International Productivity Growth Differentials And Global Scientific Research Efforts

W A Razzak[1]

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Abstract

We use EUKLEMS 2017 data to provide cross-sectional evidence that global scientific research efforts in advanced countries explain international productivity growth differentials.

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[1] The paper was written when the author was a visiting economic adviser at the Central Bank and the Ministry of Finance in Oman razzakw@gmail.com. The views, opinions, findings, and conclusions or recommendations expressed in this paper are strictly those of the author. They do not reflect the views of the Central Bank of Oman or the government of Oman. The Central Bank of Oman and the government take no responsibility for any errors or omissions in, or for the correctness of, the information contained in this paper. I thank E M Bentour (AMF) and R Ben Jelili (DHAMAN) for their valuable contributions at early stages of this research and Murat Ungor (University of Otago) for providing some references.

1. Introduction

Prescott (1998) argues that factor inputs, savings, human capital, and intangible capital differentials could not explain international productivity growth differentials; hence, a theory for total factor productivity (TFP) is needed. However, in Jones (2002), for example, TFP depends on global scientific research efforts and ideas, which is tied to the long-run population growth.

The argument that population growth affects per capita ouput growth is not new. Simon Kuznets (e.g., 1960) argued that population growth in *advanced* countries causes per capita output growth via a number of channels. In his view, *useful* or *testable* knowledge is the primary driver of per capita growth.

We use EUKLEMS 2017 data set for 11 advanced countries, Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Spain, Sweden, the U.K, and the U.S. to test whether country differences in excess knowledge explains country differences in productivity growth rates.

Next, we describe the model and the data. Section 3 presents the results. Section 4 discusses the recently observed decline in productivity in the United States and elsewhere. Section 5 is a summary.

2. The Model

Very briefly, Jones (2002) assumes that in each economy i, real output of goods, Y_t is produced by a Cobb-Douglas production function, which is constant return to scale in capital K_t. Capital evolves by the Perpetual Inventory equation, and human capital H_{Y_t}, which is the total quantity of human capital, the product of human capital per person and the total amount of labor employed in the production of goods. Human capital depends on the time spent acquiring education, training, skills and the return on such activities.); and an increasing return to scale in the factors and the accumulating stock of *ideas* created in the world A_t.

$$Y_t = A_t^{\sigma} K_t^{\alpha} H_{Y_t}^{1-\alpha} \quad , \tag{1}$$

It is assumed that $0 < \alpha < 1$, and $\sigma > 0$; subscript Y refers to the production of goods.

Ideas are non-rival and non-excludable.[i] There is a production function, where by the growth rate of ideas depends on effective research efforts in *developed* countries. Thus, the number of ideas produced at any point in time depends on the number of researchers and the existing stock of knowledge.

$$\dot{A}_t = \delta H_{At}^{\lambda} A_t^{\phi} \quad A_0 > 0, \tag{2}$$

Where a dot on the variable denotes the growth rate, and H_{At} is the effective world research effort, given by:

$$H_{At} = \sum_{i=1}^{M} h_{it}^{\theta} L_{A,it}, \tag{3}$$

where h_{it} is human capital and $L_{A,it}$ is the number of researchers. The subscript A in H_A denotes the human capital used in the production of ideas, and $M = 11$.

The model has a resource constraint on labor such that an economy populated by a number of identical, infinitely lived agents, whereby the number grows over time at a common and constant exogenous growth rate n. Each individual is endowed with one unit of time, which is divided among producing goods and services, ideas, and human capital.

Along the balanced growth path, capital-output ratio, labor used in production – total labor, and human capital are constant. The economy exhibits a stable balanced growth path, whereby all the variables grow at constant exponential rates forever. The allocations of factors along that path are also constant. The growth rate of output per worker is proportional to the growth rate of effective world research. Since human capital is constant along the balanced growth path, the growth of the effective number of world researchers is driven by population growth.

A key prediction of the model is that the long-run per capita growth is, ultimately, tied up to population growth of the advanced countries.

The model boils down to the following growth-accounting equation:

$$\dot{y}_t = \underbrace{\frac{\alpha}{1-\alpha}\left(\dot{K}_t - \dot{Y}_t\right) + \dot{h}_t + \dot{l}_{Yt} + \underbrace{\left(\frac{\sigma}{1-\alpha}\dot{A}_t - \gamma n\right)}_{Excess\ Ideas}}_{Transitional\ Dynamic} + \underbrace{\gamma n}_{Steady\ State} \quad (4),$$

where $\dot{y}_t$ is real output per hour-worked growth rate (a dot on top of the variable refers to growth rates).

3. Calibration

Since Prescott (1998) shows that neither factor inputs, nor savings differentials explain international productivity growth differentials, we focus *only* on excess ideas (excess knowledge), which represents the growth rate of TFP as a function of effective world research efforts, in excess of population growth of the advanced countries.

