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Capital in Spain, 1850–2019

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Abstract

The rising trend in the capital-output ratio and the productivity slowdown have put capital back in the economist's agenda. This paper contributes to the debate by providing new estimates of net capital stock and services for Spain over the last 170 years. The net capital (wealth) stock-GDP ratio rose over time and doubled in the last half a century. Capital services grew fast over the long run accelerating in the 1920s and from the mid-1950s to 2007. Until 1975, its acceleration was helped by an increase in the "quality" of capital. Capital deepening proceeded steadily, accelerating during 1955–1985 and slowing down thereafter for expanding sectors attracted less investment-specific technological progress. Although capital consumption rose over time, the rate of depreciation fell from 1970 to 2007 as new capital goods' relative prices declined due to embodied technological change.

Keywords Capital stock and services · Capital deepening · Capital-output ratio · Spain

JEL Classification D24 · E01 · E22 · N33 · N34

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1 Introduction

Capital is back in the economist's agenda. Thomas Piketty's (2014) claim of rising capital-output ratio over time has triggered an interest in historical research. The debate on the productivity slowdown has also stimulated the search for its historical roots and, in particular, the role played by capital accumulation.

Using "state-of-the-art" methodology, the new historical series offer consistent and integrated estimates[1] of net capital (wealth) stock and capital services that provide a sound basis to address welfare and growth issues and facilitate, for example, testing current views about increasing capital-output ratios or investigating the contribution of capital deepening to labour productivity growth.

The new set of estimates offer the first attempt to provide historical series using the OECD methodology and provide the longest homogeneous historical series of capital stock and services available internationally. This represents an improvement on existing capital estimates for Spain, in particular the historical series by Prados de la Escosura and Rosés (2010) for 1850–2000, and those for later periods (Ivie, Penn World Tables 9.1, and Conference Board), not only by considering a longer time span but, more important, by following closely OECD's Manual (2009) which provides the latest consensus on capital stock and services estimates. Furthermore, unlike the capital estimates for recent decades, the new estimates employ GFCF series obtained through splicing national accounts using the interpolation, rather than backward projection method. This procedure avoids over-exaggerating investment levels and, hence, capital stock.

But why studying Spain? The case of Spain is that of a middle-income country (at least, until 1970, according to the World Bank's definition) that succeeded in joining the upper-income countries. As most historical research on capital has focused on the pioneers of the first and second industrial revolution, providing long-run estimates of capital stock and services for a country that carried out a transition from a poor, agricultural economy to a post-industrial advanced one represents an addition to the research on welfare and growth.

The main findings can be summarised as follows.

1. Capital input (namely, the flow of capital services into production) grew at 3.6% annual rate during the last 170 years, accelerating in the 1920s and from the mid-1950s to the onset of the Global Financial Crisis (2008). Until 1975, the acceleration of capital input growth was helped by an increase in the "quality" of capital, that is, a compositional shift towards more productive assets.
2. Capital deepening (that is, capital services per hour worked) grew steadily up to 1930, accelerating between the mid-1950s and mid-1980s and slowing down thereafter, as expanding economic sectors attracted less investment-specific technological progress.

[1] By consistent and integrated estimates, Oulton and Wallis (2016) mean a common dataset and a common set of assumptions in the construction of long-run estimates of capital stock and capital services.

3. The net capital (wealth) stock-GDP ratio, at current prices, rose over time, with a fourfold increase between 1886 and 2013, contradicting one of Kaldor's (1957) stylised facts, and doubled during the last half a century, in line with Piketty and Zucman (2014) for western Europe's wealth-income ratio.
4. The consumption of fixed capital (CFC) in terms of GDP increased over time, shadowing the capital-output ratio but, as a proportion of the net capital stock (that is, the rate of depreciation), only rose up to the 1960s, falling from 1970 to 2007 as the relative prices of new capital goods declined due to embodied technological change.

The paper is organised as follows: In Sect. 1, the concepts, method, and sources used are discussed. Section 2 presents new estimates of net capital stock and productive capital stock derived with the perpetual inventory method, tests its sensitivity, and compares the results to available series of capital stock. In Sect. 3, a volume index of capital services, in which the user cost of capital is derived with an ex-ante exogenous rate of return, is provided. Then, the volume index of capital services (VICS) is compared to the productive capital stock, as a growing gap between them reveals the shift from low return and long life assets to higher return but shorter life assets, that is, an increase in the "quality" of capital. Next, trends in VICS and capital deepening are offered and weighed against available estimates. Lastly, Sect. 4 offers the evolution of the capital-output ratio, as well as the consumption of fixed capital (% of GDP) and the depreciation rate (% net capital stock).

2 Capital stock: concept, method, and sources

The publication of the OECD Manual in 2009 (OECD 2009) provided a unified methodology to measuring capital stock and services that builds bridges between previous OECD methodology and the one pioneered by Jorgenson (1963) and further developed by Jorgenson (1989, 1990) and Hulten (1990).[2] This paper follows the OECD approach and distinguishes between net capital stock, also labelled wealth, which measures capital assets at their market price, and productive stock, an intermediate stage to derive a volume index of capital services (capital input), that is, the flow of capital services into production.

In the construction of net capital stock estimates, the perpetual inventory method (PIM) is used, cumulating flows of investment, corrected for retirement and depreciation, for each asset. Implementing the PIM requires, by type of asset, (a) investment volumes and deflators; (b) average service lives; (c) depreciation rates; and (d) an initial benchmark level of capital stock.

[2] OECD (1993, 2001). For developments and applications of the Jorgenson approach, cf. Jorgenson and Griliches (1967), Hall and Jorgenson (1967), Christensenet al. (1980), Jorgenson et al. (1987), Elías (1978), and Young (1995).

(a) Four different types of asset have been distinguished: dwellings, other construction, transport equipment, and machinery and equipment. Biological resources and intellectual property products have been added to machinery and equipment assets because information on them is only available in national accounts beginning in 1980.[3] No distinction has been made between ICT and non-ICT assets due to the dearth of data in national accounts and the aim of providing homogeneous long-run series of capital stock.[4]

Gross fixed capital formation (GFCF) volume series for each type of asset are obtained by deflating current values and expressed in 2010 Euro. GFCF current value and deflator series come from Prados de la Escosura (2017, updated to 2019). GFCF series are derived from spliced national accounts for 1958–2019 (see Online Appendix A and Prados de la Escosura 2016), and through the commodity flow method (CFM), that is, production and trade data to proxy investment by asset type, for 1850–1958.[5]

It is worth noting that the GFCF deflator series have been smoothed using a Hodrick–Prescott filter in order to avoid negative values for the unit user costs. The same smoothing procedure has been applied to the general price index, which in our case, is the GDP deflator.[6]

(b) The choice of average services lives, that is, the length of time that assets are retained in the capital stock, presents a challenge. Although choosing different average lives for different periods represents the usual historical practice (Feinstein 1988; Prados de la Escosura and Rosés 2010), a single set of average service lives is used here in order to facilitate comparisons with other estimates, as services lives for each asset type are kept constant in most country studies. Moreover, there is no concluding evidence that service lives fall over the long run, as offsetting tendencies are at work.[7] Thus, dwellings and other construction are assigned average service lives of 60 and 40 years, respectively, while

[3] Conference Board (2020) follows the same practice. As a sensitivity test, we have replicated the estimates of net capital stock using six, rather than four, types of assets (that is, considering, biological resources and intellectual property products separately) from 1980 onwards. No trend discrepancies are found between the two set of estimates even though the 6 asset estimates exhibit a slightly lower level (see Figures A5 and A10 in Online Appendix C).

[4] See Pérez et al. (2019) and Conference Board (2020) for estimates for Spain which distinguish between ICT and non-ICT of assets.

[5] The CFM approach is widely used to reconstruct GFCF series in present-day developing countries (Conference Board, 2017). Also, in the Penn World Tables 9.1, in the absence of direct estimates, investment in an asset is assumed to vary with the economy-wide supply (production + imports – exports) (Feenstra et al. 2015, updated).

[6] Alternative estimates using the private consumption deflator provide similar results.

[7] On the one hand, service lives tend to fall as "product cycles" become shorter and capital goods face higher rates of obsolescence but, on the other, some assets become more durable (OECD 2009). Maddison (1995) used fixed average lives for his historical estimates.

transport and machinery equipment are attributed 15 years each.[8] Nonetheless, compositional changes in the capital stock imply that the average service life of total capital varies over time and, in so far as a shift towards more productive assets takes place, it declines.

(c) As regards depreciation rates, a declining balance is chosen, that is, a geometric rate, $\delta = R/T$, where T is the asset's average service life and R is the selected parameter. Geometric depreciation rates differ across assets but are constant over time. Following the US Bureau of Economic Analysis (Fraumeni 1997), Hulten and Wykoff's (1981) directly computed depreciation rates and implicit R values, 1.65 for transport equipment and machinery and 0.91 for structures, have been accepted. The resulting depreciation rates are, thus, 1.52%, 2.28%, 11.0%, and 11.0% for dwellings, other constructions, transport equipment, and machinery and equipment (plus intellectual property and biological resources since 1980), respectively.[9]

(d) In the absence of an initial stock of capital, two main approaches have been used to derive it. One assumes, after Harberger (1978), that the economy is at its steady state and derives it for each asset type as,

$$W^{t0} = I^{t0}/(\delta + \theta) \tag{1}$$

where I is real investment; δ, the rate of depreciation; and θ, the growth rate of investment in early years.

