ECONOMIC ANNALS, Volume LXII, No. 215 / October – December 2017
UDC: 3.33 ISSN: 0013-3264

https://doi.org/10.2298/EKA1715053T

*Ivan D. Trofimov**

CAPITAL PRODUCTIVITY IN INDUSTRIALISED ECONOMIES: EVIDENCE FROM ERROR-CORRECTION MODEL AND LAGRANGE MULTIPLIER TESTS

ABSTRACT: *The paper re-examines the "stylized facts" of the balanced growth in developed economies, looking specifically at capital productivity variable. The economic data is obtained from European Commission AMECO database, spanning 1961-2014 period. For a sample of 22 OECD economies, the paper applies univariate LM unit root tests with one or two structural breaks, and estimates error-correction and linear trend models with breaks. It is shown that diverse statistical patterns were present across economies and overall mixed evidence is provided as to the stability of capital productivity and balanced growth in general. Specifically, both upward and downward trends in capital productivity were present, while in several economies mean reversion and random walk patterns were observed. The data and results were largely in line with major theoretical explanations pertaining to capital productivity. With regard to determinants of the capital productivity movements, the structure of capital stock and the prices of capital goods were likely most salient.*

KEY WORDS: *Capital productivity, structural breaks, unit root tests, growth*

JEL CLASSIFICATION: C12, C22, N10, O47

* Kolej Yayasan Saad Business School, Malaysia, ivan.trofimov1@gmail.com

1. INTRODUCTION

The idea that several economic variables are roughly constant over the course of economic growth has been central to economic theory in general and to growth and distribution theories in particular. It dates back to early works by N. Kaldor (1961), who argued that economies operate at near-balanced growth paths and that certain "stylized facts" are present. Specifically, it posits (Kaldor 1961, pp.177-222; Jones & Romer 2009, p.2) that: 1) labour productivity (Y/L) and capital per worker (capital intensity – K/L) grow at sustained and roughly similar rates with no tendency to fall; 2) rates of return on capital remain steady; 3) capital–output ratio (K/Y) shows no systematic trend; 4) shares of labour and capital in national income remain stable; and 5) there is considerable variation in the rate of growth among fast-growing countries and in the rate of productivity growth across countries.

Following Kaldor and Mirrlees (1962) and Romer (1989), among others, this paper acknowledges the identity–type relationships between the stylised facts. Firstly, the rate of return on capital is a product of capital productivity (the inverse of the capital–output ratio) and capital share. Secondly, the product of labour productivity and the inverse of capital intensity is capital productivity (Y/L x L/K = Y/K). Thereby, stability of capital productivity and labour share implies stability of the rate of return. Likewise, the rate of change in capital productivity is sustained if labour productivity and capital intensity grow at similar rates.

Capital productivity is thus a salient variable that reflects the patterns of technical change and also determines the level of profitability in the economy. The purpose of the paper is to examine the dynamics of capital productivity in industrialised economies, and specifically to consider its statistical properties (stationarity versus mean reversion and random walk), its interaction with labour productivity, capital intensity, and other relevant variables, and its implications for technical change and balanced growth in the respective economies.

As put by Evans (2000, pp.4–5), the theoretical economic growth literature tends to express the stylised facts in terms of constancy of factor shares, capital–output ratio, and return on capital, while the real economies are inevitably stochastic economies. Hence, we consider it more appropriate to analyse respective variables using the terms “steady”, “stable”, and “mean-reverting”, and adopt this terminology throughout the paper.

The paper introduces two novelties. Firstly, it examines balanced growth stylized facts as originally formulated by Kaldor, in contrast to the more recent “balanced growth literature” (King et al. 1991, p.819) that looks for empirical support for Kaldor’s facts based on consumption, investment, and output variables (specifically considering consumption/output and investment/output ratios). Secondly, while Kaldor’s stylised facts are supposed to hold in the long run, breaks and other disruptions to balanced growth may nonetheless be present in the short run. In this connection, the paper incorporates the analysis of the structural breaks into trend and autoregressive modelling, as well as employs the recently developed Lagrange Multiplier (LM) unit root tests with one or two structural breaks. Thirdly, the relationships between capital productivity and other relevant variables are examined in a narrative form.

The paper is structured as follows. Section 2 reviews the literature relating to empirical analysis of balanced growth. The data, methodology, and empirical findings are discussed in Section 3. Concluding remarks are contained in Section 4.

2. LITERATURE REVIEW

The stylised facts of balanced growth have been the cornerstone of neoclassical growth models. The analysis of individual stylised facts and ‘multi-fact’ studies has also been the object of research in a number of studies, principally concerned with the empirical testing of long-run relationships between output, investment, and consumption within the neoclassical growth model framework (Kunst & Neusser 1990; King et al. 1991; Mills 2001; Harvey 2003; Li & Daly 2009, among others). Balanced growth patterns were identified in some cases, and rejected in others.

Evans (2000, pp.14-15) examines Kaldor’s stylised facts in the post-war US context using trend regressions and Dickey-Fuller unit root tests. He concludes that in the period considered the capital–output ratio, the net rate of return on capital, the net share of capital in output, and the net investment rate were all mean-reverting. The growth rate of per capita output was also mean-reverting and did not show a downward trend. The Kaldor facts held, despite a sharp decline in capital–output ratio and sharp increase in the return to capital during WWII years.

Steger (2001) conducts empirical testing of the stylised facts of economic growth using Penn tables in the context of developing economies. However, the facts examined are different from those originally formulated by Kaldor and concern the diversity of growth rates, correlation between savings rate and economic growth rate, correlation between the growth rate and the level of income per capita, and convergence/divergence of per capita income.

Analysis of labour share and labour productivity concerns the identification of factors responsible for slowdown and non-uniform growth rates of labour productivity (Nordhaus 2002; Gordon 2012, among others) or deterioration of labour share (Acemoglu 2002; Torrini 2005; Dunhaupt 2012).

The studies that examine capital intensity focus specifically on the dynamics of factor proportions in economic growth and conclude that the capital–labour ratio has been rising in developed economies, albeit without investigating whether the growth is steady or declining (Mills 2009; Karabarbounis & Neiman 2014). The study by Lawrence (2015, p.4) is an exception, arguing in favour of declining effective capital–labour ratios in the US, resulting from the preponderant labour-augmenting (instead of labour-saving) technical change at both aggregate and industry level.

Denison's early (1967) analysis of capital productivity and capital–output ratio confirms Kaldor's stylised fact: the level of capital–output ratio is remarkably constant across countries at different stages of development, implying that capital–output ratio is steady over time. By contrast, based on US data spanning 1900–1953, Klein and Kosobud (1961) estimate a linear trend model and establish a significant downward trend in capital productivity. More recent analyses include Mills (2009), Madsen et al. (2012), and D'Adda and Scorcu (2003). Mills' analysis of the original Klein-Kosobud data suggests that Y/K is trend-stationary around a downward trend, thus giving support to Klein and Kosobud's paper. The results of D'Adda and Scorcu are mixed: while the Y/K ratio appears to be stationary for extended periods in the US and Germany there is also a tendency for reduction in the levels of Y/K across economies; e.g., capital productivity in the 'follower' economies (Italy, France, etc.) converges to that of the leader economy (USA). By contrast, Madsen et al. provide more robust support for stationarity of capital productivity (observed in 15 out of 16

OECD economies). This is in line with earlier work by Romer (1989), who reports remarkably similar growth rates in output and capital stock in the US over the 1870–1913, 1913–1950, and 1950–1979 periods. Hofman (2000) considers capital productivity in Latin America in the context of developing countries. His mixed findings include increasing growth of capital productivity in a few economies between 1950 and 1980 and 1980 and 1998 (Argentina, Bolivia, Chile, Peru) and a slowdown in capital productivity in other economies in the region.