We measure productivity growth $\hat{y}_t$ and excess ideas $\frac{\sigma}{1-\alpha}\dot{A}_t$ for all 11 countries mentioned earlier. Productivity is defined as real output per hours worked. For real output put we use EUKLEMS value added measure (VA), which we deflate by the value added price, VA_P (2010=100). We then measure real value added per hours worked by dividing the real value added by total hours by persons – engaged (H_EMP). The growth rate of this would be our measure of productivity growth. Figure (1) plots the averages over the sample.

We use the 'market economy' measure in EUKLEMS, which excludes sectors whose outputs are "hard-to-measure." These are lines L, O, P, Q, T, and U, which are mainly services: Real Estate activity; Public Administration and Defense; Compulsory Social Security; Education, Health and Social Work; Activities of Households as Employers; Undifferentiated Goods- and Services-producing Activities of Households for own use. For excess ideas, we also use the market economy data to measure $\dot{A}_t$, TFP as reported in EUKLEMS. The Penn World Table 9.0 reports time series for the share of labor so it is $1-\alpha$ in equation (4). We take the average value over the samples. However, the parameter σ is unidentifiable. Jones (2002) assumed that it is equal to $1-\alpha$ so that A is measured in units of Harrod-Neutral productivity. We use sensitivity analysis and calibrate the equation using a number of values. We that find $\sigma = 1$ provide the best fit for every country in the sample.

To measure $\gamma = \frac{\sigma}{1-\alpha}\frac{\lambda}{1-\phi}$ we need values for λ and ϕ, but estimation of equation (2) is hampered by the discontinuity of the time series data for $L_{A,it}$ (the number of researchers in eq. 3). Jones (2002) suggested that the value for the U.S. is between 0.05 and 0.30.

However, dividing both sides of equation (2) by A_t gives:

$$\frac{\dot{A}_t}{A_t} = \delta\left(\frac{H_{A,t}^{\gamma}}{A_t}\right)^{1-\phi}. \qquad (5)$$

Thus, the growth rate of TFP depends on the ratio of the quantity of human capital used in the production of ideas to the level of productivity. Both $H_{A,t}$ and A_t are upward trending and the growth rate of TFP is I(0). Jones (2002) argues that the parameter γ de-trends the ratio $H_{A,t}^{\gamma} / A_t$ to give an I(0) TFP growth rate. Therefore, the parameter γ is approximately equal to the ratio $\dot{H}_{A,t}/\dot{A}_t$, where $\dot{H}_{A,t}$ is the growth rate. The human capital index h_t is reported in the Penn World Table 9.0, which varies significantly over time. The number of researchers is reported in the World Bank data, but the time series has missing years across the panel. For this reason, we calculate $H_{A,t}$ for the year 1995 and the year 2014 only then compute the weighted $H_{A,t}$ and the growth rate over that range. The value of the weight θ did not seem to matter for the computation of γ . We tried Zero, and the share of the number of researchers in the total number of researcher in these 11 countries. The results do not change.

Table (1) reports the values of σ, α, and γ, which we use in computing excess ideas. For Finland, we have 0.81 and -0.20 and -0.27 for Italy and Spain respectively because TFP growth over the sample was high in Finland, and negative in these two countries.

Population growth is measured by the average growth rate of the labor force of all 11 countries, which is 0.81 percent.

Figures (2) plot the data for each country. The scattered plots around the 45^{o} line indicate that excess ideas explain real value added / hour-worked productivity rather very well in most countries, except France and Spain. The effect of the global financial crisis and the Great Recession is evident, except for Germany. For the rest of the EU (2008-2009), Sweden (2008-2009, 2009-2010, and 2010-2011), and the U.S. (2007-2008) data are far from the 45^{o} line.

We define international differentials as the deviations of the magnitudes of each country of the 10-EU countries from the U.S. We measure the deviations of the *average* of each country's productivity growth and excess ideas from the U.S. average magnitudes. Figure (3) is a scatter plot of these averages – the cross sectional evidence – only France and U.K. are off the 45^{o} line. Excess ideas differentials explain 80 percent of the differences in productivity growth on average.

4. The Missing Productivity Hypothesis

Feldstein (2017) argues that the explanation of the recent productivity decline in the United State is largely a mismeasurement issue, whereby the improvements in quality of products and the value added technological changes are not reflected in the GDP data. There are, however, other different explanations.

Bloom *et al.* (2017) argue, using Johns (2002) model, which we use here as a basis for analysis, that evidence at the micro level U.S. data suggest that there has been an increase in global research efforts (i.e., the number of people in research) coupled with a sharp decline in research productivity. They say that it is getting harder to find a new idea.

Lucas and Moll (2014), however, assumed that the stock of ideas is never exhausted. Luttmer (2012) assumes that productivity is subject to a small Brownian noise.