An alternative to the steady-state assumption approach is to estimate a functional relationship between real GFCF and GDP and, supposing that such a relationship is stable over time, to derive volume GFCF series for the previous period on the basis of available GDP series. Here, the relationship between each asset type and GDP has been estimated for 1850–1920 and the regression coefficients applied to

[8] These service lives are in line with those used by Pérez et al. (2019). Alternative estimates have been computed with another set of longer average service lives: 70 years (dwellings), 50 years (other construction), and 20 years (transport equipment and machinery). Although longer service lives increase the gross stock and reduce depreciation, and hence, deliver a larger net capital stock, the comparison between the two set of estimates reveals minor differences over time. A third set of estimates has been derived by combining the longer average lives set for 1850-1958 and the shorter average lives set for 1959–2019. Interestingly, the result is lower growth of aggregate capital stock than when the shorter lives set is employed for the entire time span. This finding may be attributed to the fact that the set of average assets lives for the pre-1958 period assigns larger weight to slower growing assets and, consequently, result in lower net capital stock. (See the resulting alternative Net Capital Stock/GDP ratios in Figure A11 in Online Appendix C).

[9] Hulten and Wykoff's (1981) implicit R values were also used in Prados de la Escosura and Rosés (2010). Alternative estimates have been obtained using a double declining balance ($T = 2$) and the same average service lives, with the resulting depreciation rates of 3.3%, 5.0%, 13.3%, and 13.3% for each of the four asset types. Figure A12 in Online Appendix C compares the net capital stock derived alternatively with the double declining balance and Hulten and Wykoff's R values, revealing that the net capital stock derived with the double declining balance is lower as the depreciation rates are larger for the same average lives of assets, and so is the consumption of fixed capital (Figure A13).

the available real GDP estimates to produce GFCF volume series for each type of asset between 1780 and 1850.[10]

The initial (1850) level for each capital asset type has been derived with the PIM and the average lives and depreciation rates accepted for the post-1850 period with each approach. Figure 1 compares the results of the two approaches. It can be observed that their difference disappears by 1880. As the alternative option to the steady-state approach seems to be less stringent, it has been preferred here.

Another important issue is the sensitivity of the net capital stock series to the choice of initial level. Thus, the estimates have been replicated adopting as initial capital both half and twice the level obtained in the favoured option. Figure 2 shows that differences diminish as time goes by and fade away by the 1920s. Thus, the estimates seem to be robust to alternative ways of computing the initial level for, at least, the last 100 years.

Next, the net capital stock has been computed for 1850–2019 using the stock-flow relationship (PIM). If we define the net stock at the beginning ($^{\mathrm{B}}$) of the first year, 1850, as $W^{1850,\mathrm{B}}$, end-year ($^{\mathrm{E}}$) net stocks for each asset in all consecutive years are,

$$W^{\mathrm{tE}} = W^{\mathrm{tB}} + I^t - \delta(I^t/2 + W^{\mathrm{tB}}) \tag{2}$$

where I^t is real yearly gross fixed capital formation and δ, the rate of depreciation. All stocks are valued at average prices of 2010, and by summing them the net capital stock in 2010 Euro is obtained.

The value of the consumption of fixed capital (depreciation) for each asset at 2010 prices, D^t/P^t_0, results from applying the rate of depreciation to the net stock at the beginning of the period plus half the current period's investment,

$$D^t/P^t_0 = \delta[I^t/2 + W^{\mathrm{tB}}]. \tag{3}$$

The net (wealth) capital stock at current prices, $P^t_0W^t$, is obtained by reflating the average of the net capital stock at the beginning and the end of each year with the average yearly price index for each asset, P^t_0 and, then, summing them.

[10] The OLS regression results are (with standard error in parentheses),

$$\ln(\text{Dwellings}) = -5.75 + 1.23\ \ln(\text{GDP})$$
$$(0.995)\ (0.095) \quad \text{Adj. } R^2 = 0.70$$

$$\ln(\text{Other Construction}) = -11.23 + 1.70\ln(\text{GDP})$$
$$(1.271)\ (0.121) \quad \text{Adj. } R^2 = 0.74$$

$$\ln(\text{Machinery}) = -29.07 + 3.19\ \ln(\text{GDP})$$
$$(1.062)\ (0.101) \quad \text{Adj. } R^2 = 0.93$$

$$\ln(\text{Transport Equipment}) = -17.18 + 2.07\ \ln(\text{GDP})$$
$$(2.755)\ (0.263) \quad \text{Adj. } R^2 = 0.47$$

$$P_0^{\mathrm{t}} W^{\mathrm{t}} = P_0^{\mathrm{t}} (W^{\mathrm{tB}} + W^{\mathrm{tE}})/2 \tag{4}$$

Similarly, the current value of the consumption of fixed capital, D^t, has been derived by revaluing its constant price value with the deflator for each asset, P_0^t.

$$D^t = \delta [I^t/2 + W^{\mathrm{tB}}]\, P_0^t \tag{5}$$

A last step is to consider the destruction of capital stock resulting from the Spanish Civil War (1936–1939). Although capital assets in transport equipment and dwellings derived through PIM appear to capture war damage, it does not seem to be the case for other construction and machinery, as destruction estimates in the historical literature appear to be larger than those resulting from the PIM exercise. Hence, the historical estimates of asset destruction have been accepted and distributed at constant yearly rates over 1936–1939.[11] The resulting figures imply a 4.9% contraction of the total net capital stock between 1935 and 1939 which, by asset type, represents a fall of 2.0% (dwellings), 6.8% (other construction), 13.7% (machinery and equipment), and 30.4% (transport equipment), much lower than Maddison's (1995: 138) guesstimates for World War II destruction in belligerent European countries, except the UK.

How do the new estimates compare to the established Ivie's figures (Pérez et al. 2019) and to the recent computations of the net stock of fixed capital by the Spanish official statistical office, Instituto Nacional de Estadística (INE)? Figure 3a presents the logarithmic deviations between the new estimates and these two sets at current prices and is expressed in percentages.[12] The new estimates match rather closely INE's figures, with lower levels in the 2000s and higher ones in the 2010s, and an average absolute difference of 8.2% (standard deviation 3.8).

However, with Ivie's figures the average (absolute) difference is almost double, 15.6% (s.d. 6.0) during a similar time span, 2000–2016, and also for the entire period covered by Ivie's estimates, 1964–2016, 15.5% (s.d. 10.5). Notice also that the new estimates are smaller than Ivie's up to 1990 and larger thereafter. Furthermore, Ivie figures are lower than INE's and their average absolute (log) difference is 19.5% (s.d. 3.9).

Why does such a discrepancy exist between the new historical estimates and Ivie's? Two differential features may explain it. One is that although Ivie also uses geometric depreciation, it is double declining balance (that is, $R = 2$). While following Fraumeni (1997), the new estimates adopt Hulten and Wykoff's (1981) empirically obtained R. Another difference is that the GFCF series for the period 1965–1995 employed by Ivie have been spliced using the retropolation method, not through interpolation as in our case (see Online Appendix A and Prados de la

[11] The yearly rates assumed are −2.75% for other construction and −5.8% for machinery, following Prados de la Escosura and Rosés (2010). Although the destruction, as a share of net capital stock, is lower in the new estimates, 5% versus 7%, a fact that derives from the use of different asset average service lives and from methodological differences in the computation of the capital stock.

[12] The formula used is $100 * (\text{natural log } X - \text{natural log } Y)$, being X the new estimates and Y, Ivie and INE figures, alternatively.

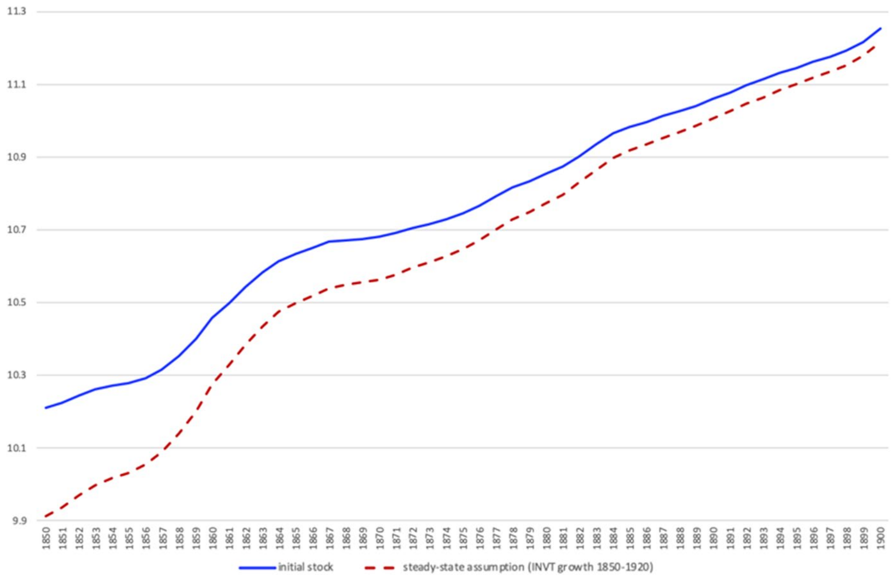


Fig. 1 Initial net capital stock: alternatives estimates, 1850–1900 (2010 Million Euro) (natural logs)

