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JEL Classification: D33, E22, G32, J24

Keywords: Intangible Capital, skill premium, knowledge based technological change, Human Capital, excess savings, mortgage credit

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Redistributive Growth

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September 2019

Abstract

We study long term effects of the technological shift to intangible capital, whose creation relies on the commitment of skilled human capital in firm production. Human capital cannot be owned, so firms need less financing. Human capital cannot be credibly committed so firms need to reward it by deferred compensation, diluting future profits. As human capital income is not tradeable, total investable assets fall. The general equilibrium effect is a gradual fall in interest rates and a re-allocation of excess savings into rising valuations of existing assets such as real estate. The concomitant rise in house prices and wage inequality leads to higher household leverage.

Keywords. Intangible capital, skill-biased technological change, mortgage credit, human capital, excess savings, house prices

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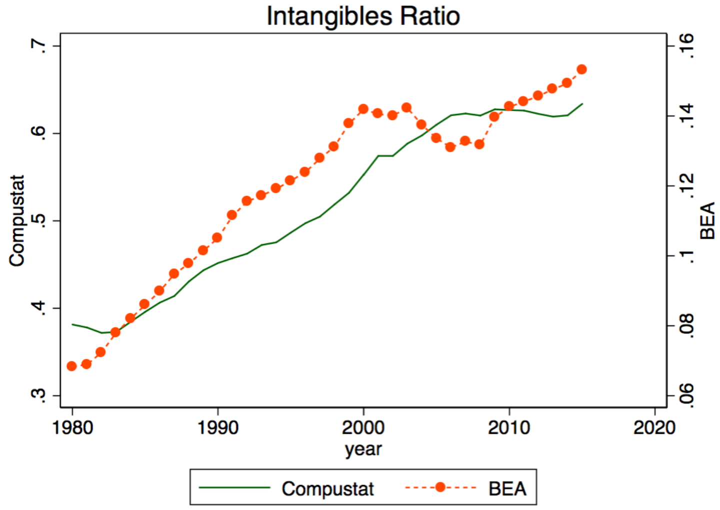

Figure 1: Ratio of intangible to total capital since 1980.

1. Introduction

A rising surplus of savings over productive investment in advanced economies has been defined as a phase of "secular stagnation" (Summers, 2014; Eichengreen, 2015). While several factors contribute to this phase, we propose a novel interpretation for a direct effect of the transition to a knowledge-based economy. This technological process is already recognized as a leading cause for a shift in skilled worker productivity and a growing wage inequality (e.g. see Autor, Katz, and Krueger, 1998; Autor, Levy, and Murnane, 2003). Our contribution studies how this technological shift also affects productive capital and its funding. The composition of corporate assets has seen a marked shift towards intangible capital. An increasing ratio of intangible to tangible investment since 1980 is (Corrado and Hulten, 2010a) documented in Figure 1.[1]

We study the effect of this transformation building on the simple insight that intangible capital creation critically relies on skilled human capital rather than physical assets. It is long recognized that intangible assets are poor collateral in default as "assets can simply walk out of the door". This can explain why firms with more intangible assets choose low or negative net leverage (Bates, Kahle, and Stulz, 2009; Falato, Kadyrzhanova, and Sim, 2013).

[1] The Compustat series is based on Peters and Taylor (2017) and capitalizes R&D as well as SG&A expenditures, while BEA data focuses on intellectual property products (IPP).