Fernald and Jones (2014) argued that the U.S. future economic growth is likely to slow down because educational attainment and population are likely to slowdown in the future. They also argue that the shape of the idea production function introduces uncertainty into the future growth. They also suggest that the rise of China and India's research growth, artificial intelligence, climate change, income inequality, and health care are among the variables that explain future productivity in the United States.

Missing productivity seems consistent with the findings of this paper. In our cross-sectional data, we show significant association between excess knowledge and productivity growth along the transitional growth path in countries other than the U.S. Figure (4) plots the average excess knowledge across all 11 countries, which seems to be trending down slightly. Italy and Spain have negative average excess knowledge growth over the sample. Figure (5) plots the average effective world research efforts, and figure (6) plots the growth rates. The *cross-sectional* trend is downward slopping. Therefore, some of the missing productivity along the transitional growth path in the developed countries could be explained, by: (1) mismeasurement of productivity, which includes sectors with hard-to-measure output such as health, education, defense, and other services. The market measure we used in this paper reveals higher growth rates, especially in countries with relatively larger public sectors and social services programs, such as Finland, France, the Netherlands, and Sweden. (2) A decline in growth rate of excess knowledge in the advanced countries in general; and (3) a decline in the growth rate of effective world research efforts, which are due to decline in the supply of labor in the production of research that occurred after the Great Recession.

In the long run, declining population growth rate might put more downward pressure on productivity growth. There is a decline in working age population across the 11 developed countries (Figure 7); a stagnation and a decline in fertility rate (Figure 8); a decline in youth population (Figure 9). Aging population is a well-known issue in the advanced country.

5. Summary

We use the EUKLEMS 2017 data to provide evidence that cross-country productivity growth differences are explained by TFP growth differentials, where TFP depends on scientific research ideas in advanced countries. Our scatter plots represent cross-sectional validations of Jones (2002) U.S. time series growth model, and it is consistent with the current literature that the frontier of technology and best practices diffuses at different rates across developed countries.

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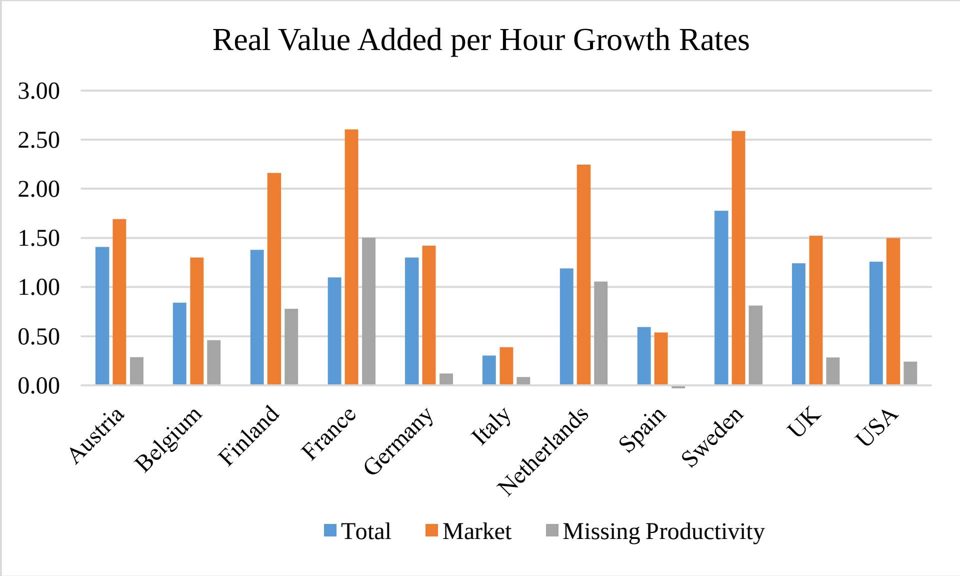
Table (1)

The values of the parameters used in the calibration of the growth equation

Country	σ	α	γ
Austria	1	0.41	0.402297
Belgium	1	0.37	0.283751
Finland	1	0.41	0.814458
France	1	0.38	0.122269
Germany	1	0.37	0.354242
Italy	1	0.47	-0.20123
The Netherlands	1	0.39	0.234447
Spain	1	0.37	-0.27976
Sweden	1	0.46	0.428839
U.K.	1	0.38	0.329777
U.S.	1	0.38	0.304491