To provide a theoretical account of the fall or slowdown in capital productivity, Foley and Michl (1999) point to the likelihood of labour-saving technical change over the course of the process of economic development. This implies, respectively, a substitution of labour for capital and rising labour productivity in tandem with falling capital productivity (and hence the impossibility of steady and trendless capital–output ratios). This argument is empirically tested for a set of developed and developing economies (King & Levine 1994, pp.22–23): the capital–output ratio is found to vary positively and significantly with income per capita.

In light of the mixed evidence, the analysis of capital productivity dynamics requires further empirical investigation. Most recent studies of capital productivity rely on the application of up-to-date econometric tests: the Gregory-Hansen cointegration test with single endogenous break (D'Adda & Scorcu 2003) and Perron-Vogelsang, Clemente-Montanes-Reyes, and Carrion-i-Silvester tests (Madsen et al. 2012). This paper likewise uses a combination of methods to deliver robust conclusions: linear trend analysis with correction for serial correlation, autoregressive modelling with breaks, and univariate Lagrange Multiplier tests with up to two endogenously determined structural breaks. In contrast to other studies of capital productivity, the paper also looks at the relationship of capital productivity to other variables of interest and analyses capital productivity within the broader context of economic growth and productivity.

3. EMPIRICAL RESULTS

3.1 Data

The data for this paper was obtained from the European Commission's AMECO database, which collects national accounts data for respective European and selected non-European economies. The original data is prepared by Eurostat or national statistic bodies.

The capital productivity variable (AVGDK) is defined as the ratio of GDP at constant market prices to net capital stock at constant prices. The latter for any particular period was calculated using the perpetual inventory method (PIM) and depreciation rates from respective national accounts, as net capital stock at constant prices in the previous period plus gross fixed capital formation at constant prices (total economy) minus consumption of fixed capital (total economy) divided by price deflator for gross fixed capital formation. Instead of assuming homogenous capital stock, separate estimates of the capital stock were obtained for structures (residential and non-residential), equipment, agricultural assets, mineral exploration assets, and various intangible assets (Caselli & Wilson 2004). The starting capital stock in the series was calculated assuming a fixed K/Y ratio in 1960 (K/Y=3).

We note that the dynamics of capital productivity are intertwined with movements in labour productivity and capital intensity. These latter variables were considered and defined as follows. The labour productivity variable (RVGDE) was defined as the ratio of GDP at constant market prices to total employment in all domestic industries. The latter included both residents and non-residents, covered employed and self-employed persons, and was calculated as a yearly average. The capital intensity variable (RKNDE) was defined as the ratio of net capital stock at constant prices to total employment in all domestic industries.

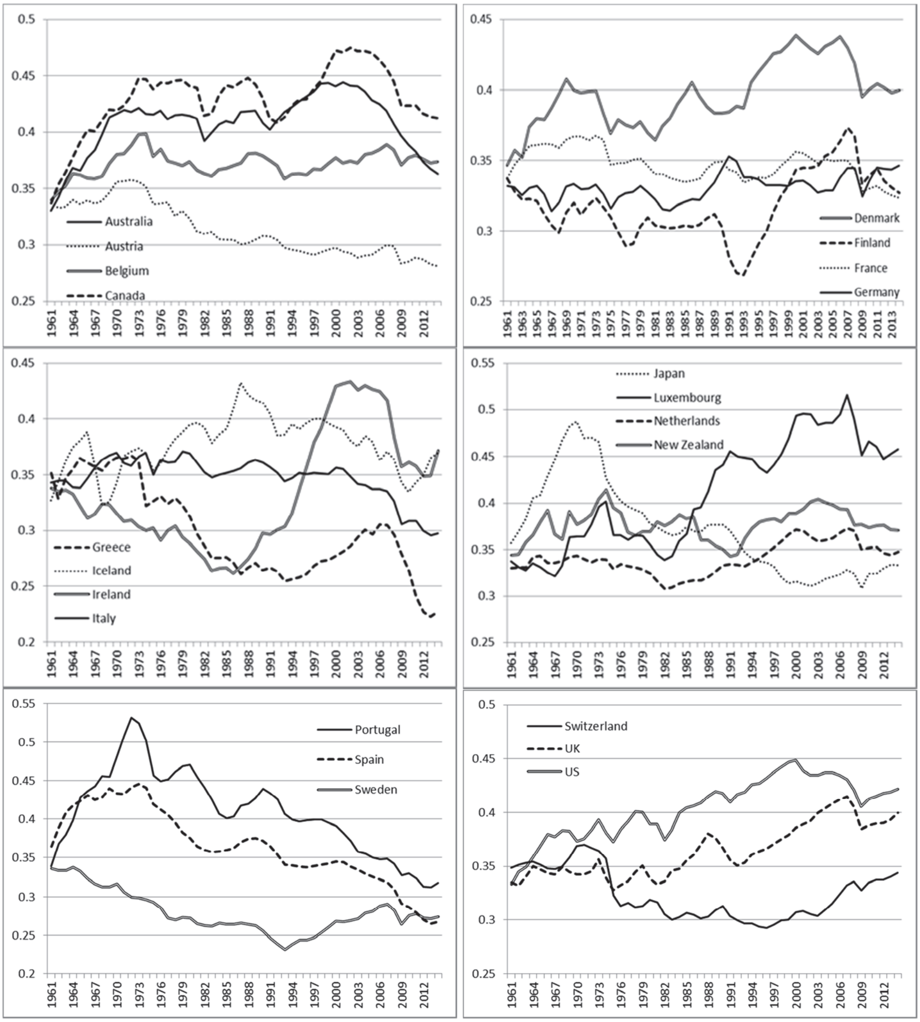
The period covered for each economy, 1960–2014, was set to be sufficiently long to examine variation in capital productivity. For other variables of interest that determine capital productivity the period covered was 1961–2014 for labour productivity growth rates and 1963–2014 for capital intensity growth rates. The paper considers the following developed economies: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Portugal, Spain, Sweden, Switzerland, the UK, and the USA.

3.2 Empirical results

First, the series were inspected visually (Figure 1). Several economies demonstrated rising capital productivity (Belgium, Denmark, Luxembourg, the UK, and the USA). Capital productivity fell in Austria, Greece, Italy, Spain, and

Portugal. Trendless patterns or random walk behaviour appeared to characterize capital productivity in Australia, Finland, France, Ireland, the Netherlands, Iceland, and New Zealand.