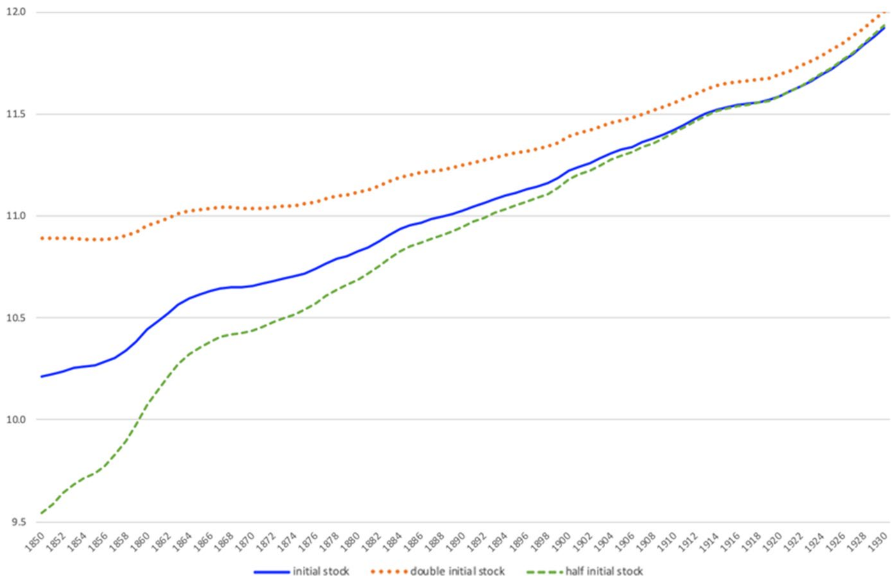
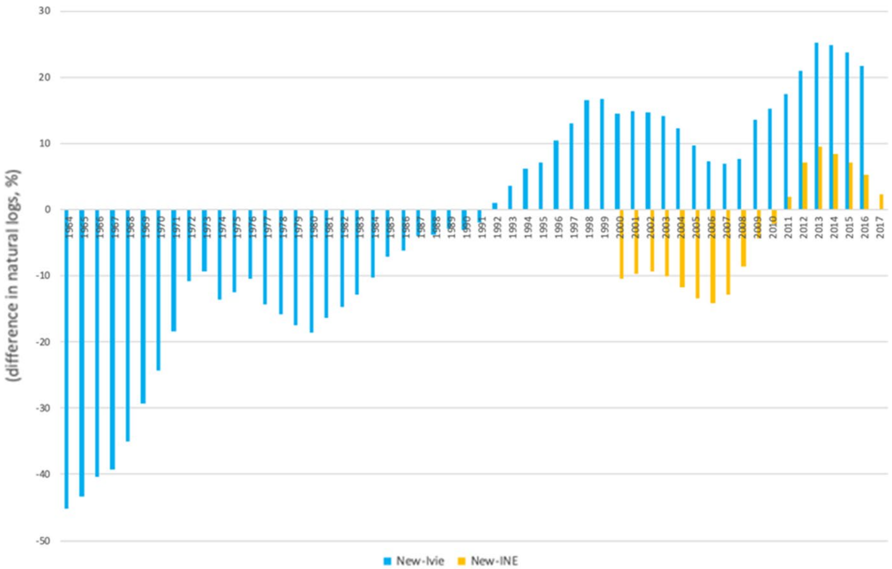
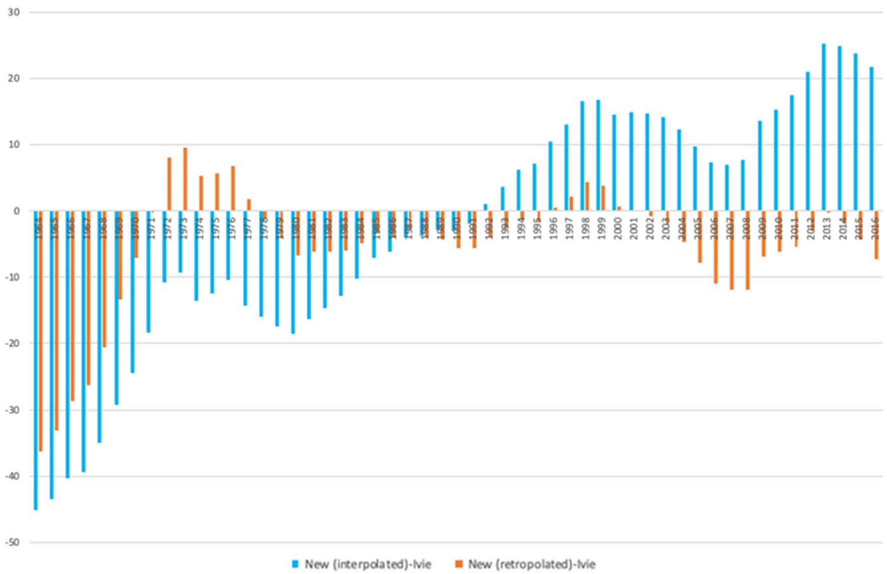


Fig. 2 Initial net capital stock: sensitivity to alternative options, 1850–1930 (2010 Million Euro) (natural logs)



(a)



(b)

Fig. 3 **a** Net capital stock*: differences with INE and Ivie estimates, 1964–2017 (natural logs %) (current prices) * computed with interpolated GFCF and declining balance. **b** Net capital stock computed with interpolated GFCF and declining balance and with retropolated GFCF and double declining balance: differences with Ivie Estimates, 1964–2016 (natural logs %) (current prices)

Table 1 Wealth survey and perpetual inventory method estimates in 1965. *Sources*: Universidad Comercial de Deusto (1968–1972), reproduced in Myro (1983) Table 2.3; PIM estimates, see text

(000 million Peseta)	(I) Wealth survey	(II) PIM estimate	(III) [(II)/(I)]
Dwellings	1166	1006	0.86
Other structures	1236	827	0.67
Machinery and equipment	633	352	0.56
Transport equipment	194	146	0.75
Total capital stock	3229	2330	0.72

Escosura 2016). In Fig. 3b, we have replicated the comparison but, now, the new net capital stock estimates are computed with retropolated GFCF series and double declining balance geometric depreciation. The resulting gap between the two series narrows down remarkably with the average (absolute) difference shrinking to 7.1% (s.d. 8.0). Therefore, methodological differences explain about half of the discrepancy between the two set of estimates.

Another test results from comparing the estimates obtained with the PIM and the capital stock derived from a wealth survey for 1965 (Universidad Comercial de Deusto 1968–1972) are often used to initialise capital stock series.[13] It can be observed that the wealth survey exaggerates the size of the capital stock (Table 1).[14]

Lastly, productive stock, K^t, has been obtained by adding investment in the latest period to the net capital (wealth) stock,

$$K^t = I^t/2 + W^{tB} \tag{6}$$

It is worth noting that while to derive the net capital stock the cumulating flow of investment is corrected for retirement and depreciation; in the case of productive capital only efficiency losses are subtracted. In practical terms, their difference results from the fact that the net capital is valued at the end of the year and the productive capital represents the average value in the year. Moreover, productive stocks for each type of asset are computed at constant prices only and used to derive capital service flows.

It is worth comparing our results for the productive capital stock (PKS) to those already available. Figure 4a presents the new estimates along those provided for Spain by the Penn World Tables 9.1 (PWT 9.1) (Feenstra et al. 2015, updated) and Ivie (Pérez et al. 2019) since 1950 and 1964, respectively. Although the three series present similar trends, the new estimates exhibit a steeper trend, that is, grow at a faster pace. The explanation of the differential partly lies in the use of retropolated GFCF series before 1995 and the double declining balance geometric depreciation, particularly in the case of the PWT9.1 series, since the difference narrows down sharply when the new PKS estimates are replicated with retropolated GFCF series

13 For example, in Myro (1983) and Mas et al. (2000).

14 Cf. Young (1995: 650-1) for similar results in the cases of South Korea and Taiwan.

and double declining balance (Fig. 4b). In the case of Ivie's series, however, other elements also contribute to explain it (i.e. its initial level derived from the 1965 wealth survey and a more detailed breakdown by asset type).

3 Capital services

We can now proceed to compute the capital input, that is, the flow of capital services into production. To do so, a volume index of capital services is derived as a weighted average of productive stock indices by type of asset in which each asset's share in total user cost of capital (that is, the current value of capital services) are the weights. This procedure implies that, for each asset, its flow of capital services is proportional to its productive stock, although the rate of variation of capital services differs across assets (Jorgenson and Griliches 1967).

Thus, we need to compute the unit user cost of capital for each asset, which represents the marginal return an asset generates during one period of production (OECD 2009). Once obtained, the unit use cost, F_0^t, is multiplied by the asset's productive capital stock, $K^{k,t}$, to derive the value of its capital services, $U^{k,t}$. Summing the values of all assets, we get the total value of capital services, U^t.

Different rates of return have been used to compute the unit user cost in empirical studies. The *ex-post* endogenous rate of return is the realised rate of return and, in principle, preferable. For example, The Penn World Tables 9.1 (Feenstra et al. 2015, updated) and Conference Board (2020) use it. An *ex-post endogenous* rate of return equals the value of capital services to capital compensation in national income (that is, the gross operating surplus plus the capital share in gross mixed income), which is consistent with an economy of perfect competition and constant returns to scale (OECD 2009).[15] The use of an *ex-post endogenous* rate of return requires, however, a complete coverage of all assets and a distinction between market and government

[15] Thus, the endogenous, ex-post rate of return for every period is computed by equating capital compensation G^t plus capital-related taxes on production $T_K{}^t$ to the total user costs of capital U^t

$$G^t + T_K^t = U^t = \sum_{k=1}^{N} P_0^{k,tB}(1+\rho^t)\,[r^{t*} + \delta^k(1+i^{k,t*}) - i^{k;t*}]K^{k,t} \tag{7}$$

From which the ex-post endogenous real rate of return can be derived,

$$r^{t*} = \left\{ (G^t + T_K^t)\,(1+\rho^t) - \sum_{k=1}^{N} P_0^{k,tB}[\delta_0^k(1+i^{k,t*}) - i^{k;t*}]K^{k,t} \right\} \Big/ \left\{ \sum_{k=1}^{N} P_0^{k,tB} K^{k,t} \right\} \tag{8}$$

Then, the ex-post user cost per unit of capital services for a particular type of asset is obtained as

$$F_0^t = P_0^{k,tB}(1+\rho^t)\,[r^{t*} + \delta_0^k(1+i^{k,t*}) - i^{k,t*}] \tag{9}$$

where G^t Non-labour income consists of gross operating surplus and the part of mixed income that can be attributed to capital; T_K^ttaxes on production; $P_0^{k,tB}$ is the purchase price of a new asset at the beginning (^{B}) of year t; ρ^t is the rate of change of the consumer price index at the beginning of period t; r^{t^*} is the real rate of return that applies at the beginning of period t; δ^k is the rate of depreciation for a new asset k; i^{k,t^*} is the ex-post, real rate of asset price inflation for asset k during period t; $K^{k,t}$ is the productive capital stock of asset k during period t.