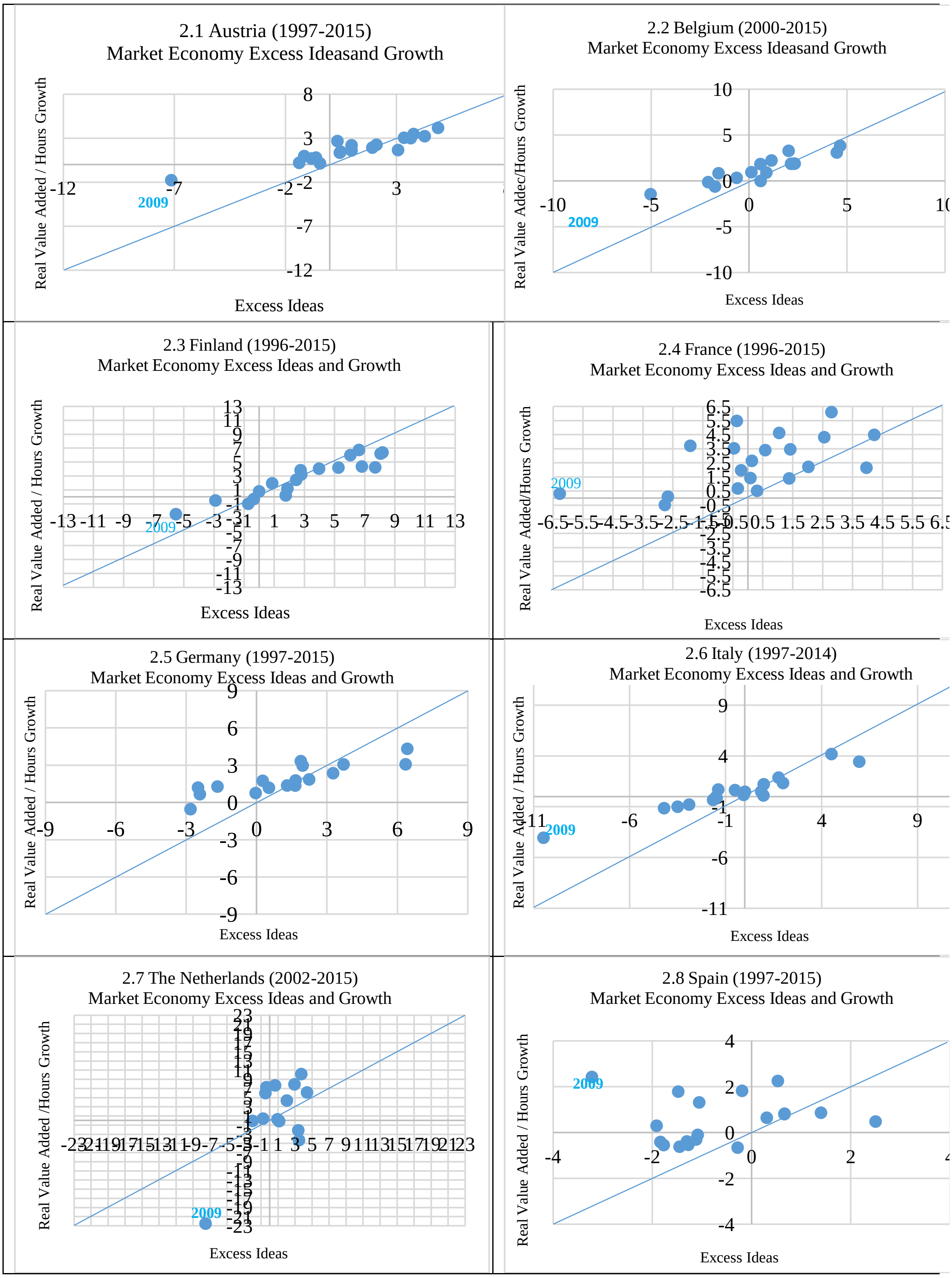
We conducted a sensitivity analysis for σ using values equal to $1-\alpha$ up to one and we found that a value of one gives the best fit.

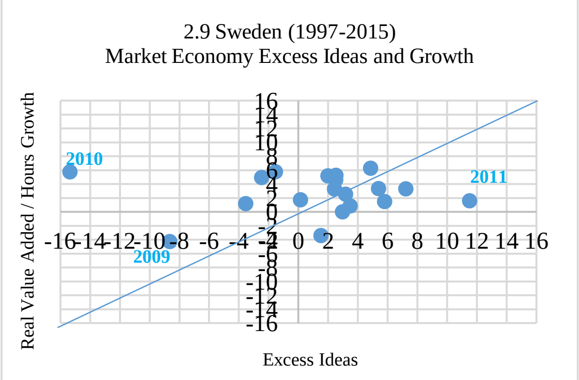
Figure (1)

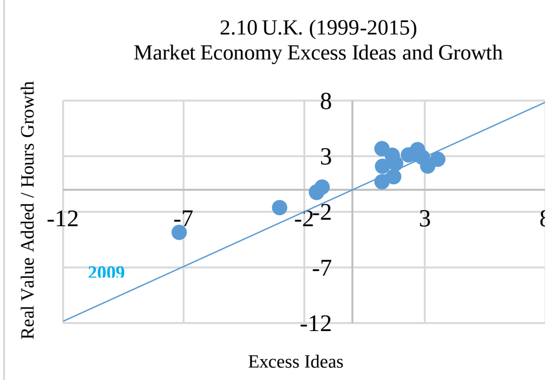


The sample is 1996-2015, except for Belgium (2000-2015) and the U.S. 1999-2015 because not all the data are available.