An important insight from the labor literature is that IT technological advances not only boost skilled productivity, but also substitute physical labor. The equivalent process for firm capital is that intangible capital is not just more productive, but in fact substitute for most physical investment at the productive frontier. This leads to a shift within the capital share towards intangible capital, produced by the commitment of skilled talent by entrepreneurs and innovative employees (Eisfeldt and Papanikolaou, 2013). Indeed, the productive sector has become a net lenders in many developed economies (Gruber, 2015). This paper shows how reduced corporate leverage may also reflect a drop in credit demand as firm capital composition changes. Critically, firms cannot purchase human capital (Hart and Moore, 1994), as innovators can leave at will. Thus firms need to defer the bulk of compensation to human capital to ensure its motivation and retention until output is realized (Oyer and Schaefer, 2005). This has two consequences. The shift to intangible assets reallocates value in favor of skilled human capital (Eisfeldt and Papanikolaou, 2014). This leads to a rising future profit share must be assigned to innovators. Second, this process does not lead to more financially constrained firms. While corporate assets may indeed become less pledgeable, firms fund a smaller share of capital formation because of co-investment by human capital. Firms do co-invest in intangibles (eg by acquiring patents, data and advertising), but the bulk of intangible investment is into human capital. As a consequence, firms have lower funding needs for investment purposes.

We incorporate this notion in an overlapping generations (OLG) growth model, with a general CES production function where physical capital is complementary with manual labor, while intangible capital is complementary with skilled labor. Land (housing) serves as durable consumption good as well as a store of value for agents' life-cycle retirement savings.

The inability to contract on future human capital rewards implies that as the intangible capital share rises, investors have fewer investable claims for their retirement savings. The result is a growing excess of savings over investment funding needs. In combination with an inelastic long term saving supply (Blinder and Deaton, 1985; Matthew Canzoneri and Diba, 2007), the capital composition shift leads to falling interest rates. In general equilibrium, the non-investable surplus is reallocated to the purchase of existing assets, so it is in fact *stored* in a higher valuation of existing assets (Deaton and Laroque, 2001), such as equities and real estate.

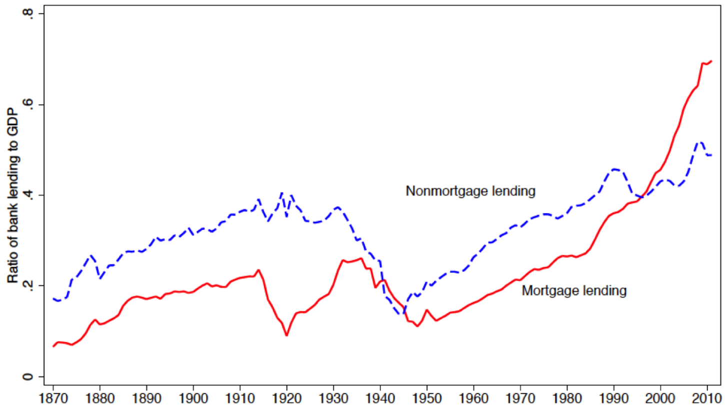

Figure 2: Mortgage and commercial credit in OECD countries (Jordà et al., 2016)

The combined effect on wage and capital markets leads to a rising demand for mortgage credit since house prices rise relative to unskilled wages. This may account for the vast rise of mortgage credit in all OECD countries (Jordà, Schularick, and Taylor, 2016, see Figure 2), now amply larger than credit to the productive sector.

In equilibrium, positive growth and a rising intangible capital ratio may be generated by various drivers affecting factor productivity or their supply, each with distinct general equilibrium implications for major trends. We assess how well different candidate driver replicate the historical change in the main endogenous variables, using a comparative statics exercise on the model's long-run equilibrium. The approach assumes that each candidate driver underwent a structural transition over 1980-2015, and compares their performance in reproducing all other major trends. This analytical exercise is complemented by a numerical assessment, using a calibration of the model to U.S. data.

We show that in our setup only a highly redistributive shift towards intangibles predicts the direction of major trends. In particular, it is unique in its ability to account simultaneously for a drop in physical investment and the interest rate, interpreted as a declining return on productive assets that are funded externally. The drop in both quantity and price of physical factors can only be explained by declining demand. This result is akin to the labor literature, where new technologies replace old factors at the technological frontier (e.g. Acemoglu and Autor, 2011).

Alternative growth formulation fail to predict the direction of some trends. Technological growth drivers such as a general rise in capital productivity, in the innovation rate, education level or changes in factor supply cannot reproduce the combination of declining tangible investment and corporate leverage along with falling rates and a rising skill premium. Explanations based on savings supply (driven by higher longevity or capital flows) directly imply low rates but cannot explain skill premia, low investment and leverage, since physical capital should benefit from the increased supply of funding.