Figure 1. Capital productivity in industrialized economies (1961–2014)



As a second step, a trend model was estimated using a semi-logarithmic equation, as follows:

$$\ln x_{it} = c + \beta_i t + \mu_{it}, \quad (1)$$

where x is the variable in question for country i, t is the year of observation, and μ_{it} is a random disturbance term. Parameter β_i indicates the average annual change of variable x along the linear trend. To correct for possible autocorrelation, the Prais-Winsten iterative procedure was adopted (Canjels & Watson 1997).

Following Nelson and Kang (1984), it is acknowledged that making assessments based on visual inspection of the series or estimation of the linear trend prior to consideration of the unit root properties of the series may be erroneous, due to the possibility of spurious regression (or spurious cyclicality or breaks). On the other hand, Canjels and Watson (1997) provide arguments in favour of autoregressive (AR) models. We therefore retain trend estimates, to be interpreted in conjunction with other tests.

The results of linear trend estimation are presented in Table 1. A negative trend in capital productivity was present in 9 out of 22 economies (statistically significant only in the case of Austria, Greece, Italy, Spain, and Sweden). A positive and significant trend was identified in Belgium, Denmark, Germany, Luxembourg, the UK, and the USA. The largest significant decline was in Greece (–41.40%) and the largest increase in Luxembourg (36.86%).

Table 1. Trend estimates of capital productivity

Country	Trend	Cumulative change (%)	p-value	rho	Break	Model
Austria	–0.0039	–20.44	0.00	0.86		TS
Australia	0.0018	9.43	0.45	0.99		
Belgium	0.0011	5.72	0.09	0.82		TS
Canada	0.0037	19.69	0.13	0.98		
Denmark	0.0026	13.96	0.02	0.88		TS
France	–0.0010	–5.52	0.11	0.86		
Finland	0.0003	1.70	0.86	0.92		
Germany	0.0009	4.55	0.04	0.67		TS
Greece	–0.0078	–41.40	0.00	0.93		TS
Iceland	0.0014	7.59	0.36	0.86		
Ireland	0.0021	11.27	0.52	0.97		
Italy	–0.0026	–13.63	0.08	0.94		TS
Japan	–0.0019	–10.14	0.47	0.97		
Luxembourg	0.0070	36.86	0.00	0.89		TS
Netherlands	0.0012	6.20	0.29	0.93		
New Zealand	0.0009	4.62	0.35	0.79		
Portugal	–0.0014	-7.49	0.71	0.99		
Spain	–0.0059	–31.53	0.02	0.98		TS
Sweden	–0.0038	–20.33	0.08	0.97		TS
Switzerland	–0.0004	-2.09	0.83	0.98	1975–76	
UK	0.0036	19.01	0.00	0.84	2009	TS
USA	0.0041	21.83	0.00	0.88		TS

Notes: TS indicates the presence of deterministic trend.

As a third step, a more general autoregressive model with trend was considered that avoids spurious results by incorporating both trend-stationary and difference-stationary model components (Bleaney & Greenaway 1993).

The model equation is:

$$\Delta \ln x = \alpha + \beta t + \psi \ln x_{t-1} + \delta \Delta \ln x_{t-1} + \nu_t \tag{2}$$

where x is a respective variable, β is a trend coefficient, v_t is a random disturbance term, and ψ is an error-correction term. The autoregressive model is correctly specified when $\psi < 0$. The variable in question follows random walk with zero mean when $\beta = 0, \psi = 0$; reverts to historical mean when $\beta = 0, \psi < 0$; performs random walk with drift (i.e., has a stochastic trend) when $\beta \neq 0, \psi = 0$ and $\beta > 0$ or $\beta < 0$; and reverts to a non-zero deterministic trend when $\beta \neq 0, \psi < 0$, specifically $\beta < 0, \psi < 0$ or $\beta > 0, \psi < 0$. In the fourth case, when a trend was present the annual rate of change of x along the trend was estimated as $-\beta\psi^{-1}$. Also, a reliable guide as to the future behaviour of the series was obtained only in the second and fourth case (i.e., series with no random walk). Standard t-ratio statistics were used to determine the significance of all terms except $\ln x_{t-1}$ (in which case Dickey-Fuller unit root t-statistics were used).

Impulse or shift dummies were added to capture the break in the level or trend of the series. When heteroscedasticity was present and/or autocorrelation was not removed, a model with Newey-West and/or Huber-White terms was estimated.

Autoregressive model results are presented in Table 2. The coefficient of the error-correction term (ψ) was negative, and hence the model was considered valid. A deterministic trend for capital productivity was observed in 11 economies based on t-statistics, and in 3 economies based on Dickey-Fuller statistics. The latter economies are Germany, the UK, and the US. Positive and significant trends in capital productivity were observed in Finland, Germany, Ireland, Luxembourg, Sweden, the UK, and the US. A negative significant trend was present in Austria, Australia, France, Japan, Portugal, and Spain.

Table 2. Results of the autoregressive model

Country	δ	p-value	ψ	t-statistics	Break	Trend	R^2	Notes	Model
Austria	−0.0006	0.08	−0.140	−1.98	2009	−0.43	0.19		DT
Australia	−0.0005	0.01	−0.043	−1.25	1982	−1.09	0.48		ST
Belgium	−0.0001	0.45	−0.147	−1.78	1975	X	0.24		MR
Canada	−0.0001	0.47	−0.100	−2.44	1982	X	0.47		MR
Denmark	0.0003	0.27	−0.143	−2.13	2009	X	0.19		MR
France	−0.0002	0.04	−0.106	−1.84	1975, 2009	−0.23	0.48		DT
Finland	0.0005	0.03	−0.107	−2.40	1991, 2009	0.45	0.50		DT
Germany	0.0005	0.00	−0.379	−4.34	2009	0.13	0.38	HW	DT
Greece	−0.0007	0.18	−0.152	−2.29	1974	X	0.21	HW	MR
Iceland	−0.0004	0.10	−0.188	−3.64	1967–8	−0.21	0.53		DT/MR
Ireland	0.0006	0.03	−0.047	−1.70	2008	1.29	0.43		DT
Italy	−0.0005	0.05	−0.069	−1.12	1975, 2009	−0.67	0.40	NW	ST
Japan	−0.0010	0.00	−0.090	−2.41	1974, 2010	−1.09	0.59		DT
Luxembourg	0.0012	0.07	−0.132	−1.90	2008–9	0.91	0.23		DT
Netherlands	0.0002	0.18	−0.061	−1.34	2009	X	0.29		RW
New Zealand	−0.0002	0.37	−0.237	−2.83	1967	X	0.24		MR
Portugal	−0.0012	0.00	−0.105	−2.96	1975	−1.16	0.55		DT
Spain	−0.0010	0.01	−0.115	−2.99	2009	−0.90	0.55		DT
Sweden	0.0003	0.10	−0.028	−0.80	2009	1.16	0.26	NW	ST
Switzerland	0.0001	0.45	−0.011	−0.31	1975	X	0.52		RW
UK	0.0008	0.01	−0.226	−3.25	1974	0.34	0.38		DT
USA	0.0006	0.03	−0.206	−3.33	1982, 2009	0.30	0.34		DT

Notes: DT, ST, MR, and RW indicate a deterministic trend, stochastic trend, reversion to historical mean, and random walk respectively. X implies that the trend coefficient is not significant and is considered to be zero. HW indicates Huber-White heteroscedasticity-consistent standard errors due to the presence of heteroscedasticity. NW indicates Newey-West standard errors to overcome heteroscedasticity and autocorrelation.