Figure (2)


2.1 Austria (1997-2015)
Market Economy Excess Ideasand Growth
Real Value Added / Hours Growth
Excess Ideas
2009
2.2 Belgium (2000-2015)
Market Economy Excess Ideasand Growth
Real Value Added/Hours Growth
Excess Ideas
2009
2.3 Finland (1996-2015)
Market Economy Excess Ideas and Growth
Real Value Added / Hours Growth
Excess Ideas
2009
2.4 France (1996-2015)
Market Economy Excess Ideas and Growth
Real Value Added/Hours Growth
Excess Ideas
2009
2.5 Germany (1997-2015)
Market Economy Excess Ideas and Growth
Real Value Added / Hours Growth
Excess Ideas
2.6 Italy (1997-2014)
Market Economy Excess Ideas and Growth
Real Value Added / Hours Growth
Excess Ideas
2009
2.7 The Netherlands (2002-2015)
Market Economy Excess Ideas and Growth
Real Value Added /Hours Growth
Excess Ideas
2009
2.8 Spain (1997-2015)
Market Economy Excess Ideas and Growth
Real Value Added / Hours Growth
Excess Ideas
2009


2.9 Sweden (1997-2015)
Market Economy Excess Ideas and Growth
Real Value Added / Hours Growth
Excess Ideas
2010
2009
2011


2.10 U.K. (1999-2015)
Market Economy Excess Ideas and Growth
Real Value Added / Hours Growth
Excess Ideas
2009

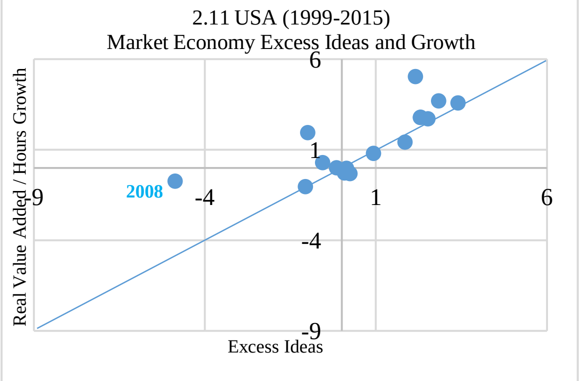

2.11 USA (1999-2015)
Market Economy Excess Ideas and Growth
Real Value Added / Hours Growth
Excess Ideas
2008

Figure (3)

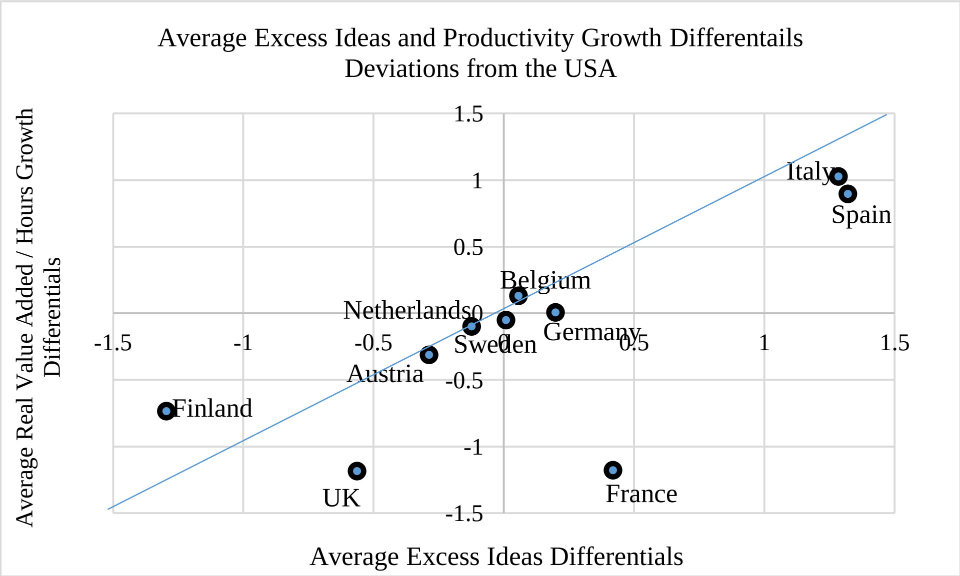

Average Excess Ideas and Productivity Growth Differentails
Deviations from the USA
Average Real Value Added / Hours Growth Differentials
Average Excess Ideas Differentials
1.5
1
0.5
0
-0.5
-1
-1.5
-1.5
-1
-0.5
0.5
1
1.5
Italy
Spain
Belgium
Netherlands
Sweden
Germany
Austria
Finland
UK
France

