member states has moved to the member states of the "old EU" since 2004. As a consequence, the population living in the new member states has declined. There have been national deficits in many job categories, ranging from medical doctors to industrial production line workers. Under such realignment, resulting in qualitative and quantitative alterations to the labour force, applying the production function in output studies (and projections) seems problematic due to the instability of the economic processes under pressure of sudden changes in the labour characteristics. Estimating the structural parameters based on historical records, including the period before the EU was formed, has not been appropriate. Procedures used to assess α and β have delivered a highly unique approximation of the manner in which the factors of production have been transformed into output. However, these were different before the EU was formed, and have changed again after the new member states have joined the Common Market.

How useful would β be for projections and policy making, if estimated from records reflecting already non-existent economic relationships? It seems that the production function framework requires very special characteristics to be effectively and credibly applied on time series for national-level studies. This requirement is mostly about the stability of the underlying population, both in terms of the growth rate and its composition, i.e. its qualitative characteristics. When analysing the economic history of Europe over the last 600 years, it becomes obvious that this particular element (i.e. β) can hardly be perceived as stable. Every case of disease (Table 2), famine, war (Table 1) or other population-decreasing development (Table 3) must have had a different effect on the real GDP than in the recovery period. This is due to a different β prevailing during each period preceding and following such events.

The most recent period in the European Union, after 2004, has been associated with a decline in the population of most of the new member states. Why is

the analysis of economic growth very different when the focus is on negative population developments? Empirical investigation leads to strange estimates for coefficients (i.e. negative), indicating a mechanism inconsistent with the production function framework. As such, it does not allow the application of this particular methodology to deliver arguments for the just distribution of output or for discussions concerning political economy. However, there might be some value in discovering negative β in European Union countries after 2004.

Table 2. Diseases in Europe with more than 10 000 lives lost, since 1600

Period	Disease type	Region affected	Deaths
1603	plague	England	30 000
1625	plague	England	35 000
1629–1631	plague	Italy	280 000
1636	plague	England	10 000
1647–1652	plague	Spain	150 000
1656	plague	Italy	1 250 000
1663–1664	plague	Netherlands	24 148
1665–1666	plague	England	100 000
1668	plague	France	40 000
1679	plague	Austria	76 000
1720–1722	plague	France	90 000
1738	plague	Balkans	50 000
1770–1772	plague	Russia	50 000
1813	plague	Romania	70 000
1816–1819	typhus	Ireland	65 000
1829–1851	cholera	Europe	73 279
1852–1860	cholera	Russia	1 000 000
1857	yellow fever	Portugal	40 000
1866–1867	cholera	Russia, Germany	225 000
1870–1871	smallpox	Germany	75 712
1899–1923	cholera	Europe	800 000
1918–1922	typhus	Russia	3 000 000

Source: own study, based on (Ackerknecht, 1965; Gregg, 1985; Patterson, 1993; Paneth et al., 1998; Porter, 2001; Hays, 2005; Fusco, 2007; LeMay, 2016; Ross, 2018; UCLA School of Public Health, 2018).

The literature on growth focuses on increases in population as a factor fueling the output. Population has been a steadily growing variable (the average growth rate in Europe has been at 0.65% since the year 1400, with a standard

deviation of 0.69%). Private investment spending is a highly volatile variable (the average rate of 0.68%, and standard deviation of 10.08%). There are many consequences of such a stable behaviour of one of the two arguments in the production function. In the first place, β must comply with the original assumption that population is a proxy for labour force. This is not always a true assumption, especially when one considers tragic events and periods of substantial reductions in population, and in consequence, a drop in the labour force. As long as the population is growing without reversals, and the labour force remains the same proportion of the population, β seems to work well for transforming positive, and gradual changes in population into output. The estimated β may reflect the quality of the labour used in the process of generating output. Accumulation of knowledge, development of skills, and passing both of them from generation to generation can be captured by this parameter. However, for all events (and periods) featuring a reduction in population, the β estimated for the former period is neither efficient nor valid in transforming "labour" into output afterwards. It is difficult to provide precise estimates of the losses for many of the well-known episodes of plagues, diseases and wars in the Middle Ages. Even the Renaissance, the colonial period, and the more recent times of the French Revolution or the Napoleonic Wars still lack credible statistics for such an analysis. However, all those cases of sudden reductions in populations of whole nations, and whole continents, allow a narrative that will prepare the ground for an empirical investigation.