The largest increase along the deterministic trend was in Ireland and Luxembourg (1.29% p.a. and 0.91% p.a.), while the largest decrease was in Portugal (–1.16% p.a). The series in Belgium, Canada, Denmark, Greece, and New Zealand reverted to the historical mean, while the series in the Netherlands and Switzerland followed a random walk. Capital productivity in Australia, Italy, and Sweden followed a stochastic trend. In the case of Iceland the model's findings are inconclusive, with either a deterministic trend or a mean reversion possible.

In most cases the correctly specified autoregressive model was obtained if dummy variables (of impulse of shift form) representing structural breaks in the series were included. These breaks largely correspond to country-specific or global economic events and developments. The breaks were principally located during business cycle troughs: the global recession of 2008–2010 (13 cases), the recession of 1973–1975 that followed the 1973 oil crisis and the collapse of Bretton-Woods (8 cases), the recession of the early 1980s in the USA (triggered by contractionary monetary policy), the 1967–1968 recession in Iceland (attributed to a fall in fish exports and decline in export prices), and the 1967 recession in New Zealand (associated with the collapse of wool prices on the international market). Breaks also represented major structural changes in the respective economies (1991 in Finland, corresponding to the collapse of COMECON and trade with the Eastern bloc), and possibly political changes (such as the break in 1974, indicating the restoration of democratic rule in Greece).

It is known that the Augmented Dickey-Fuller test, on which the autoregressive model is based, tends to have low power in the presence of structural breaks and is biased towards non-rejection of the unit root null. The Lee and Strazicich (2003, 2004) Lagrange Multiplier (LM) tests adopted in this paper address this shortcoming, and also have other advantages: they determine up to two structural breaks endogenously, and solve the problem of spurious rejections typical of other tests with breaks (consideration of time series as stationary when they are non-stationary with breaks).

Lee-Strazicich LM tests are based on the

$$y_t = \delta' Z_t + e_t \tag{3}$$

and

$$e_t = \beta e_{t-1} + \mu_t \tag{4}$$

data-generating process, where y_t are series, δ is the coefficients' vector, μ_t is the error term, and Z_t is a matrix of exogenous variables. While two models (A and C) are available for the LM test, this paper uses the C model, as more general and encompassing Model A (Sen 2003). In Model C, $Z_t = [1, t, D_t, DT_t]$, i.e., it allows for a shift in intercept and change in the trend slope under H_a. The LM unit root statistics are obtained from

$$\Delta x_t = d' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum x_i \Delta \tilde{S}_{t-i} + \varepsilon_t \tag{5}$$

where $S_t = x_t - \hat{\psi}_x - Z_t \delta_t$, $t = 2, ..., T$; δ are coefficients in the regression of Δx_t on ΔZ_t ; ψ_x is given by $x_t - Z_t \delta$; and x_1 and Z_1 are first observations of x and Z . LM test statistics are derived assuming $H_0 : \phi = 0$. The relevant structural breaks are grid-searched over the trimmed $(0.1T, 0.9T)$ region, where T is the sample size. The optimal lag length is determined through a general-to-specific procedure (maximum number of lags of k=8, and the 10% significance value of the last lag is equal to 1.645). The breaks are located where LM t-statistics are at the minimum.

The LM tests were implemented in a sequential manner. An LM unit root test with two endogenous structural breaks (Model C) was run. The results of the test were considered final and the series were seen as either trend stationary with two breaks or containing a unit root with two breaks, if based on t-statistics critical values, one of the following held: 1) two level (B_{jt}) and two trend (D_{jt}) dummies were significant; or 2) two trend dummies and one level dummy were significant; or 3) Two trend dummies were significant. In other cases, an LM unit root test with one endogenous break was run. If the trend dummy was significant, the series were seen as either trend stationary with single break or containing a unit root with single break.

The LM unit root tests with breaks demonstrate mixed results (Table 3). Up to two structural breaks were identified in all economies (a single break in Austria, Finland, Ireland, and Sweden).

Table 3. Lagrange Multiplier test results

Country	LM test (2 breaks)					LM test (1 break)				Model
	Break significance			Break dates		Break significance			Break date	
Austria						−4.150	[8]	D1	1983	URB
Australia	−4.844	[8]	D1D2	1987	1991					URB
Belgium	-5.986^{**}	[4]	B1D1B2D2	1979	2002					TSB
Canada	−4.603	[5]	D1D2	1973	1997					URB
Denmark	−5.115	[8]	D1B2D2	1986	1992					URB
France	−4.097	[6]	D1D2	1973	1995					URB
Finland						−3.956	[3]	D1	1997	URB
Germany	-5.974^{**}	[1]	D1D2	1987	1994					TSB
Greece	−4.586	[3]	D1D2	1978	2000					URB
Iceland	-6.788^{*}	[3]	B1D1D2	1985	2007					TSB
Ireland						-5.642^{*}	[5]	B1D1	1993	TSB
Italy	-5.710^{**}	[3]	B1D1B2D2	1974	2005					TSB
Japan	−4.355	[4]	B1D1D2	1978	1996					URB
Luxembourg	−4.996	[7]	D1D2	1984	2002					URB
Netherlands	−4.177	[1]	D1D2	1980	1998					URB
New Zealand	-6.450^{*}	[5]	B1D1D2	1973	1998					TSB
Portugal	-7.461^{*}	[2]	D1D2	1973	1988					TSB
Spain	-7.426^{*}	[4]	B1D1D2	1973	1993					TSB
Sweden						-4.785^{**}	[6]	D1	1993	TSB
Switzerland	-5.966^{**}	[4]	B1D1D2	1979	2003					TSB
UK	−5.117	[5]	B1D1D2	1973	2001					URB
USA	−5.230	[1]	D1D2	1980	1999					URB

Notes: B1, B2, D1, and D2 indicate significant level and trend break points at the 5% significance level (for the first and second break respectively). Lags selected by general-to-specific procedure are shown in square brackets. Series are considered trend stationary with breaks at the 5% significance level; symbol (*) indicates significance at the 1% level and symbol (**) significance at the10% level. LM test (Model C with 1 break) 5% critical values range from −4.45 to −4.51, depending on break location. LM test (Model C with 2 breaks) 5% critical values range from −5.59 to −5.73 depending on break location.

The timing of these breaks correspond moderately with major events and developments: out of 40 breaks, only 1 break tallies with the global recession of 2008–2010, a further 7 breaks tally with the 1973–1974 recession, and another 7 with the early-1980s recession. We acknowledge in this regard that LM is a test for unit root with break versus trend stationarity with breaks, rather than a test for the timing of breaks, and hence breaks suggested by the test may have no or little relation to actual economic changes. Trend stationarity with break(s) was observed in Belgium, Germany, Iceland, Ireland, Italy, New Zealand, Portugal, Spain, Sweden, and Switzerland. In other economies, capital productivity series were seen to contain a unit root with break(s).