Figure (4)

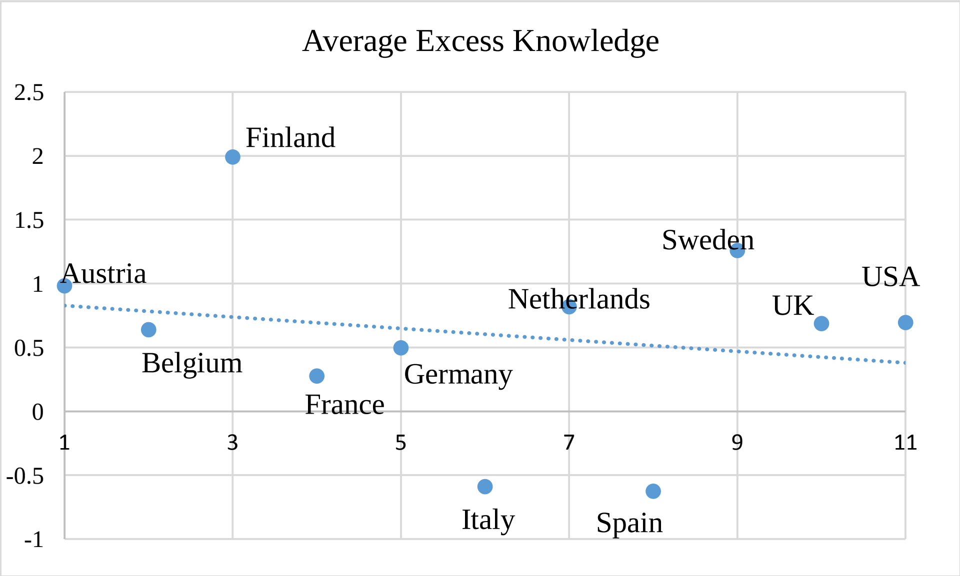


Figure (5)

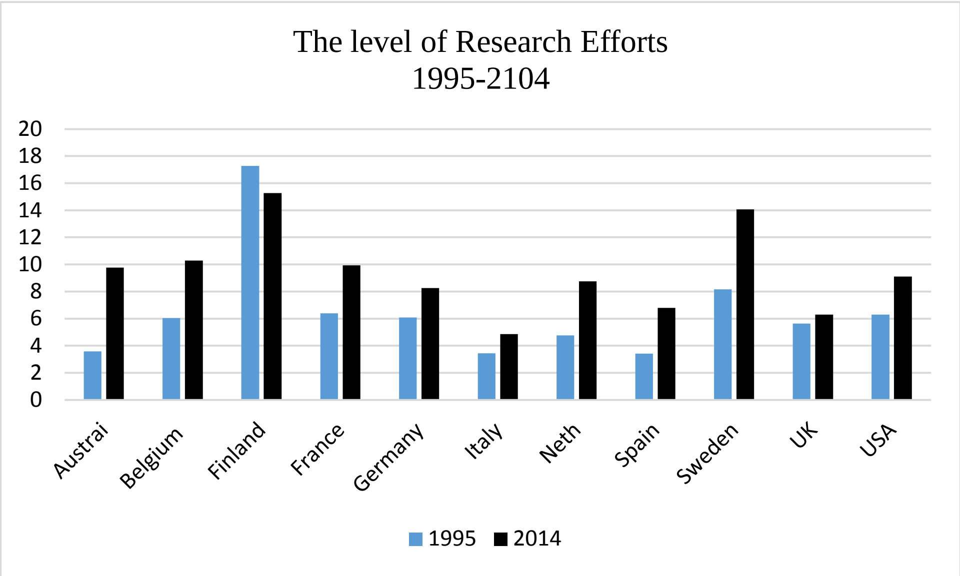


Figure (6)