The production function for a country, with its estimated β, assumes that every new member of a society contributes to the real GDP in the same magnitude. This may be true when a population grows steadily, knowledge is accumulated and passed from generation to generation, skills are perfected, and there are no events that reduce the population or modify its composition. Such an idyllic scenario has never been the case for European countries, though. Aside from the many wars, there have been many diseases that negatively affected the population of the whole continent. There were also numerous cases of more-or-less local genocide events that were detrimental for growth in particular countries. In the case of wars, the most affected fraction of any society is the one that is the most productive at that time. Not only are the young, strong, educated, ready-to-work members of a society involved, but also those who are the keepers of knowledge and masters of skills. The loss of such members by any society results in severe consequences for economic growth in the short and medium term. The recovery of knowledge has become easier and quicker in the modern era though, thanks to the availability of printed books. The skills carried by an individual may be lost permanently, and require a whole process of rebuilding them by trial-and-error. It has always been detrimental for economic growth when a war wipes out the most productive members of an underlying society.

Table 3. Genocide in Europe in the 20th century

Genocide name	Region affected	Deaths
Holodomor (Ukrainian genocide, part of the greater Soviet famine of 1932–33)	Ukrainian Soviet Socialist Republic	7 500 000
Porajmos (Romani genocide)	Nazi-Germany controlled Europe	500 000
Polish Operation of the NKVD (Polish genocide)	Soviet Union	111 091
Latvian Operation of the NKVD (Latvian genocide)	Soviet Union	16 573
The Holocaust / Nazi genocides and war crimes	Nazi-Germany controlled Europe	17 000 000
Genocide by the Ustaše (Serbian genocide)	Independent State of Croatia	600 000
Bosnian genocide	Bosnia and Herzegovina	301 107

Source: own study based on (Rosefielde, 1983; Niewyk, 2000; Goldman, 2011; Calic 2012; Holocaust Encyclopedia).

A disease (or a plague) affects negatively all groups of an underlying society at more-or-less the same magnitude. As a consequence, part of the knowledge and skills accumulated previously is lost (permanently or temporarily), and a growth model based on the estimated production function fails to deliver credible projections.

Genocide (Table 3) differs from wars and diseases in its impact on the composition of the labour force. As a consequence, it may be claimed that due to the focused extermination of a specific ethnic group in a society, the magnitude of the negative impact on economic growth may be even larger. Genocide is very often an action against a particular fraction in a society. Case-by-case analysis shows that in the Soviet Union and in Europe controlled by the Nazis, the targeted groups could be considered the most productive ones. In the most recent ethnic-background genocides in Europe (Bosnia), this was just a reduction of a separate part of the underlying society characterised by rather similar productivity. However, even in such cases unique knowledge and particular skills might have been lost.

As a consequence, any production function estimated on records that include periods of population decline should be approached with caution. Even if the fitness of an econometric model is reasonably high, the usefulness of β for any analysis and projections may be low. The reason is in the lack of actual continuity in the underlying economic mechanism. A population that changes its composition, including its knowledge and skill characteristics, is idiosyncratic for the period. One may say it is a quirk of history. The time series are no longer consistent, and therefore not compatible with the transformation method embodied in the estimated production function.

The instability of β characterises contemporary Europe. There are sudden changes to the labour force in the EU that occur due to intra-EU migration, and, most recently, large numbers of incoming migrants from the Middle East. The

situation in most of the new member states is analogous to historical sudden negative developments. Therefore, when working on a prospective analysis, one must monitor these new factors.

Contemporary issues in modeling economic growth in the EU

Modeling economic growth against the current situation of Europe faces a very similar problem to the one described above. In spite of there being a full portfolio of prognostic models of economic growth (ECB, OECD, IMF, European Commission), the current migration-related developments in the underlying labour force seem to create serious issues. One can find some hints for interpretation in a recent work by Jorgenson *et al.* (2017), who find a significant link between education (associated with quality of labour) and economic growth in the U.S. Currently, the European Union is witnessing a sudden, unexpected and unprecedented inflow of an uneducated population from the Middle East. There are several reasons why this group is not going to fuel European production in the same magnitude as European citizens would. The crucial argument drawn from the modern literature on growth is about the quality of labour. Empirical analysis for the U.S. indicated a strong link between education, labour productivity and output. The current investigation into the nature of the economic growth mechanism is a highly simplified approach. It is motivated by an intention to pronounce the consequences of intra-union migration for the production function framework. It may, therefore, be considered as indirect support for all the new approaches to modeling economic growth that include qualitative information on human capital, necessary in capturing the very nature of the growth mechanism.