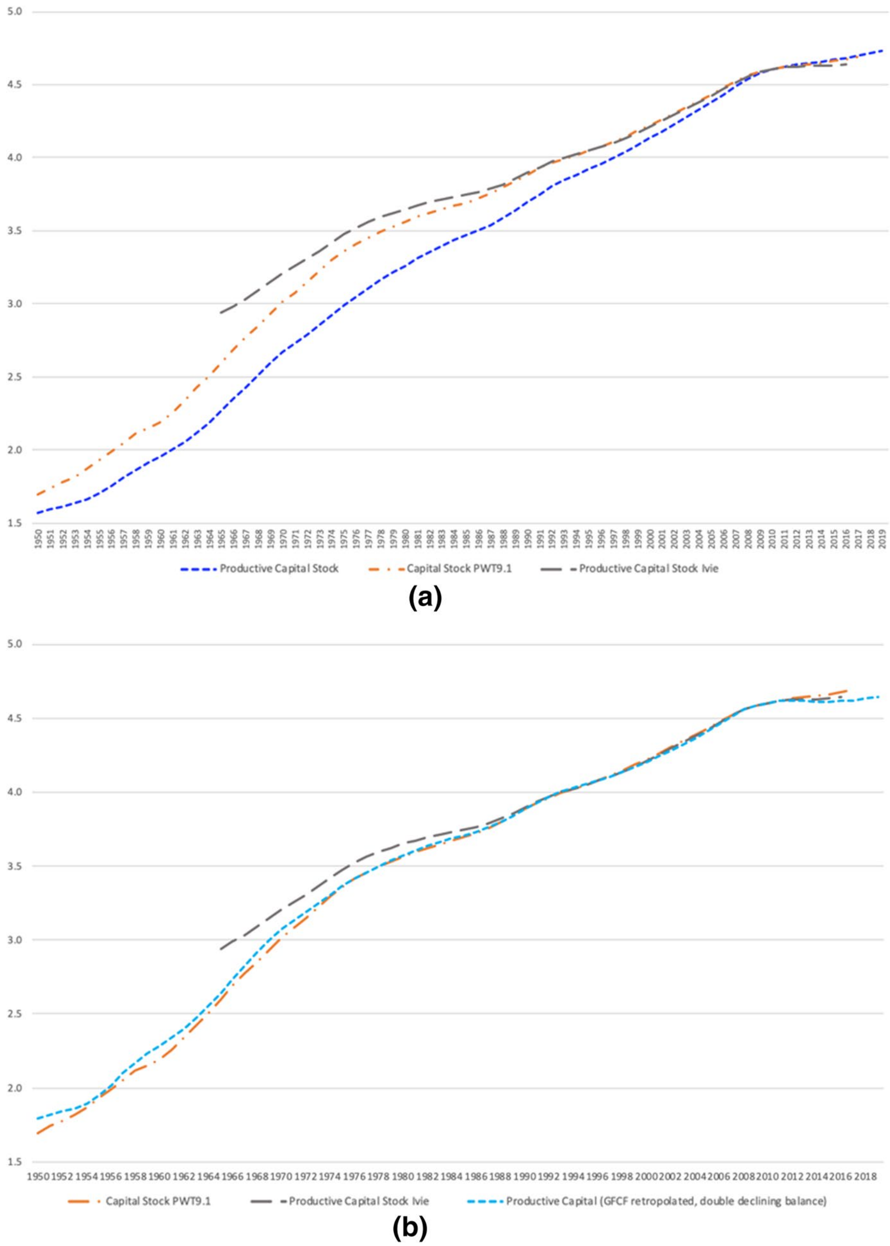


Fig. 4 **a** Productive capital stock, 1950–2019: comparison with PWT9.1 and Ivie estimates (2010 = 100) (natural logs). **b** Productive capital stock derived with GFCF retropolated series and double declining balance geometric depreciation, 1950–2019. Comparison with PWT9.1 and Ivie estimates (2010 = 100) (natural logs)

sectors. Otherwise, the rate of return will be biased.[16] Unfortunately, our data do not meet such stringent requirements.

The alternative is, then, to compute an ex-ante exogenous rate of return, that is, the one expected by the investor.[17] In an ex-ante approach, the rate of return for investment on a given asset should not be higher than in an alternative investment of comparable risk. The OECD Manual (OECD 2009) recommends working with real rates of return and real changes in asset prices as they are independent from inflation and less volatile and, in particular, suggests a 4% real rate of return, which is close to Spain's historical rate, and adopted in Ivie's estimates (Pérez et al. 2019).[18] In fact, assuming a fixed real rate of return on investment matches one of Kaldor's (1957) stylised facts, namely, the rate of return on investment is roughly constant over long periods of time. It can be objected, though, that when an ex-ante exogenous rate of return is chosen the resulting value of capital services may not match capital compensation in national income.

The ex-ante unit user cost, or capital service price, F_0^t, can be defined as

$$F_0^t = P_0^{k,\mathrm{tB}}(1 + \rho_{(\mathrm{tB})}) \left[r_a^* + \delta_0(1 + i^*_{(\mathrm{tB})}) - i^*_{(\mathrm{tB})} \right] \tag{10}$$

The ex-ante user cost of an asset,

$$U^{k,t} = F_0^t K^{k,t} \tag{11}$$

And the total user cost of capital,

$$U^t = \Sigma_{k=1} U^{k,t} \tag{12}$$

where $P_0^{k,\mathrm{tB}}$ is the purchase price of a new asset at the beginning ($^{\mathrm{B}}$) of year t, $\rho_{(t\mathrm{B})}$ the rate of change of the price index (GDP deflator) at the beginning ($^{\mathrm{B}}$) of year t, r_a^* the real rate of return (the nominal rate corrected for inflation), 4%, in this case, $i^*_{(\mathrm{tB})}$ the real anticipated change in asset prices at beginning ($^{\mathrm{B}}$) of year t, δ_0 the rate of depreciation of a new asset, $K^{k,t}$ the productive capital stock of asset k during period t.

Furthermore, a simplified ex-ante exogenous rate of return can be derived by setting the anticipated real holding gains term i^{*t} equal to zero. Although this approach has the advantage that it does not require us to estimate anticipated real holding gains, it is only a reasonable alternative if asset price changes do not deviate significantly from changes in the GDP deflator. The resulting user cost, then, becomes,

[16] Upwards biased if coverage is incomplete, since capital income will be compared to an under-valued capital stock and downwards biased if no clear distinction is made between market and government sectors since, probably, only market capital income will be compared to the value of the total capital stock.

[17] Nonetheless, capital services have also been derived using an ex-post endogenous rate of return in order to provide a contrast to the ex-ante exogenous estimates. See Online Appendix C.

[18] Actually, in Ivie's estimates 4% real rate of return is chosen for the market sector and 3.5% rate for the non-market sector. The average real rate of return of bank deposits in Spain since 1850 is 4.5% (computed from underlying data in Prados de la Escosura and Rosés (2010), updated to 2019.

$$SF_0^t = P_0^{k,t\mathrm{B}}(1 + \rho_{(t\mathrm{B})})\,[r_a^* + \delta_0] \tag{13}$$

Lastly, a Törnqvist index of aggregate capital services is computed as,

$$\ln(KS^{k,t}/KS^{k,t-1}) = \Sigma\bar{v}^{k,t}\ln(K^{k,t}/K^{k,t-1}) \tag{14}$$

where $K^{k,t}$ is the productive capital stock of asset k and $\bar{v}^{k,t} = 1/2(v^{k,t-1} + v^{k,t})$, the two adjacent year average share of each asset in total user cost of capital, being $v^{k,t} = U^{k,t}/U$. Then, the volume index of capital services (VICS) is obtained as the exponential.

It is worth noting the different weighting of the capital stock (the share of assets in its total current value) and the index of capital services (the share of assets in total returns to capital). Figure 5 shows the composition of the net capital stock, dominated by structures (dwellings and other construction) that in spite of the long-term fall in the share of dwellings until the early 1990s and the rise of machinery and equipment up to the early 1960s, still contribute four-fifths of the net capital stock value in 2019. A different and more volatile picture results from the composition of capital returns as assets with lower average service lives (and, hence, higher depreciation rates) are those with higher marginal returns (Fig. 6). Thus, machinery and equipment matches the share of other construction since the mid-twentieth century and the share of dwellings declines more than in the net capital stock.[19]

But how different is the composition of capital services when they are obtained with the simplified ex-ante exogenous rate of return, as favoured in Ivie's estimates (Pérez et al. 2019)? Similar but less volatile trends appear even though machinery and equipment's remains below the share of other construction (Figure A2), but the validity of the simplified approach depends on the stability of relative GFCF prices.

Figure 7 offers the evolution of the price of each type of asset relative to the GDP deflator and shows how they fluctuate.[20] For example, the relative price of both machinery and transport equipment experienced a decline between the late 1850s and 1880s, that coincided with railway construction and the early stage of industrialisation, and a sustained fall from the 1950s, which was steeper until the late 1970s. Embodied technological change helps explain these assets' trends. Thus, assuming that asset prices mimic the general price index is unrealistic and alters the weighting of the volume index of capital services.

The different weighting of the net capital stock and capital services also reflects in the evolution of productive capital stock and the volume index of capital services since VICS grows faster than PKS as more dynamic assets are usually those of shorter average service life but higher returns. Figure 8 confirms their divergent evolution that has widened since the 1970s.[21]

[19] Similar trends, although less marked, and machinery and equipment never matches other construction, are observed when the ex-post endogenous rate of return is used (Figure A1).

[20] Similar results are obtained using the private consumption deflator.

[21] The gap is narrower gap when VICS is obtained with an ex-post endogenous, rather than an ex-ante exogenous rate of return. This finding is consistent with the presumed underestimate of capital services derived with an ex-post endogenous rate of return when information on capital assets is incomplete as it is our case (Figure A3).