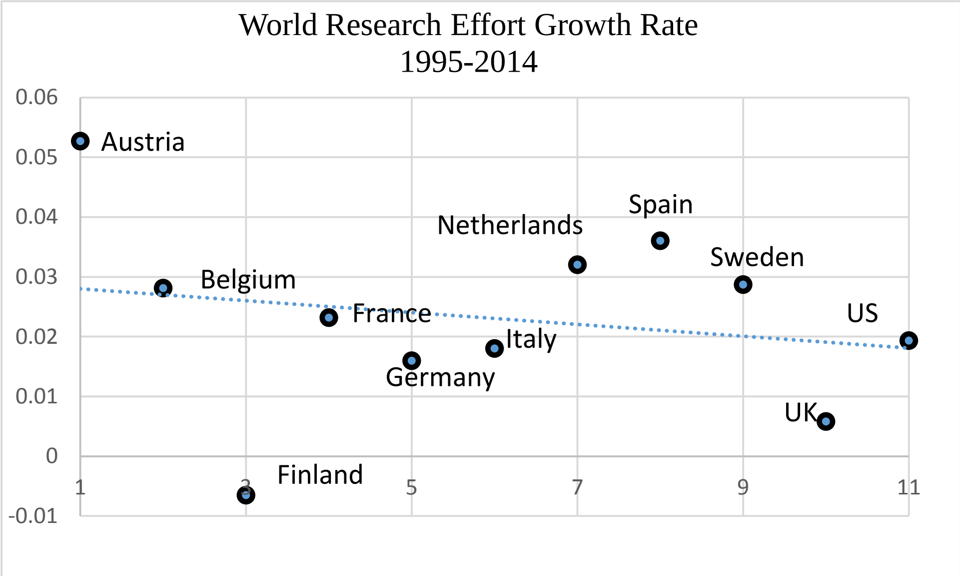

World Research Effort Growth Rate
1995-2014
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
1
3
5
7
9
11
Austria
Belgium
France
Germany
Italy
Netherlands
Spain
Sweden
US
UK
Finland

Figure (7)

Percentage of Working Age Populatio (15-64)

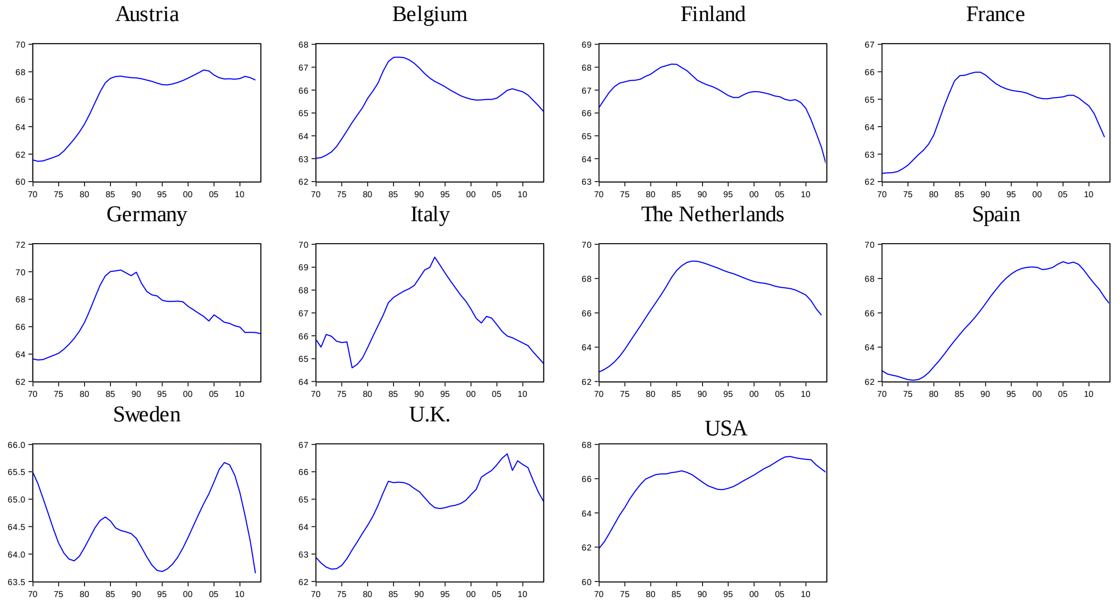


Figure (8)

Fertility Rate (child per Woman)