If the inflow of migrants continues, it will result in accumulating uneducated and unskilled labour. This may trigger investment in developing proper skills that match the labour market's demand. However, cultural differences may still reduce efficiency of such endowments. The knowledge and skills possessed by migrants are very different from the pattern observed in the European labour force. While the whole European Union faces the problem of a persistent lack of jobs for young, well-educated, EU-citizens (in Spain youth unemployment was 56.1% in 2013, 57.9% in 2014, 36% in 2018, and 30.6% in January 2020), the inflow of un-skilled, un-educated labour force can only aggravate the current difficult situation in this regard. There were some positive forecasts by OECD regarding the Spanish unemployment rate in 2018 and 2019 (OECD, 2017), which proved correct.

Estimations of Production Functions for EU states

The EU in 2019 is far from being a homogenous group, in terms of economic growth experience. EU countries fall into more than one category of historical factors

for growth and growth patterns over the periods preceding economic integration. For the purpose of capturing the transformation of labour and capital into output, a simple economic model is used, based on a production function with a constant (equation 1).

Estimation of structural parameters is based on observations for EU-27 (plus the UK for comparison). The procedure is restricted to the most recent consistent records, from 2004 to 2016. This design is motivated by the fact that earlier economic performance in the new member states was based on a different legal and institutional framework. These featured a very different transformation of factors of production into output. Only after full EU accession (from 2004, or for some states even later) did the national economic systems begin to operate in a manner similar to what could be expected in the future.

For a prospective analysis (projection of economic growth in the EU up to the year 2030) based on the parameters estimated here, interested readers should refer to Młodkowski (2019). The author assumed that the population in the EU would follow the path defined by Eurostat demographic projections. There is a new factor in this regard, however, as the inflow of refugees who are granted residency in the EU might be a potentially positive growth factor. The GDP growth rate may be supported to some unspecified degree through the inflow of migrants that may cause sluggish demographic growth, and for changes in the population structure due to aging European societies.

Table 4. Nominal value of Chinese foreign direct and portfolio investment in the EU, 2008–2016 (bln USD)

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Foreign direct and portfolio investment	29.51	4.84	5.59	16.5	17.11	13.37	29	33.84	55.83

Source: own study based on China Global Investment Tracker by American Enterprise Institute.

When it comes to capital fueling economic growth in the European Union, one should bear in mind that there has been a reversal in international capital flows. After 20 years of moving European production to Asia, one can observe the global expansion of China (Table 4), based on its accumulated massive foreign exchange reserves.

This process is not only about foreign investment, both portfolio and direct, but also about providing financing for large-scale infrastructure projects in Europe which are entrusted to Chinese contractors, like the nuclear power plant under construction in Bradwell, Essex, UK, to name just one example. If such cases become more frequent, expanding infrastructure with foreign capital may be an additional growth impulse to be monitored in studies and projections for the GDP.

When it comes to interpretation of the results, there is only one country that seems to exhibit a negative returns to scale: Portugal, but its parameter for *POP* is not statistically significant. The UK, as a benchmark, is the only country to exhibit constant returns to scale with the sum of estimated parameters at unity (Table 5). All other EU states seem to experience positive returns to scale, with the Netherlands and Austria at the top of the list. There is an anomaly in the case of the structural parameter estimated for population (*POP*). All small EU countries that joined the Union after 2004 have an excessively high assessment of this element which, at the same time, is statistically significant. The interpretation of such an anomaly requires an unorthodox and holistic approach to the production function. The case for Germany, the largest EU economy, is also puzzling as the estimated parameter is also negative, but not statistically significant. In alternative estimations, with different functional forms, and on rates of change of all variables, Germany was assigned the lowest structural parameter among the EU-12, at just 0.2. This may indicate the actual level of the assessment in the main empirical exercise.