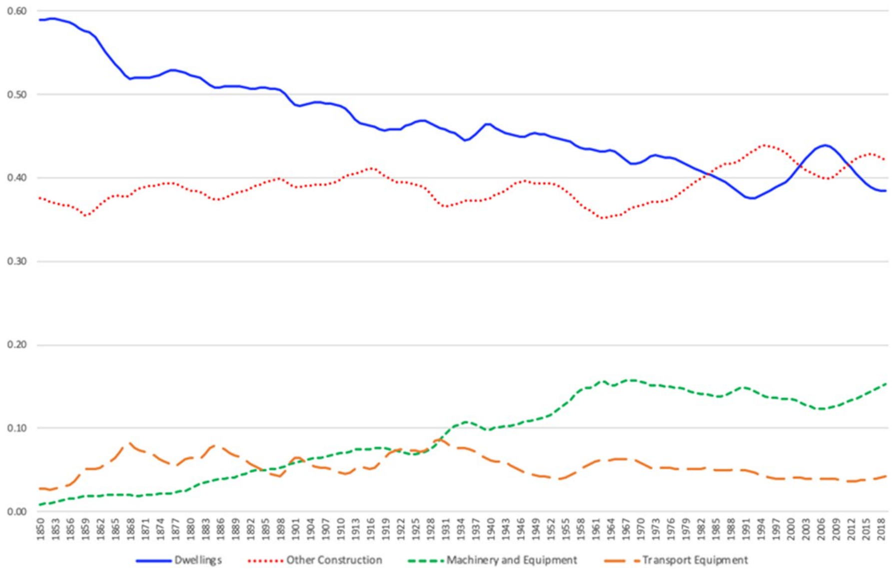


Fig. 5 Net capital stock composition (current prices) (%)

An index of capital "quality" that measures the capital input's composition effect can be derived as the ratio between the volume index of capital services and that of productive capital stock,

$$KQ^{k,t} = KS^{k,t}/K^{k,t} \tag{15}$$

Figure 9 shows a long-run increase in the "quality" of capital, punctuated by reversals, in which a contraction during the Civil War (1936–1939) and its autarkic aftermath (1939–1953) and a fast increase between the mid-1950s and the late 1970s, followed by deceleration, stand out. A rise in the index signals a shift towards capital goods with higher unit user costs and, hence, higher marginal productivity.[22]

It is worth stressing that the VICS derived with the full and simplified ex-ante exogenous rate of return is practically identical until 1970 when the "simplified" VICS lags gradually behind the "full" VICS (Figure A4). Thus, the choice of a "simplified" VICS underestimates the improvement in capital quality since the late 1960s (Figure A6b).

A comparison between the new volume index of capital services and earlier estimates is pertinent. In the first place, let us compare the new results with Prados de la Escosura and Rosés (2010) estimates, under similar assumptions (namely, Hulten and Wykoff's declining balance depreciation rates and GFCF

[22] Although the evolution of "quality" of capital using alternatively ex-ante exogenous and ex-post endogenous rates of return share the same tendencies, the level of capital "quality" is lower for the latter as could be anticipated due to the possible underestimate of capital services when they are computed with incomplete information (Figure A6a).

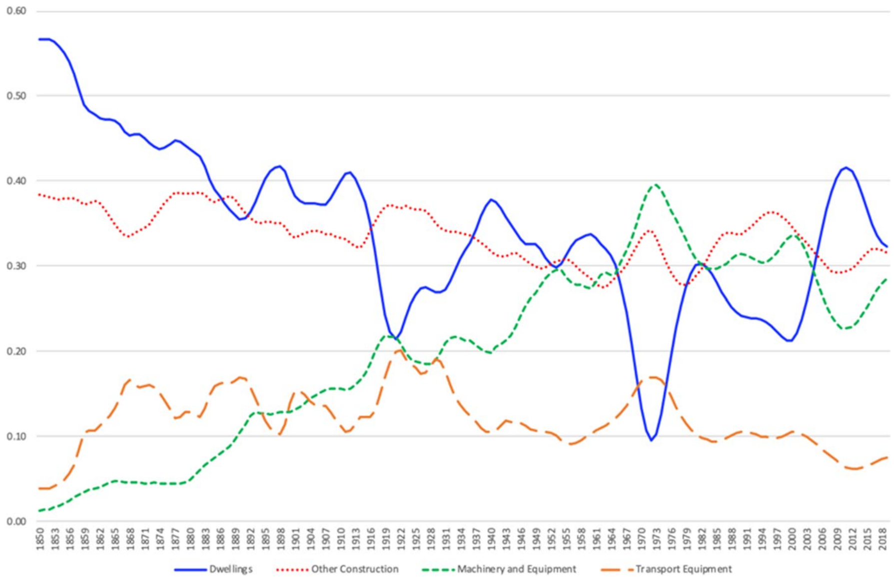


Fig. 6 Capital services' composition (ex-ante exogenous rate of return) (current prices) (%)

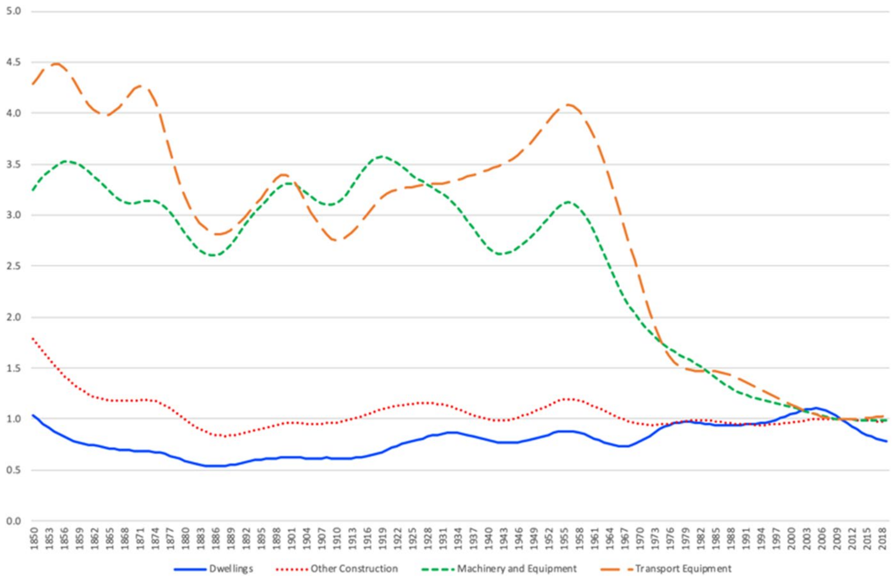


Fig. 7 GFCF prices relative to the GDP deflator (2010 = 1) (Hodrick–Prescott smoothed)

series spliced through interpolation). A common pattern is found, but the new VICS presents lower levels, although they tend to converge in the late twentieth century (Fig. 10). Such a difference may derive from the lower (and fixed)

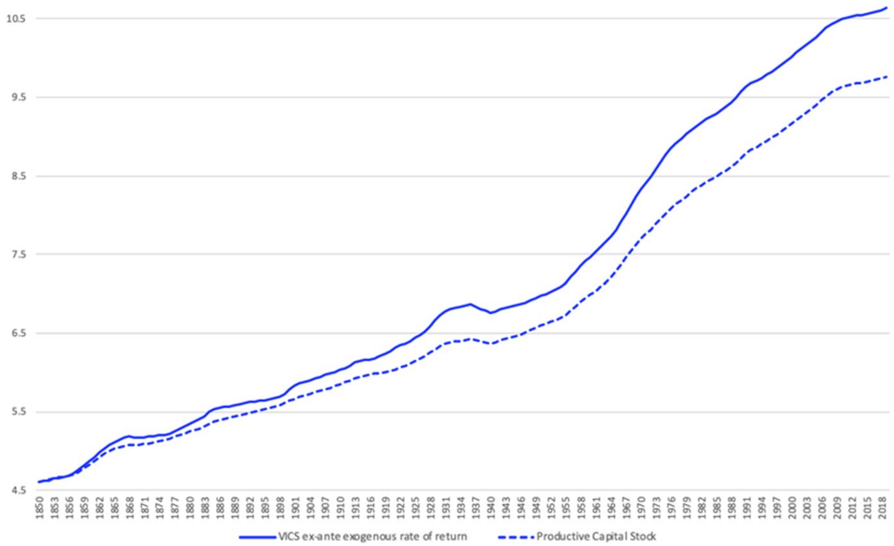


Fig. 8 Volume index of capital services (ex-ante exogenous rate of return) and productive capital stock (1850 = 100) (natural logs)

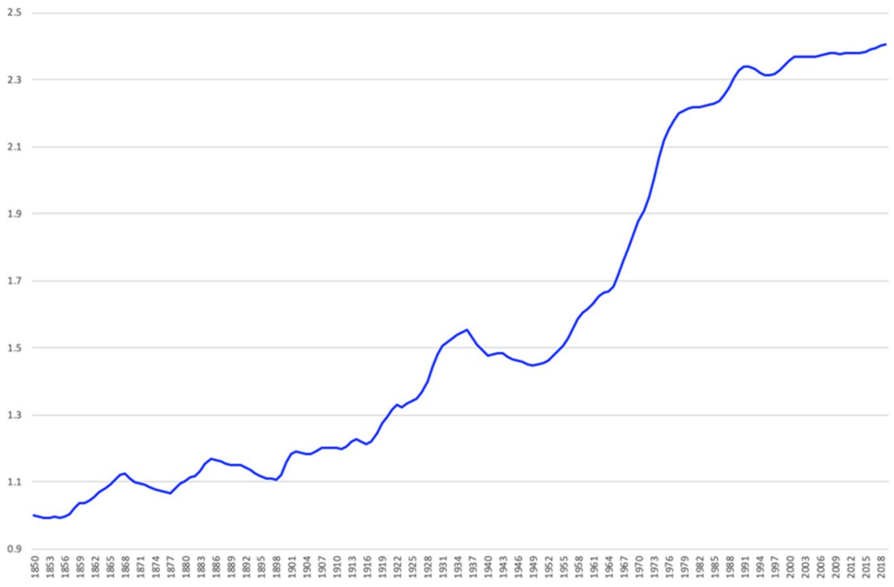


Fig. 9 Capital quality (ex-ante exogenous rate of return) (1850 = 1). *Note*: Capital quality = Ratio of volume index of capital services to productive capital stock

average service lives used here, while Prados de la Escosura and Rosés employed higher (and variable) average service lives, which, by increasing the gross stock and reducing depreciation, result in a larger net capital stock.