In conclusion, while arguably many different drivers are behind major economic trends, our results indicate that redistributive technological growth is an important driver behind changes in corporate asset composition, asset repricing and rising inequality within both capital and labor income.

While the model predicts a rise over time in the mortgage default rate, its neoclassical framing with no externalities nor financial constraints implies that the equilibrium is dynamically efficient. Limits on loan-to-value ratios do reduce house prices (as they are in fixed supply), redirecting savings to physical investment by subsidizing its cost (Deaton and Laroque, 2001). This would result in higher labor wages and output, and a large intra- and intergenerational transfer. However, public intervention may only be Pareto-improving in the presence of a strong externality for financial stability. A proper financial stability analysis requires a model with further frictions, beyond the scope of this paper.

Section 2 discusses our key assumptions and places our work in the literature. Section 3 identify the main secular trends and their potential drivers in the context of the model. Section 4 presents the model and its steady state solution. Section 5 considers alternative interpretations of the trends and derives our analytical results. Section 6 presents numerical results using a calibration of the model, and considers policy implications. Section 7 concludes.

2. Key Assumptions and Related Literature

Key Assumptions While our formulation of the production function is quite general, any growth process is the result of specific supply and demand elasticities. Our analysis relies on specific though plausible assumptions, whose accuracy is an important empirical issue.

Excess savings require a low elasticity of savings to real interest rates, a well documented phenomenon (Blinder and Deaton, 1985; Matthew Canzoneri and Diba, 2007). The results also require a limited elasticity of housing supply. While higher land prices may lead to more dense housing, population growth and urban congestion have countervailing effects.

The model assumes a fixed supply of skilled labor, easily relaxed by educational choices. Its effect would be to dampen the effect of a technological shift on intangible value, but not alter its effects. Globalization may be seen here as a rise in world labor supply which depresses the comparative advantage of labor in developed countries in addition to automation.

A critical assumptions concerns an inelastic supply of innovation. Innovative intangible capital cannot be scaled up easily, so technology enables innovators to earn rising rewards. If all returns to innovation were easily competed away by entry, there would be no rise in innovation rents nor excess savings. Instead, we assume that intangible capital can only be created by a subset of innovative high-skill workers, who cannot sell claims on the return to intangible assets. The inability of innovators to borrow against their future income is a common assumption in labor economics as it reflects moral hazard as well as the inalienability of human capital (Hart and Moore, 1994).

Related Literature A redistributive growth process is related to the literature on the effect of technological change on wages in developed economies (e.g. Katz and Murphy, 1992; Autor et al., 1998, 2003). A rising skill premium cannot be due only to rising intangible productivity, as it also reflects a fall in absolute labor wages. The leading explanation is that automation directly substitute labor Acemoglu and Autor (2011). A redistributive shift in the innovator share relative to passive investors' returns mirrors this approach within the capital share along the change in capital composition. Our approach studies income polarization driven by productivity, a variation of the original interpretation by Pareto (1897) or the assortative matching view by Kremer (1993). A neoclassical framing in a context with no bequests clearly cannot capture all historical changes in wealth distribution (Piketty, 2014) [2], and changes in welfare, education and fiscal policy certainly had a major role. It is consistent with a rise in the income share of innovators (Smith, Yagan, Zidar, and Zwick, 2017; Koh, Santaeulàlia-Llopis, and Zheng, 2016), a rising market power associated with new technology (Gutiérrez and Philippon, 2016; Gauti Eggertsson and Wold, 2018) and highly disruptive entrants (Garlenau and Panageas, 2017).[3] Finally, the approach can help interpret a rising real estate share in total wealth (Rognlie, 2015). Our setup interprets a redistribution within

[2] Wealth inequality is even more skewed than income, perhaps reinforced by intergeneration accumulation (Becker and Tomes, 1979). See Benhabib and Bisin (2017) for a thoughtful review.