Table 5. Positive structural parameters of the production function in the EU, 2004–2016

Country	*POP*	t-stat *POP*	*CAP*	t-stat *CAP*	*POP+CAP*
Belgium	**0.92**	9.50	**0.26**	7.40	**1.18**
Denmark	**1.33**	13.47	**0.23**	12.18	**1.56**
France	**1.19**	21.69	**0.24**	10.24	**1.43**
Germany	-1.55	-1.59	**0.52**	3.24	-1.03
Greece	1.67	2.16	**0.26**	16.17	1.93
Ireland	**1.69**	6.45	**0.36**	7.68	**2.05**
Italy	**0.56**	2.15	**0.26**	7.82	**0.82**
Luxembourg	**0.86**	4.09	0.19	1.71	1.05
Netherlands	**2.06**	10.02	**0.34**	7.41	**2.40**
Portugal	0.32	0.40	**0.1**	3.63	0.42
Spain	**1.32**	9.04	**0.26**	9.10	**1.58**
U.K.	**0.81**	4.47	**0.2**	5.27	**1.01**
Austria	**1.69**	5.26	**0.37**	2.80	**2.06**
Finland	**1.3**	3.87	**0.41**	5.34	**1.71**
Sweden	**1.07**	13.59	**0.33**	16.50	**1.40**
Cyprus	**0.87**	13.56	**0.23**	14.77	**1.10**
Czech Rep.	**3.88**	11.57	**0.48**	9.93	**4.36**
Malta	**3.51**	12.63	0.01	0.20	3.52
Slovakia	**27.09**	5.42	**0.4**	2.42	**27.49**
Slovenia	**6.82**	10.21	**0.37**	9.21	**7.19**

Source: own study.

The Ordinary Least Squares procedure delivered other interesting results. Most EU countries have been characterised with parameters consistent with the original idea behind the production function. However, there is also a substantial group of EU countries for which estimations delivered a negative assessment of the structural parameter for the *POP* variable (Table 6).

All countries listed in Table 6, except Croatia, have statistically significant parameters. The negative "role" of population in the new member states results from the co-occurrence of trends inconsistent with the production function framework implicit assumptions. It seems that the literature on the production function does not include any hints on the requirements for the "labour" argument to be useful in this particular framework. The current study intends to fill this methodological gap by providing explanations on the consequences for output studies of the unstable characteristics of the working population (captured here by *POP*).

Table 6. Negative structural parameters of the production function in the EU, 2004–2016

Country	*POP*	t-stat *POP*	*CAP*	t-stat *CAP*	*POP+CAP*
Estonia	**-4.55**	-8.18	**0.3**	9.20	**-4.25**
Hungary	**-5.28**	-5.81	**0.28**	4.15	**-5.00**
Latvia	**-1.65**	-5.69	**0.34**	5.82	**-1.31**
Lithuania	**-1.42**	-7.53	**0.24**	4.85	**-1.18**
Poland	**-42.42**	-3.38	**0.34**	2.79	**-42.08**
Bulgaria	**-3.52**	-20.22	**0.2**	8.23	**-3.32**
Romania	**-2.19**	-7.13	**0.28**	4.95	**-1.91**
Croatia	-1.57	-1.43	**0.25**	4.37	-1.32

Source: own study.

This is the main reason for including an in-depth historical analysis of the instability of the qualitative and quantitative characteristics of European citizens throughout the ages. There is a very similar, historically observed, common negative population tendency shared by the new member states since 2004. Simultaneously, these countries have experienced economic growth fueled by the EU accession-related factors. One can, therefore, observe a very special phenomenon in the EU. Member states that have been losing workforce still gain in terms of output due to catching-up via modernization, increased capital investment, technological advances, and switching to modern management. As such, economic growth in this group is of an intensive nature. In the second round it has the potential of releasing even more of labour for employment in other EU countries. The advanced EU economies that welcome well-educated migrants from the less-advanced EU countries continue to grow. They grow faster than they would otherwise. This would seem to be a straight extensive mode, rather than an intensive one. Therefore, there are two distinctive groups of countries in the EU

that can be recognised by the different signs estimated for the population (*POP*) parameter in the respective production functions.

Conclusions

The production function framework is suitable only for cases maintaining stable characteristics of the working population over time. It is able to accommodate trends in growth factors (here: *CAP* and *POP*), and delivers consistent results only when the trends are positive, while the growth mode (extensive versus intensive) is not important. However, in all other cases of the intensive growth mode, any negative trends in the production function parameters invalidate this framework for any output studies. This feature of the production function framework has been discovered while estimating structural parameters on the EU data over the period 2004–2016. It should be labeled: *EU-production-function-anomaly*.

While the actual empirical evidence for this new explicit requirement for the production function framework has been discovered due to negative population (*POP*) trends, the same invalidation of the underlying analytical framework could be caused by any other production function parameter that is declining, while the growth mode is intensive.