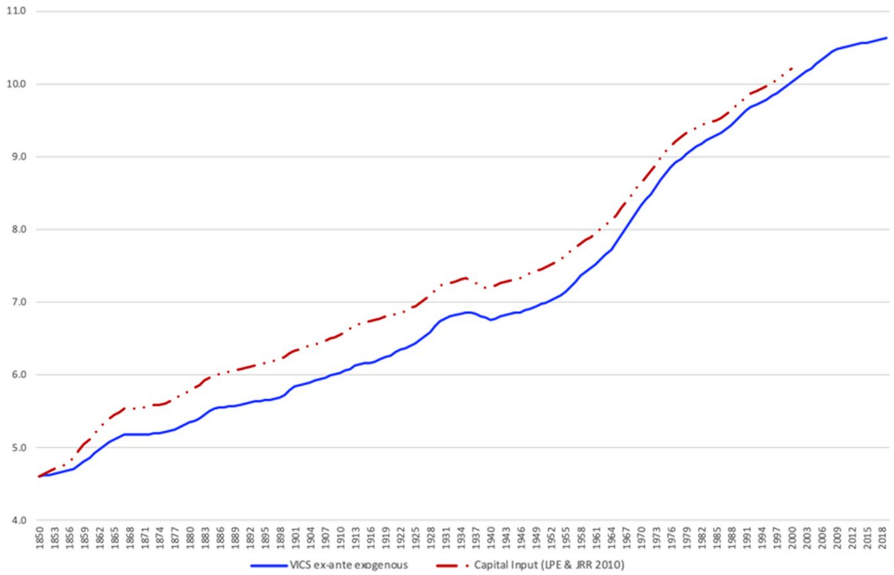


Fig. 10 Volume index of capital services*: comparison with Prados de la Escosura and Rosés (2010) (1850 = 100) (natural logs) *ex-ante exogenous rate of return

Another contrast is carried out with VICS derived by PWT9.1 and Ivie (Pérez et al. 2019) to which Conference Board (2020) estimates since 1990 have been added. Slower growth results from PWT9.1 and Ivie series, but slightly faster from the Conference Board series (Fig. 11a).[23] The main explanation of the different pace of growth is that both PWT9.1 and Ivie estimates are based on pre-1995 GFCF series spliced through retropolation, unlike the new VICS that draw on GCFC interpolated series. Figure 11b confirms that when VICS is derived using retropolated GFCF series and double declining balance geometric depreciation, the gap with PWT9.1 and Ivie narrows down sharply, especially from the late 1970s onwards. Moreover, as PWT9.1 estimates are derived with ex-post endogenous rates of return, the differential narrows further down when the new VICS is computed with this rate of return (Figure A8). The comparison in terms of capital quality, that is, the ratio between capital services and productive capital indices, reveals that quality gains are much larger in the new estimates and Ivie's than in the PWT9.1 ones (Fig. 12).[24]

What are the observed trends in capital input? Capital services grew at 3.6% during the last 170 years, but its pace was uneven. It is possible to distinguish a period of steady growth, slightly above 2% per year, up to 1920, in which the compositional change of capital (capital quality) represented a minor proportion (Table 2).

[23] See Figure A7 for a comparison that included the new estimates derived with both ex-ante exogenous and ex-post endogenous rate of return.

[24] Figure A9 adds up the new estimates of capital quality derived with ex-post endogenous rate of return that exhibits milder gains than when obtained with the ex-ante exogenous rate of return.

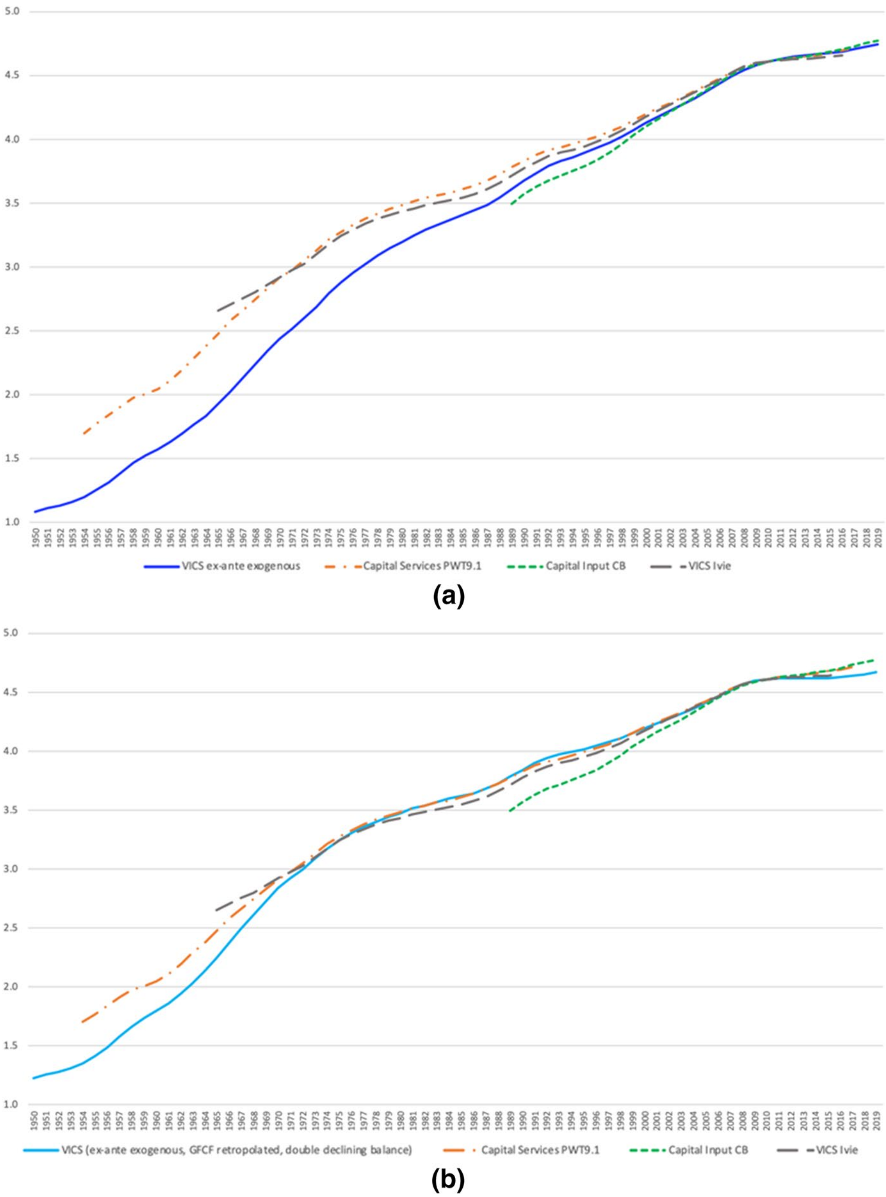


Fig. 11 **a** Volume index of capital services: comparison with PWT9.1, CB, and Ivie estimates, 1950–2019 (2010 = 100) (natural logs). **b** VICS, 1950–2019. Alternative estimates derived with GFCF retropolated series and double declining balance comparison with PWT9.1, CB, and Ivie estimates (1850 = 100) (logs)

In the 1920s, the growth rate doubled, with more than one-third contributed by capital quality. The slowdown of the early 1930s did not revert to the pre-1920 growth, thanks to its compositional change. After shrinking during the Civil War

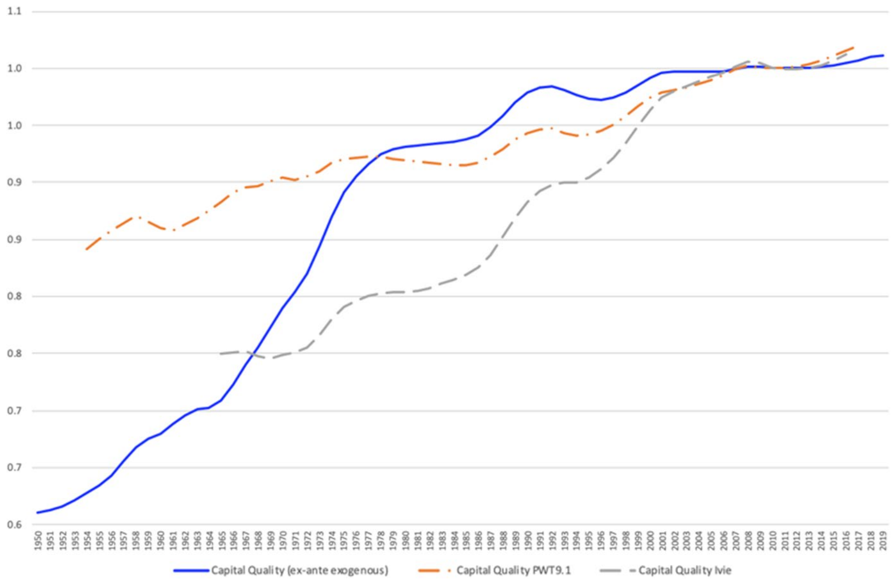


Fig. 12 Capital quality: comparison with PWT9.1 and Ivie estimates, 1950–2019 (2010 = 1)