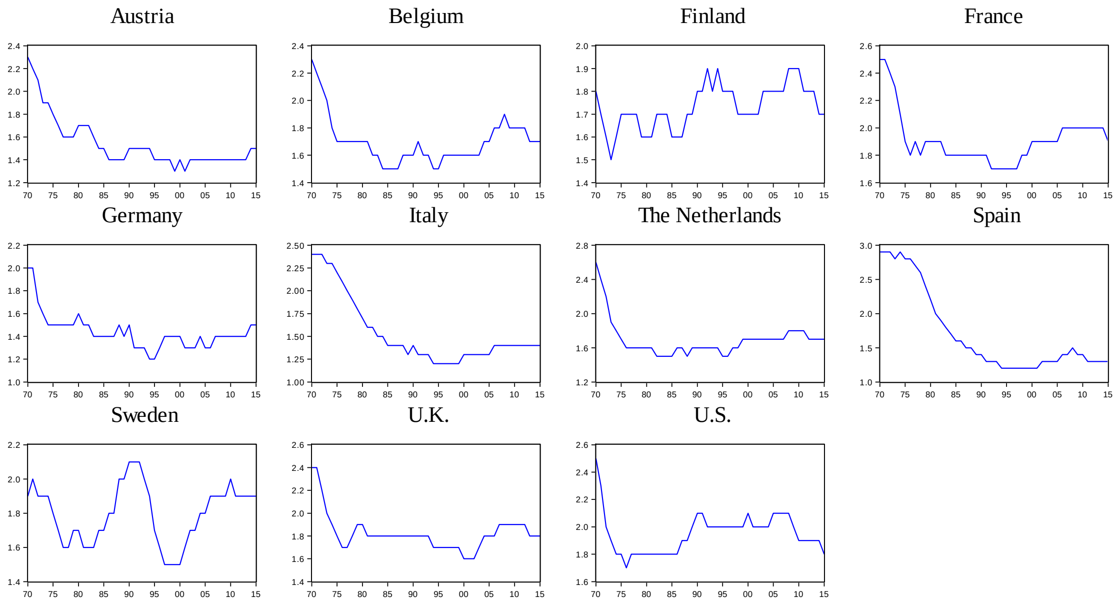
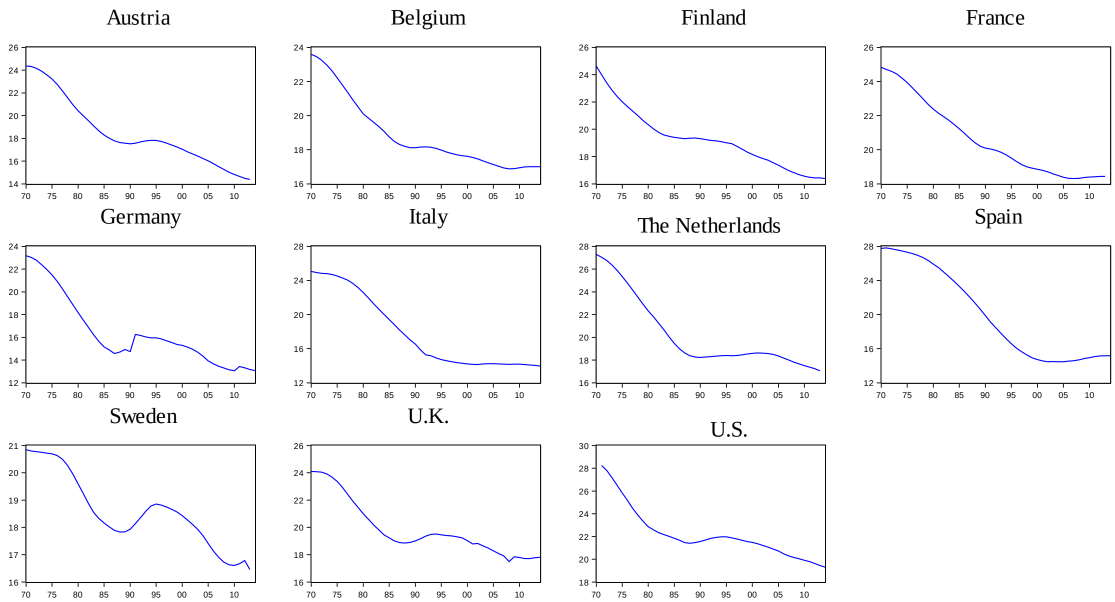


Figure (9)

Percent of Young Population (less than 15)



Appendix II

The data are from EUKLEMS (2017). The data set include all European countries and the United States. However, we only use the original EUKLEMS EU10 and the United States because the required data for the other countries are incomplete.

We measure productivity y_{it} by real value added per hours worked. We deflate the value added VA (Gross value added at current basic prices- in millions of national currency) by the price VA_P (Gross value added, price indices, 2010 = 100) then divide by hours worked H_EMP (Total hours worked by persons engaged in thousands). EU Stat defines gross Value Added (VA) as output value at basic prices less intermediate consumption valued at purchasers' prices. VA is calculated before consumption of fixed capital.

The aggregate TFP is Market Economy data. The Market Economy measure excludes lines L, O, P, Q, T, and U, which are the sectors real estate activity; Public administration and defense; compulsory social security; Education, Health and Social Work; and Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use.

The data for the market value added output, prices, and hours are from 1995 to 2015. The *level* of market TFP and sectoral TFP's varies. For Austria (1996-2015); Belgium (1999-2015); Finland (1996-2015); France (1995-2015); Germany (1996-2015); Italy (1996-2015); The Netherlands (2001-2015); Spain (1996-2015); Sweden (1996-2015), U.K. (1998-2015); and the U.S. (1999-2015).

The share of labor / capital and the human capital index are taken from the Penn World Table 9.0.

Population is measured by the Labor Force as in Jones (2002), from OECD data.

The number of researchers is from the World Bank.

[i] In Lucas and Moll (2014) ideas are rival in the short run increasing productivity requires more efforts; ideas in the long run are non-rival.