The three types of estimates (linear trend with Preis-Winsten correction for autocorrelation, autoregressive modelling, and Lee-Strazicich tests) in many instances tended to identify different behaviours in the series. Acknowledging that the autoregressive model and Lee-Strazicich tests are based on more robust methodologies (but that the linear trend model and visual inspection may nonetheless provide insights as to the series' patterns), the following conclusions are made as to the series. 1) If all three methods suggest a significant trend (with or without breaks) in the series, the series are considered to be trend stationary (with or without breaks). The opposite holds if trends are not identified. 2) If either the autoregressive model or the Lee-Strazicich test points to a significant trend, while the other method does not, the conclusion is made based on the linear trend model with correction for autocorrelation (i.e., whether this model suggests a significant trend or not) and visual examination. 3) If both the autoregressive model and the Lee-Strazicich test point to a significant trend, but this contradicts the linear trend model and the 'eyeball' test, a statistically significant trend is deemed to be present. This rule will also apply to the opposite situation (i.e., if the autoregressive model and Lee-Strazicich indicate no trend, but the linear trend model and visual observation do, no significant trend is seen to be present).

We conclude overall that the empirical results are mixed. Taking into account all three tests, capital productivity followed a trend with breaks in 11 cases, and reverted to the historical mean or exhibited stochastic patterns in another 11 cases. All three tests unequivocally indicated trend stationarity with two breaks in Germany and Spain, and non-stationary behaviour in Australia, Canada, and the Netherlands. Of these three economies, capital productivity in Canada was mean-reverting (in line with balanced growth predictions), while in Australia and the Netherlands the series followed a random walk or random walk with drift. In all other countries the tests yielded conflicting results and the decision was made as per the aforementioned sequential procedure. Interpreting the LM test and the autoregressive model results in conjunction, mean reversion could also be identified in Denmark and Greece, and possibly New Zealand and Iceland.

3.3 Economic significance

The empirical results attest to a number of tendencies and developments taking place in the industrialised economies.

The fall in capital productivity in several economies illustrates the ongoing economic growth process and convergence to the steady-state as per the Solow model in the long run (Jones & Manuelli 1990). While arguably none of the OECD economies was in a steady state by the 1960s (complete substitution of labour for capital and per capita income determined solely by technological factors), economies such as Japan, Italy, Greece, Portugal, and Spain were the furthest away from the most advanced economies of the time (USA), as attested by the respective GDP-per-capita differentials. Falling capital productivity in these economies thus demonstrates lower per-capita capital stock at the beginning of the period, and catching-up proceeding at a higher speed than in the rest of the economies considered. This result is in line with Feu's (2003) observations of capital productivity in Italy and Japan. The use of this theoretical framework, however, leaves unexplained why capital productivity fell in Sweden and Switzerland (countries likely to be near or at steady state) and not in Ireland and Iceland (countries that had similarly low GDP and per capita capital in the early 1960s). Overall, capital productivity estimates for the AMECO set confirm results by D'Adda and Scorcu (2003) as to the direction and general pattern of the variable for Japan, Italy, and the Netherlands, but not for France, the UK, the USA, and Germany.

The levels and trends in capital productivity were also considered in terms of the efficiency and effectiveness of the use of capital. The McKinsey Global Institute study (1996) on capital productivity identifies German and Japan "productivity puzzles" (despite much saving and an increase in labour inputs in Japan and capital-deepening in Germany, the labour productivity levels lag behind US levels). The results of the analysis confirmed McKinsey's "puzzles": the levels of capital productivity (and efficiency of capital use) in these economies were much lower than in the US (falling in Japan and virtually stable in Germany), translating into sizeable slowdowns in labour productivity (in contrast to rising Y/L in the US). In Germany, Japan, and the US the growth rates of capital productivity in 1964–1969 were 4.78%, 3.05%, and 2.06% per annum, in 1990–1999 were 0.50%, 1.06%, and 2.01% per annum, and in 2000–2009 were 0.35%, 0.755%, and 1.33% per annum respectively. The results showed a high level of Y/K in Canada (on a par with the US, due to tight economic integration), and in Luxembourg (higher than the US level, in line with higher GDP per capita and labour productivity). The lowest levels of Y/K were identified in Greece, known for inefficient use of capital inputs, particularly in agriculture (Polyzos & Arabatzis 2006), and Sweden, where low capital productivity is due to the high depreciation rates (specifically for the period since the 1970s) used in AMECO (Perez & Garcia 2014).

The paper showed that in the short run the movements in capital productivity and capital–labour ratio growth rates were attributed to business cycle fluctuations. Specifically, the segments of falling capital productivity coincided with recessions or periods of sluggish growth. This regularity applied to most economies (to a lesser extent in Austria, Greece, and Japan), with the exception of Portugal and Spain, where falls in capital productivity were driven more by structural and policy factors. Capital deepening also accelerated during recessions, when job destruction is at its highest and the opportunity costs of job reallocation and shedding are the lowest (Caballero & Hammour 1996), resulting in capital productivity falls. Spikes in the capital–labour ratio were observed in Canada, the USA, Italy, Belgium, and the Netherlands during the three recessions of the early 1980s, early 1990s, and the global financial crisis of 2008–2009. In other economies the capital–labour ratio increased during one or two major recessions, while in Japan, Germany, and New Zealand the capital–labour ratio was acyclical.

Regarding factors underpinning capital productivity movements, Mohun (2009) identifies three drivers: 1) the relationship between growth in labour productivity and growth in capital intensity (capital deepening), with capital productivity falling when the latter exceeds the former and rising otherwise, as per identity relationship; 2) changes in the relative price of capital goods (rising prices lead to falling capital productivity); 3) the structure of capital stock (specifically the proportion of capital stock in productive versus non-productive and less-productive activities, and the changing composition of aggregate capital stock).

Regarding the first factor, as shown in Table 4, growth in labour productivity exceeded growth in capital intensity in 16 economies in the 1960s, 9 economies in the 1970s and the 1980s, 11 economies in the 1990s, 4 economies in the 2000s, and 7 economies in 2010s, indicating a gradual deterioration of capital productivity in most economies. On the other hand, positive trends in capital productivity were present in many instances (the growth rates ratio $\Delta Y/L:\Delta K/L$ was greater than 100% in 16 economies in the 1960s and 11 economies in the 1990s; i.e., during the periods of likely growth or resurgence in capital productivity).

This latter observation is in line with the trend model results presented in Table 1 (showing positive trends in capital productivity in 13 economies), and also the results presented by Mohun (2009) and Weiss (1998).

If the whole period (1964–2014) is examined, capital productivity was far from stable: the growth rate ratio fell within (95%; 105%) band only in New Zealand, Portugal, and the UK. On a decade-by-decade basis, the ratio fell within (95%; 105%) in Austria, Belgium, Germany, and the UK in the 1970s, Finland and Iceland in the 1980s, Finland, Luxembourg, and the Netherlands in the 1990s, and Austria in the 2000s. The ratio exceeded the band in all economies in the 1960s and the 2010s.

This lack of stability in capital productivity (together with other discrepancies, such as slowing down and reversal of capital deepening, as shown in Table 5) may cast doubts on the presence of balanced growth in the OECD economies during the study period.