Table 2 Capital input growth*, 1850–2019

	*Ex-ante exogenous rate of return (Annual average logarithmic rates %)		
	Productive capital stock	Capital quality	Capital input
1850–2019	3.0	0.5	3.6
1850–1872	2.2	0.4	2.6
1873–1892	1.9	0.2	2.2
1893–1913	2.1	0.3	2.4
1914–1919	1.2	0.7	2.0
1920–1929	3.0	1.3	4.2
1930–1935	2.0	1.1	3.2
1936–1939	−0.8	−0.9	−1.7
1940–1945	1.4	−0.3	1.1
1946–1953	2.5	0.1	2.6
1954–1958	4.6	1.4	6.1
1959–1975	6.6	1.7	8.3
1976–1985	4.7	0.5	5.2
1986–2007	4.6	0.3	4.9
2008–2013	2.7	0.0	2.7
2014–2019	1.4	0.2	1.6

and recovering mildly during the World War II years, capital input growth went back to its pre-1920 growth trend until the mid-1950s when it began an acceleration that

Table 3 Capital deepening* growth, 1850–2019

	*Ex-ante exogenous rate of return (Annual average logarithmic rates %)	
	Productive capital stock/hour	Capital input/hour
1850–2019	2.6	3.1
1850–1872	1.6	2.0
1873–1892	1.9	2.1
1893–1913	1.5	1.8
1914–1919	0.8	1.6
1920–1929	2.3	3.6
1930–1935	0.4	1.6
1936–1939	−0.1	−1.1
1940–1945	0.7	0.4
1946–1953	1.2	1.3
1954–1958	3.9	5.3
1959–1975	6.4	8.1
1976–1985	7.8	8.3
1986–2007	2.2	2.5
2008–2013	5.7	5.7
2014–2019	−0.8	−0.6

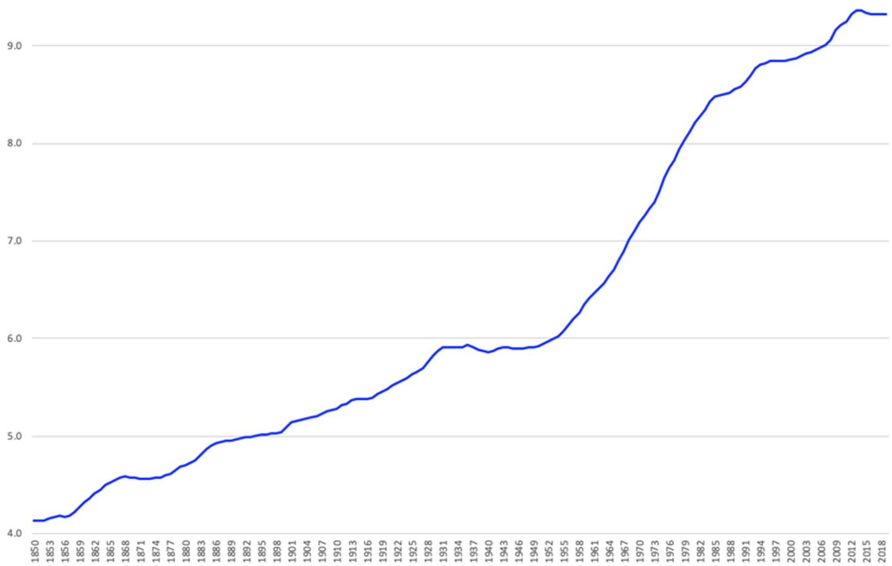


Fig. 13 Capital deepening* (2010 = 100) (natural logs of *x* 100 level). *Note*: *Volume index of capital services (ex-ante exogenous rate of return) per hour worked

lasted for half a century and was cut short by the onset of the Global Financial Crisis (2008). During Spain's delayed and short Golden Age (1959–1975), capital input growth was nearly fourfold that of the pre-1920 era, with capital quality contributing at least one-fifth of it. The oil shocks that coincided with the decade of "transition to democracy" (1976–1985) represented a substantial slowdown in absolute and per capita GDP but not in terms of capital input that, with hardly any quality improvement, kept growing at 5% yearly during the "transition" decade and after Spain's accession to the European Union. The Great Recession (2008–2013) nearly halved the post-1975 rate of capital services growth and, since 2014, capital input has been growing at the slowest pace since World War II.

If we look now at the volume of capital services per hour worked, that is, capital intensity or deepening, it grew steady up to 1930 and after nearly stagnating for two decades, it expanded at an accelerated pace between the early-mid 1950s and mid-1980s (Table 3 and Fig. 13). Capital deepening slowed down thereafter, particularly between the mid-1990s and 2007 and, after a spurt during the Great Recession, has declined mildly in recent years. A comparison with alternative capital deepening figures shows that the new estimates grew faster than PWT9.1 estimates and slightly slower than Conference Board's since 1989 (Fig. 14).

It is worth highlighting the inverse association between capital deepening and employment growth in post-Franco's Spain (Fig. 15). Employment destruction during the decade of "transition to democracy" (1976–1985) and the Great Recession (2008–2013) contribute to explain capital deepening in those years; conversely, from the accession to the EU to the onset of the Global Financial Crisis (1986–2007), and in the post-2014 recovery, employment creation underlies the deceleration and contraction in capital deepening. Thus, capital deepening slowdown since 1986 suggests that expanding sectors have not attracted much investment-specific technological progress.

4 Capital-output ratio and capital consumption

Capital has a dual nature as a storage of wealth and provider of capital services to production (OECD 2009). So far the focus has been on capital services. Let us now look at the evolution of wealth or net capital stock.

Piketty's (2014) claim of a fluctuating capital-output ratio going back to the eighteenth century has challenged one of Kaldor's (1957) stylised facts, namely the stability of the capital-output ratio. Such a claim is hardly news for economic historians, who have long been sceptical about empirical regularities. Prados de la Escosura and Rosés (2010) challenged the long-run stability of the capital-output ratio, and Gallardo-Albarrán and Inklaar (2020) have rejected it for more than 30 countries over the last 100 years.

The evolution of net capital stock ratio to GDP, expressed at current prices, shows that after declining until the early 1880s, a sustained increase took place, with the capital-output ratio rising fourfold between 1886 and 2013 (Fig. 16). A first phase of expansion reached up to the early 1930s, in which the ratio more than doubled, peaking during the Civil War (1936–1939) when economic activity severely contracted.

Relative stability from the late 1940s to 1960, with the ratio ranging between 2.0 and 2.5, was followed by a dramatic fall until the mid-1960s, at a time of fast economic growth, and a subsequent recovery that heralded a strong and sustained increase in the capital-output ratio, punctuated by reversals in the late 1980s and, again, in the late 2010s. The sustained rise of the capital-output ratio and capital deepening led to the decline of capital productivity (that is, real GDP per VICS) over the long run (Fig. 17).

From the late 1990s, low interest rates and the scarcity of urban land fuelled a boom in the price of dwellings—as the increase in the relative price of dwellings until the mid-2000s confirms (Fig. 7)—that contributed to the rise of the capital-output ratio. That is why the capital-output ratio excluding dwellings is also presented. The same trends, but with less intensity, are confirmed.

The evolution of the capital-output ratio in Spain matches the experience of a large sample of countries during the last century in which the capital-output ratio doubled (Gallardo-Albarrán and Inklaar 2020), although the increase seems to have been more intense in the Spanish case, unlike the UK's where the capital-output ratio stopped its expansion and declined during the last two decades of the past century (Oulton and Wallis 2016). By 2013, the capital (wealth)-output ratio at current prices reached a value of 4, when it was just 2 in 1970, in line with the findings of Piketty and Zucman (2014) for western European countries. However, this represents practically half the ratio of personal wealth to national income estimated for Spain, although it also doubled during the same time span (Artola-Blanco et al. 2018). A necessary caveat is that private wealth estimates add financial assets to the net capital (wealth) stock (that is, non-financial assets) and exclude financial liabilities.

The consumption of fixed capital, expressed as a proportion of GDP, follows the pattern of the capital-output ratio, jumping from 3 to nearly 15% between the late 1880s and 2013 (Fig. 18). However, when the ratio of capital consumption to net capital stock—that is, the depreciation rate—is considered, it expanded up to the mid-1930s and, again, since 1950, peaking in the late 1960s, and, then, declined steadily until the mid-2000s, to rebound later. What explains this behaviour? As the composition of capital stock changes towards more productive but higher depreciation assets, one would expect a rise in the depreciation rate. However, new capital goods are more productive as they embodied new vintage technology, so a decline in its relative prices would accompany its expansion (Fig. 7) and help explain the fall in the rate of depreciation between 1970 and 2007.[25]

[25] It is worth stressing that the described patterns for the capital-output ratio and the consumption of fixed capital are confirmed for alternative estimates derived using different average service lives and depreciation rates. Longer lives, by reducing depreciation, increase the level of net capital stock (Figure A11), and the use of the double declining balance implies higher depreciation rates, which increases capital consumption and, hence, reduces the level of net capital stock (Figure A12), while increases the ratio of the consumption of fixed capital ratio to GDP and net capital stock, respectively (Figure A13).