There might be a potential solution for the anomaly observed in case of most new member states. The negative assessment of the *POP* parameter might be avoided by introducing additional variables to the transformation equation. These should probably capture any "intensive" factors characterising the production process.

Other findings and observations that open new areas for economic growth studies include the following: EU countries are not homogenous in terms of the growth mode; most of the new member states have experienced intensive growth after accession, while growth of the old member states (EU-12) has been extensive, fueled by intra EU migration and further capital accumulation, supported by growing inflows of Chinese savings.

When it comes to methodological studies on the efficiency of different modeling frameworks, the anomaly presented here may be a starting point for further investigations into the most appropriate models to deal with the intensive growth mode when its factors are declining.

Economic growth studies in the EU face the problem of an inconsistent and idiosyncratic transformation mechanism over time. Projecting the trajectory for the GDP at the national level does not seem to be problematic (see: Młodkowski, 2019), but establishing an aggregated forecast at the level of the whole EU may be a real challenge. The submission next year to the journal will present a similar growth study based on another class of macroeconomic growth models. In this way, interested readers will be offered a comparison of methods. It shall shed new

light on competing approaches to capturing the growth mechanism in the most challenging of all studies that must deal with "diversity in unity".

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Summary

The purpose of the study is to present the problematic situation when capturing the economic growth mechanism in the European Union. Due to intra-EU migration, the prominent production function framework fails to deliver consistent results. Estimation of structural parameters on data covering the post-accession period up to 2016 delivered a negative (!) assessment of the contribution of "labour" to output for most of the new member states. This result called for further investigations, and a holistic interpretation. It seems that this is the first time a methodological study on the

production function framework offers an explicit formulation of the requirements for this method to be effectively employed in output investigations. In short, the production function can be used for cases where the growth mode is extensive, while arguments display declining or ascending trends. However, when the growth mode is intensive, while any of the arguments decline in value, this particular framework will become invalid for capturing the growth mechanism. The observed failure of the production function calls for introducing a new term to the economic growth literature: EU-production-function-anomaly. The method seems to be a far-reaching simplification. The reason for utilizing a very general formulation (excluding human capital and technology) is motivated by the focus on the demographic developments responsible for the anomaly.

Keywords: production function, EU population, economic growth, new member states, growth mode.

Niestabilność populacji a anomalia funkcji produkcji w krajach UE

Streszczenie

Celem badawczym jest prezentacja problematycznej sytuacji występującej podczas próby uchwycenia mechanizmu wzrostu gospodarczego w krajach członkowskich Unii Europejskiej. W wyniku wewnątrzunijnej migracji, popularna funkcja produkcji przynosi niespójne wyniki podczas estymacji na poziomie kraju członkowskiego. Oszacowania parametrów strukturalnych modelu dokonano w oparciu o szeregi czasowe od 2004 do 2016 roku. W przypadku wielu nowych krajów członkowskich uzyskano ujemne oszacowanie parametru odpowiadającego za wkład czynnika „praca". Taki wynik, istotny statystycznie, stanowił wyzwanie i przyczynę dalszych, rozszerzonych badań w celu holistycznej interpretacji przyczyn.

Wydaje się, że niniejsze studium funkcji produkcji jest pierwszym w literaturze przedmiotu, które podaje dyskusji e*xplicite* wymagania dotyczące poprawności metodologicznej funkcji produkcji, w zależności od natury procesów wzrostowych. Funkcja produkcji może być stosowana w przypadkach, gdy wzrost jest ekstensywny, przy argumentach podlegających trendom wzrostowym lub spadkowym. Jednakże, w przypadkach wzrostu intensywnego, gdy wartość argumentów funkcji produkcji maleje w czasie, to podejście do modelowania wzrostu staje się nieskuteczne. Zaobserwowana niezdolność funkcji produkcji do poprawnego uchwycenia procesów wzrostowych wzywa do wprowadzenia nowego terminu do literatury: anomalia funkcji produkcji na poziomie kraju członkowskiego UE. Wykorzystana metoda badania wzrostu gospodarczego jest oczywiście daleko idącym uproszczeniem. Przyczyną wyboru prostej funkcji produkcji (bez kapitału ludzkiego i technologii) jest intencjonalne skoncentrowanie się na zmianach sytuacji demograficznej, odpowiedzialnych za postulowaną anomalię.

Słowa kluczowe: funkcja produkcji, populacja UE, wzrost gospodarczy, nowe kraje członkowskie, wzrost intensywny, wzrost ekstensywny.

JEL: E23, E27, F22, O47.