Table 5 also shows that both labour productivity and capital intensity were growing at a diminishing rate: labour productivity was slowing down in all economies, and capital intensity was slowing down in all economies except Australia, Canada, New Zealand, and the USA (indeed, in some of the economies capital deepening halted, as in Australia and Canada in the 1960s, Ireland in the 1990s, and Switzerland in the 2000s). In addition, actual movements in capital productivity did not appear to reflect factor input substitution. The substitution process implies that a rise in real wages encourages firms to substitute capital for labour, thereby increasing the capital intensity of production and reducing capital productivity (the opposite changes will take place if real wages fall).

Table 4. Comparison of labour productivity and capital intensity average annual growth rates ($\Delta Y/L$ and $\Delta K/L$).

Country	1964-2014	1964-69	1970-79	1980-89	1990-99	2000-09	2010-14
Austria	106.4	127.0	99.1	116.8	86.5	97.2	125.5
Australia	117.2	227.8	69.4	112.4	231.2	36.3	126.7
Belgium	108.7	107.3	100.9	106.5	88.6	61.7	–964.4
Canada	106.5	87.4	80.1	91.3	–572.8	55.7	156.9
Denmark	75.4	108.6	81.8	–16.7	110.9	118.7	–48.3
France	74.2	128.1	73.9	91.7	53.6	28.4	50.2
Finland	92.5	111.8	90.3	96.0	103.2	48.1	75.8
Germany	87.7	124.9	103.5	90.3	81.1	0.8	42.1
Greece	172.5	195.4	107.4	241.0	213.0	–50.7	142.7
Iceland	105.3	114.0	87.7	96.3	420.2	66.9	86.9
Ireland	87.2	113.5	87.7	69.6	87.7	63.5	67.3
Italy	90.0	228.9	107.9	77.8	76.6	32.3	59.7
Japan	101.0	90.2	92.0	112.2	126.1	107.3	57.4
Luxembourg	83.0	75.5	54.1	79.6	97.1	111.5	280.1
Netherlands	120.7	108.0	108.8	153.8	103.9	115.0	1242.6
New Zealand	102.9	32.8	195.1	272.0	71.1	63.3	–3.3
Portugal	95.4	109.0	50.3	80.1	44.7	–900.4	–74.9
Spain	132.9	385.2	169.7	152.7	148.1	57.3	291.7
Sweden	92.1	190.2	66.1	91.4	36.4	82.2	–618.4
Switzerland	126.9	–2174.3	190.5	88.3	137.7	35.0	70.0
UK	102.4	–1433.3	104.7	109.7	130.7	33.0	42.7
USA	110.6	2623.9	2.3	80.6	320.2	76.8	64.0

Note: The comparison is performed by constructing the ratio of labour productivity growth rate to capital intensity growth rate (expressed in percentages). Values equal to or close to 100 indicate similar or roughly similar growth rates in a specific period.

As shown in Table 5, capital deepening decelerated in 18 economies over the 1964–2014 period and proceeded at a sustained or increasing rate in the remaining four (Australia, Canada, New Zealand, and the USA). In particular, over the 1964–1989 period, deceleration took place in all economies except those mentioned above as well as Portugal, and over the 1990–1999 period in all economies except Australia, Belgium, Canada, Iceland, Sweden, the UK, and the USA. However, the four Anglo-Saxon economies mentioned witnessed negative growth in real wages (Western & Healy 1999), while other economies only experienced slowdown in real wage growth (and some, such as Austria, Finland, Germany, and the UK, experienced solid growth). Also, Australia, Canada, New Zealand, and the USA experienced increased growing capital productivity, despite sustained capital deepening.

These apparent contradictions between actual movements in capital productivity on the one hand and real wages, labour productivity, and capital intensity changes on the other may be explained by the relative prices of capital and the structure of capital stock.

The relative prices of capital and the structure of capital stock were likely behind the reversal of capital productivity in the 1980s and the 1990s. On a decade-by-decade basis, visual observation and the analysis of trend segment suggests that the highest incidence of rising capital productivity was in the 1960s and the 1990s (14 cases each), followed by the 1980s (9 instances), 2000s (3 instances), 2010s (2 cases), and 1970s (1 case), implying a preponderance of negative trends in capital productivity in the 1970s, followed by positive trends in the 1980s–1990s, and sluggish capital productivity again in the 2000s and 2010s (Weiss 1998; Mohun 2009). As put by Eichengreen (2015) and Fisher (2006), capital goods prices rose in the 1970s (due to the increased energy intensity of investment goods) and have fallen ever since, reaching a minimum in the 2000s. This distorted capital investment incentives (in the corporate sector in particular): firms were pushed to invest less in order to support underlying capital goods prices, resulting in higher capital productivity. We note that this price factor seems to explain well capital productivity movements in the 1980s–1990s, but less so in the 2000s (when the drop in capital prices reached its limit).

Table 5. Average annual growth rates in capital intensity and real wages.

Country	ΔK/L by decade (%)					Real wages growth	
	1964–1969	1970–1979	1980–1989	1990–1999	2000–2014	1974 – 1982	1983 – 1992
Australia	*−0.16*	*1.32*	***1.04***	**1.90**	2.19	1.30	−1.53
Austria	4.90	3.95	2.71	2.35	0.95	2.61	1.98
Belgium	3.51	3.26	**1.78**	**1.85**	0.68	2.90	0.29
Canada	*−0.11*	*0.69*	***0.89***	**0.98**	1.43	1.52	−0.11
Denmark	1.97	2.53	1.29	0.92	1.24	1.70	1.15
France	4.48	3.75	2.04	1.56	1.26	3.11	0.68
Finland	5.03	4.29	2.46	2.26	0.85	1.17	2.19
Germany	4.45	2.96	0.98	0.57	0.33	1.56	2.08
Greece	8.78	6.07	1.50	1.15	1.82		
Iceland	2.64	1.92	**0.41**	**1.73**	2.17		
Ireland	5.05	4.92	4.01	−0.56	2.68	3.77	0.83
Italy	4.57	3.05	2.01	2.00	1.25	2.41	1.83
Japan	4.55	6.62	3.85	2.91	0.54	1.38	1.50
Luxembourg	1.88	1.28	1.31	0.67	0.38		
Netherlands	4.16	3.35	1.50	0.36	1.31	0.94	0.70
New Zealand	*0.06*	*0.53*	*2.04*	0.43	1.15	−0.41	−2.05
Portugal	*2.44*	*4.64*	*4.35*	3.43	2.42		
Spain	4.59	5.58	2.54	2.06	2.73		
Sweden	4.69	2.98	**1.95**	**2.60**	0.98	0.22	0.83
Switzerland	2.98	2.81	0.58	0.50	−0.25	0.67	0.87
UK	2.84	2.15	**1.34**	**1.86**	0.64	1.01	2.76
USA	*0.54*	*0.65*	***0.90***	**1.36**	1.69	−0.49	−0.74

Notes: Values indicated in bold represent an increasing growth rate in capital intensity over the 1990–1999 period relative to the 1980–1989 period. Values shown in italics show acceleration of capital deepening over the 1964–1989 period. Growth in real wages is taken from Western and Healy 1998, Table 1, p.234.