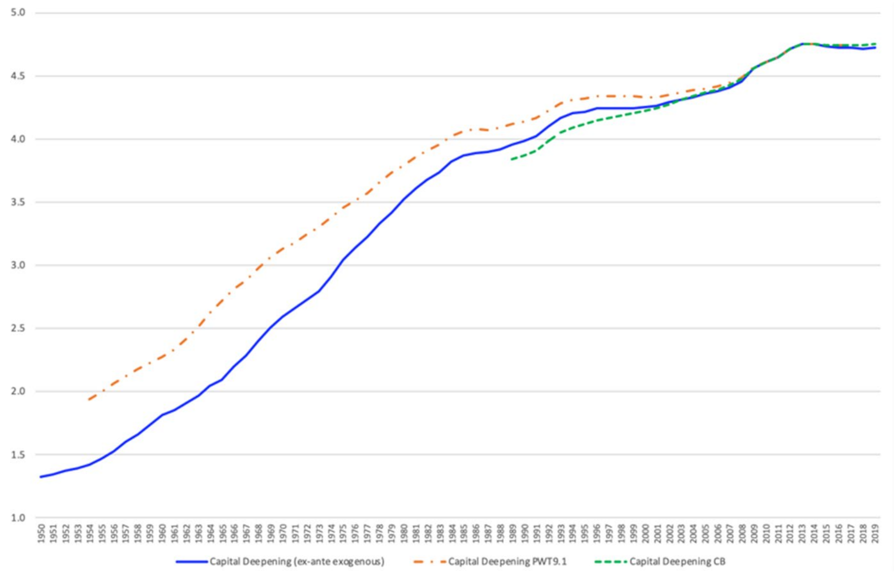


Fig. 14 Capital deepening*, 1950–2019: comparison with PWT9.1 and Ivie (2010 = 100) (natural logs). *Volume index of capital services (ex-ante exogenous rate of return) per hour worked

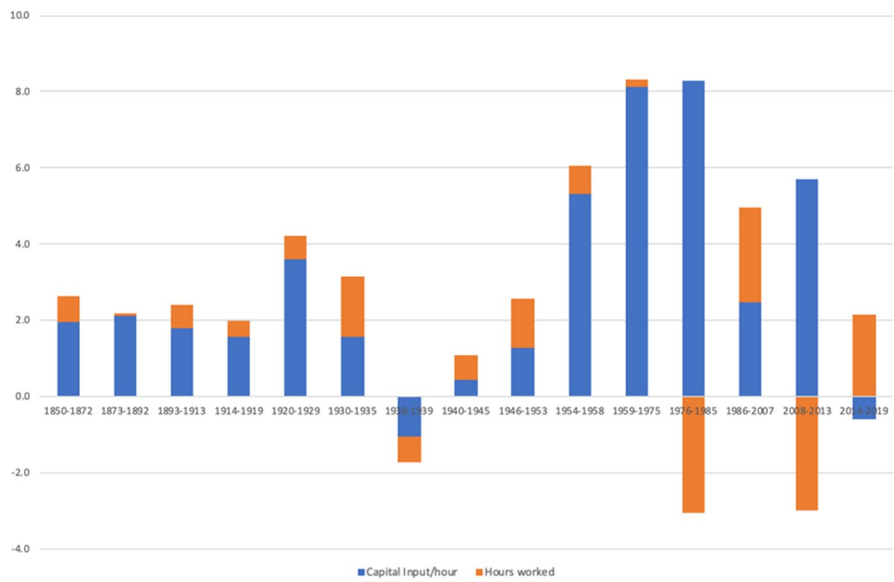


Fig. 15 Volume index of capital services* (ex-ante exogenous rate of return): growth breakdown (%). *Note*: *VICS = VICS/hour × Hours worked

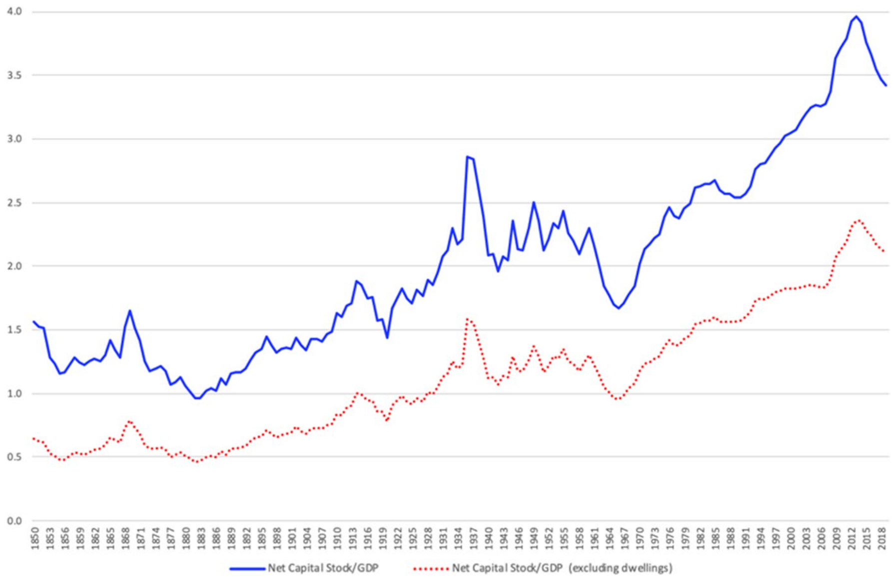


Fig. 16 Net capital stock/GDP ratio (current prices): with and without dwellings

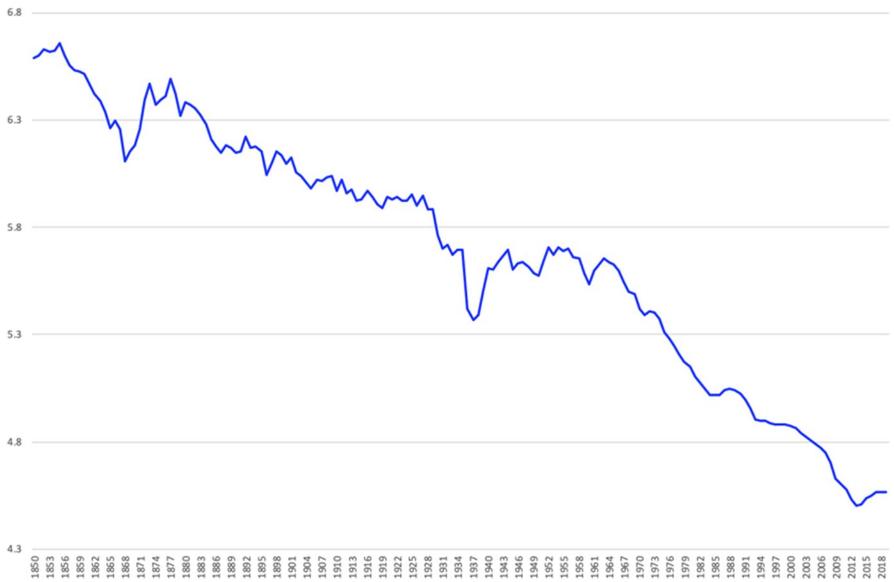


Fig. 17 Capital productivity (ex-ante exogenous rate of return) (2010 = 100) (natural logs). *Note*: Capital productivity: ratio of real GDP to volume index of capital services

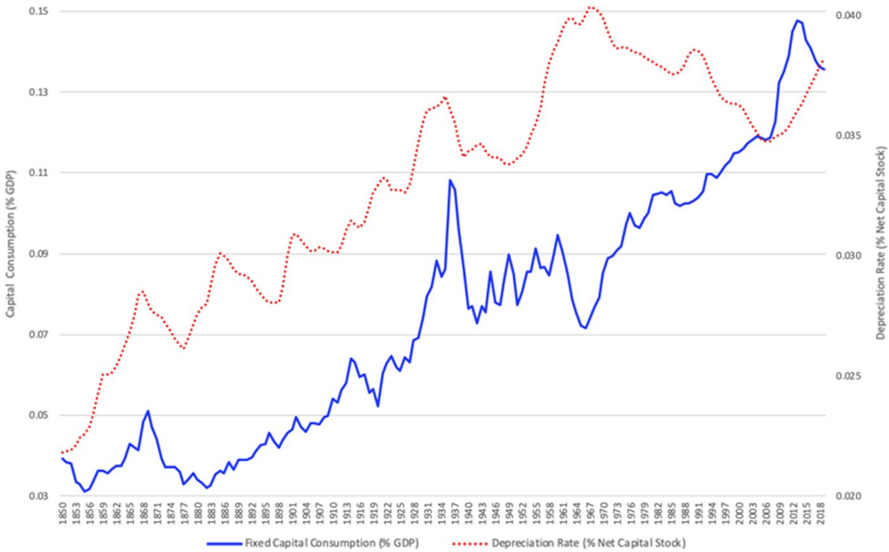


Fig. 18 Consumption of fixed capital (% GDP) and depreciation rate (CFC as % net capital stock), (current prices)

5 Conclusions

The ongoing debate on the rising trend in the capital-output ratio and the productivity slowdown requires long run, consistent, and integrated series of output and production factors. This paper presents new estimates of net capital (wealth) stock and capital services for Spain during the last 170 years that allow us to address welfare and growth issues.

Methodological differences matter for the resulting estimates. The new OECD methodology used in the paper clearly differentiates between stock as wealth and capital as an input (that is the flow of services capital provides to production) and represents a major advance in the construction of capital estimates reconciling different approaches, including those previously used by the OECD and those by Jorgenson and his school. Most historical estimates, however, are based on outdated methodologies that are not compatible with recent capital stock and services estimates. Consistency with the latest vintage methodology used by international organisations facilitates, for example, testing current views about increasing capital-output ratios or investigating the contribution of capital deepening to labour productivity growth. The paper also rejects the option of using GFCF series derived by splicing national accounts through backwards projections as they bias GFCF levels upward and, consequently, capital stock levels too, and adopts GFCF series derived through interpolation of national accounts. These methodological contributions can be applied elsewhere, especially to those developing countries experiencing a deep structural transformation and in the construction of historical series.

The new net capital stock estimates are not off the mark when compared to official national statistical series for the early twenty-first century, and their differences for the last half a century with the Penn World Tables 9.1 and Ivie's figures largely result from methodological differences.

Capital services expanded over time accelerating in the 1920s and between the mid-1950s and 2007, with capital "quality" contributing until 1975. Capital deepening increased in the long run, especially from 1955 to 1985, slowing down after Spain's accession to the European Union, as expanding economic sectors attracted less investment-specific technological progress.

The net capital (wealth) stock-GDP ratio rose over time, contradicting Kaldor's (1957) stylised fact while confirming Piketty and Zucman (2014) results. Although the consumption of fixed capital (% GDP) shadowed the capital-output ratio, the rate of depreciation fell from 1970 to the onset of the Global Financial Crisis as new capital goods' relative prices declined due to embodied technological change.

The inverse association between capital deepening and employment growth in post-Franco's Spain mimics the behaviour of labour productivity, which raises when employment falls and declines when employment expands (Prados de la Escosura 2017). How much did capital deepening contribute to raising labour productivity over the long run? Providing an answer is the matter for a new investigation.

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