The resurgence of capital productivity in the 1980s–1990s was also due to structural changes in capital and production. As put by Weiss (1998), the relative importance of capital-intensive sectors (heavy industry, manufacturing) has been in decline, while the services sector (which is less capital-intensive and requires lower capital inputs for a given level of labour productivity) grew in importance, thereby lifting economy-wide capital productivity. The counterargument could be that the services sector has lower productivity than manufacturing, and hence a fall in capital intensity coupled with lower labour productivity in services may prevent capital productivity from rising.

Another likely explanation of rising capital productivity is the growing importance of human capital and the relative decline in the importance of physical capital, the latter being used in the calculation of capital productivity (McCloskey 2016, p.175).

Also acknowledged is the possibility of capital intensity moving in tandem with labour productivity (i.e., higher capital intensity of production enhances labour productivity due to more capital goods available for workers, and hence capital productivity is stable), or alternatively the growth in capital stock lagging behind employment growth (i.e., the labour productivity growth rate exceeds the capital intensity growth rate, and capital productivity rises). In the Netherlands and Ireland in the 1990s, capital productivity increased sharply due to a substantial increase in employment and active employment-creation policies, with capital accumulation lagging behind, reducing the rate of capital deepening (Ederveen et al. 2007).

In addition to the aforementioned factors, economic, political, and social institutions should be mentioned as core factors underpinning economic performance and affecting the patterns of economic growth. As put by Hall et al. (2010), the cases where accelerated capital investment does not translate into superior labour productivity growth may in fact be an illustration of the poor quality of institutions, a problem that is hidden behind the terms 'inefficient use of capital' and 'productivity puzzle', as in McKinsey's (1996) study.

With institutions as the intervening variable, it is posited that good institutions allow investment in physical (and human) capital to deliver positive private benefits to individuals and public benefits to society at large (Hall et al. 2010, p.387). The 'good' quality of institutions is frequently associated with the absence of the plunder of wealth, abuse of law, rent-seeking (Olson 1965), and opportunities that encourage such behaviour, e.g., resource abundance and the "resource curse" mentioned by Acemoglu et al. (2001).

The economies considered in this paper are mature market economies that most likely not experience extreme forms of institutional malaise (typical of the developing world) over the study period. In this regard, the differential productivity and capital use patterns are likely to be explained by minor (or more moderate) institutional malfunctioning: the different legal systems and their effect on investment and business performance, with common law systems arguably better suited to the improvement of capital and labour productivity (La Porta et al. 2008); the varying size and scope of government, the public sector, and bureaucracy, and the negative effects of the public sector on productivity (Peden & Bradley 1989; Griliches 1997); and the perverse effects of a high level of transaction costs on the economy (North 1993).

The analysis of these institutional factors might clarify sustained capital productivity growth in Canada, Denmark, and the US (the economies with higher institutional quality), and stagnation of capital productivity in Greece and Italy. To prevent further inconsistencies and puzzles caused by the inclusion of institutional variables, the analysis would necessarily need to conceptualize a country's institutions as a system, with institutions at various levels (institutions at the shop floor level, a broader social contract, governance at the top political level) being interrelated. These systemic issues have been explained in the literature on the varieties of capitalism that looks at differences between developed economies' economic systems (Hall & Soskice 2001), and by heterodox theories of the "social structures of accumulation" (Kotz et al. 1994). The consideration of the role of ideas and culture as informal institutions is also indispensable (Blyth 2002; Greif 2006).

The formal statistical modelling of the above institutional variables (many of which are qualitative in nature) is beyond the scope of this paper; the consideration of these variables, however, presents an opportunity for fruitful research in the future.

4. CONCLUSION

The stability of the capital productivity variable has been part and parcel of the balanced growth theory and one of the stylised facts of balanced growth. This paper examined systematically the statistical properties of the variable in the industrialized economies and also considered capital productivity in relation to other economic growth variables, and more broadly as a variable in economic models.

To this end, a set of tests (trend analysis, autoregressive model and univariate Lagrange Multiplier tests) and qualitative analysis were performed. Overall, diverse capital productivity patterns were found: in half of the economies in the sample, trend stationarity with breaks was identified, while in the other half, capital productivity followed stochastic patterns or reverted to the historical mean.

In a broader theoretical context, the following results emerged. Firstly, some of the 'late-comer' economies showed capital productivity convergence to the US level. Secondly, results seem to confirm some productivity puzzles where slack labour productivity is attributed to low capital productivity, in turn conditioned by microeconomic factors related to inefficient use of capital. Thirdly, in many cases capital productivity movements tracked the business cycle well.

As to the driving forces of capital productivity, the analysis revealed that labour productivity and capital–labour ratio growth rates were unequal and a slowdown in the variables was observed, thereby confirming tests results showing that balanced growth was unlikely. The effect of real wages and the capital–labour substitution played a minor role in explaining capital productivity movements. By contrast, the decline in the price of capital goods, changing economic structure, and composition of capital stock could be an important factor behind the capital productivity resurgence of the 1980s–1990s.

REFERENCES

Acemoglu, D., Johnson, S. & Robinson, J. A. (2001). The colonial origins of comparative development: An empirical investigation. *American Economic Review*, 91, pp. 1369–1401.

Acemoglu, D. (2002). Technical change, inequality, and the labour market. *Journal of Economic Literature*, XL, pp. 7–72.

Bleaney, M. & Greenaway, D. (1993). Long-run trends in the relative price of primary commodities and in the terms of trade of developing countries. *Oxford Economic Papers*, 45 (3), pp. 349–363.

Blyth, M. (2002). *Great transformations: Economic ideas and institutional change in the twentieth century*. Cambridge: Cambridge University Press.

Caballero, R. & Hammour, M. (1996). On the timing and efficiency of creative destruction. *Quarterly Journal of Economics*, 2, pp. 805–852.

Canjels, E. & Watson, M. W. (1997). Estimating deterministic trends in the presence of serially correlated errors. *Review of Economics and Statistics*, 79 (2), pp. 184–200.

Caselli, F. & Wilson, D. (2004). Importing technology. *Journal of Monetary Economics*, 51 (1), pp. 1–32.

D'Adda, C. & Scorcu, A. (2003). On the time stability of the output-capital ratio. *Economic Modelling*, 20, pp. 1175-1189.

Denison, E. F. (1967). *Why growth rates differ*. Washington: The Brookings Institution.

Dunhaupt, P. (2012) Financialization and the rentier income share – evidence from the USA and Germany. *International Review of Applied Economics*, 26 (4), pp. 466–487.

Ederveen, S., Van Der Horst, A. & Tang, P. (2007). Is the European economy a patient and the union its doctor? On jobs and growth in Europe. *In* Heshmati, A., Tausch, A. (eds.). *Roadmap to Bangalore? Globalisation, the EU's Lisbon Process and the structures of global inequality*. New York: Nova Science Publishers.

Eichengreen, B. (2015) Secular stagnation: The long view. *American Economic Review: Papers and Proceedings*, 105 (5), pp. 66–70.

Evans, P. (2000). *US stylized facts and their implications for growth theory*. (Ohio State University, Department of Economics Discussion Paper).

Fisher, J. D. (2006). The dynamic effects of neutral and investment-specific technology shocks. *Journal of Political Economy*, 114 (3), pp. 413–451.

Foley, D. & Michl, T. (1999). *Growth and distribution*. Cambridge: Harvard University Press.

Gordon, R. J. (2012). *Is US economic growth over? Faltering innovation confronts the six headwinds*. (NBER Working Papers No. 18315), Cambridge, MA: National Bureau of Economic Research.

Greif, A. (2006). *Institutions and the path to modern economy: Lessons from medieval trade*. Cambridge: Cambridge University Press.

Griliches, Z. (1997). Education, human capital and growth: A personal perspective. *Journal of Labor Economics*, 15, pp. S330–344.

Hall, J. C., Sobel, R. S. & Crowley, G. R. (2010). Institutions, capital and growth. *Southern Economic Journal*, 77 (2), pp. 385–405.

Hall, P. A. & Soskice, D. (2001). *Varieties of capitalism: The institutional foundations of comparative advantage*. Oxford: Oxford University Press.

Harvey, D. I., Leybourne, S. J. & Newbold, P. (2003). How great are the great ratios? *Applied Economics*, 35 (2), pp. 163–177.

Hofman, A. (2000). *The economic development of Latin America in the twentieth century*. Cheltenham: Edward Elgar.

Jones, C. I. & Romer, P. M. (2009). *The new Kaldor facts: Ideas, institutions, population, and human capital*. (NBER Working Papers No. 15094), Cambridge, MA: National Bureau of Economic Research.

Jones, L. E. & Manuelli, R. E. (1990). A convex model of equilibrium growth: Theory and policy implications. *Journal of Political Economy*, 98, pp. 1008–1038.

Kaldor, N. (1961). Capital accumulation and economic growth. *In* Lutz, F. A., Hague, D. C. *The Theory of Capital*. New York: St. Martin's Press.

Kaldor, N. & Mirrlees, J. A. (1962). A new model of economic growth. *Review of Economic Studies*, 29 (3), pp. 174–192.

Karabarbounis, L. & Neiman, B. (2014). *Capital depreciation and labor shares around the world: Measurement and implications*. (NBER Working Papers No. 20606), Cambridge, MA: National Bureau of Economic Research.

King, R.G. & Levine, R. (1994). *Capital fundamentalism, economic development, and economic growth*. (World Bank Policy Research Working Paper No. 1285).

King, R. G., Plosser, C. I., Stock, J. H. & Watson, M. W. (1991). Stochastic trends and economic fluctuations. *American Economic Review*, 81 (4), pp. 819–840.

Klein, L. & Kosobud, R. (1961). Some econometrics of growth: Great ratios in economics. *Quarterly Journal of Economics*, 75, pp. 173–198.

Kotz, D., McDonough, T. & Reich, M. (1994). *Social structures of accumulation: The political economy of growth and crisis*. Cambridge: Cambridge University Press.

Kunst, R. & Neusser, K. (1990). Co-integration in a macroeconomic system. *Journal of Applied Econometrics*, 5 (4), pp. 351-365.

La Porta, R., Lopez-de-Silanes, F. & Shleifer, A. (2008). The economic consequences of legal origins. *Journal of Economic Literature*, 46, pp. 285–332.

Lawrence, R. Z. (2015). *Recent declines in labor's share in US income: A preliminary neoclassical account*. (Peterson Institute for International Economics, Working Paper 15-10).

Lee, J. & Strazicich M. (2003). Minimum Lagrange multiplier unit root test with two structural breaks. *The Review of Economics and Statistics*, 85 (4), 1082–1089.

Lee, J. & Strazicich M. (2004). *Minimum Lagrange multiplier unit root test with one structural break*. (Appalachian State University, Department of Economics, Unpublished Manuscript).

Li, H. & Daly, V. (2009). Testing the balanced growth hypothesis: Evidence from China. *Empirical Economics*, 37, pp. 185–200.

Madsen, J., Mishra, V. & Smyth, R. (2012). Is the output-capital ratio constant in the very long-run? *Manchester School*, 80 (2), pp. 210–236.

McKinsey Global Institute. (1996). *Capital productivity*. Washington: DC.

McCloskey, D. (2016). Measured, unmeasured, mismeasured, and unjustified pessimism: A review essay of Thomas Piketty's capitalism in the twenty first century. *Economic Policy*, 4, pp. 153–195.

Mills, T. (2001). Great ratios and common cycles: Do they exist for the UK? *Bulletin of Economic Research*, 53 (1), pp.35–51.

Mills, T. (2009). Revisiting Klein & Kosobud's great ratios. *Quantitative and Qualitative Analysis in Social Sciences*, 3 (3), pp. 12–42.

Mohun, S. (2009). Aggregate capital productivity in the US economy, 1964–2001. *Cambridge Journal of Economics*, 33, pp. 1023–1046.

Nelson, C. R. & Kang, H. (1984). Pitfalls in the use of time as an explanatory variable in regression. *Journal of Business and Economics Statistics*, 2 (1), pp. 73–82.

Nordhaus, W. (2002). Productivity growth and the new economy. *Brookings Papers on Economic Activity*, 2, pp. 211–244.

North, D. C. (1993). Institutions, transaction costs and productivity in the long run. *Economic History*, No. 9309004. Retrieve December 13, 2017, from https://dlc.dlib.indiana.edu/dlc/handle/10535/4567

Olson, M. L. (1965). *The logic of collective action: Public goods and the theory of groups*. Cambridge: Harvard University Press.

Peden, E. A. & Bradley, M. D. (1989). Government size, productivity, and economic growth: The post-war experience. *Public Choice*, 61 (3), pp. 229–245.

Perez, J. E. & Garcia, J. M. (2014). New estimates of capital stock for European regions. *Revista de Economia Aplicada*, 66 (22), pp. 113–137.

Polyzos, S. & Arabatzis, G. (2006). Labour productivity of the agricultural sector in Greece: Determinant factors and interregional differences analysis. *Mediterranean Journal of Economics, Agriculture and Environment*, 1, pp. 58–65.

Romer, P. M. (1989). Capital accumulation in the theory of long-run growth. *In* Barro, R. J. (ed) *Modern business cycle theory*. Oxford: Basil Blackwell, pp. 51–127.

Sen, A. (2003). On unit-root tests when the alternative is a trend-break stationary process. *Journal of Business and Economics Statistics*, 21, pp. 174–184.

Steger, T. M. (2001). *Stylised facts of economic growth in developing countries*. (Ernst-Moritz-Arndt University of Greifswald Discussion Paper 08/2001).

Torrini, R. (2005). *Profit share and returns on capital stock in Italy: The role of privatisations behind the rise of the 1990s*. (Centre for Economic Performance Discussion Paper No. 671).

Weiss, T. (1998). Has the decline in the productivity of capital been halted? *Intereconomics*, 33(2), pp. 86–92.

Western, B. & Healy, K. (1998). Explaining OECD wage slowdown. Recession or labour decline? *European Sociological Review*, 15 (3), pp. 233–249.

Received: April 26, 2017
Accepted: December 18, 2017