[3] The current role of innovation on growth is an open issue for research (Gordon, 2012).

the labor and capital shares, and while it does nor imply a rising profit share (Barkai, 2016) it may be modified to accomodate it. However, we show that a rising capital share by itself cannot replicate all major trends.

Direct micro evidence for our interpretation is offered by Dell'Ariccia, Kadyrzhanova, Minoiu, and Ratnovski (2017), who show that as US firms shift toward intangible investment, their local banks expand real estate lending. Krishnamurthy and Vissing-Jorgensen (2015) and Mian, Sufi, and Verner (2017) show that credit supply shocks boost leveraged asset purchases rather than productive investment.Finally, our approach can explain a declining response of traditional investment to interest rates, and its declining or even negative correlation with Tobin's Q in recent years (Gutiérrez and Philippon, 2016; Dong Lee, 2016). High intangible firms will have both a high valuation and less tangible investment. Indeed, weak investment in the US and Europe is associated with a growing role for intangible capital (Gutiérrez and Philippon, 2016; Alexander and Eberly, 2016; Döttling, Gutiérrez, and Philippon, 2017).

Human capital receives the bulk of its reward in deferred form via IPOs and share grants, as well as tenure and career advancement (Oyer and Schaefer, 2005; Pendergast, 1999). Döttling, Ladika, and Perotti (2019) shows how the optimal financing and compensation of intangible investment requires innovating firms to become net lenders so as to minimize risk for unvested claims, thus adding to the savings glut. Firm also co-invest in intangible assets such as patents, R&D and organizational capital (Eisfeldt and Papanikolaou, 2013). Firms capture some intangible value in their equity value, but the human capital share appears large and able to affect stock prices (Eisfeldt and Papanikolaou, 2014). Smith et al. (2017) show most of the rise of top incomes since 2000 is due to business income for active owner-managers in skill-intensive sectors.

Intangible capital is correlated at the firm level with falling net leverage and rising cash hoardings (Bates et al., 2009). Some authors view a falling leverage as reflecting rising financial constraints (Falato et al., 2013; Giglio and Severo, 2012; Caggese and Perez-Orive, 2017). Yet firms with more intangible capital have lower investment spending and higher free cash flow, yet pay out just as much as more tangible firms(Döttling, Ladika, and Perotti, 2017). As they offer more share grants, investors in these firms suffer more equity dilution due to human capital compensation.

In his assessment of secular stagnation, Eichengreen (2015) favors technological explanations over low demand, in particular the fall in the relative price of investment goods as a more likely cause than a drop in opportunities (see also Karabarbounis and Neiman, 2013; Sajedi and Thwaites, 2016). This interpretation fits a technological shift that incorporates more IT technology in physical equipment, reducing its productivity-adjusted cost.

Finally, the setup interprets the historical repricing of long term assets and house prices, which in turn boost mortgage credit.[4] Trends in mortgage and household debt have been interpreted by country-specific factors, such as populist pressure (Rajan, 2010) or large capital inflows (Forbes, 2010). Yet the share of mortgage to total credit has risen steadily in all OECD countries (Jordà et al., 2016).

3. Identifying Major Trends

This section identifies major trends in labor and capital markets since 1980.

Falling real interest rates Real rates have gradually fallen across advanced economies since the early 1980s (King and Low, 2014), reaching historical lows. From a peak above 8% in the early 1980s, US real rates have steadily been declining to almost 0% in recent years, falling even during the 2002-2007 credit boom.

Rising intangible investment ratio Corporate investment in intangible assets has risen even as total investment declined since 1980.[5] Figure 1 shows the US ratio of intangible to total capital, using both the narrow definition by the BEA (intellectual property rights and some capitalized R&D), and the average Compustat firm-level measure as in Peters and Taylor (2017), which includes spending on knowledge capital, organizational capital and brand equity.

Decreasing corporate funding needs The right panel of Figure 3 shows a steadily rising net financial position for the U.S. non-financial sector using Flow of Funds data, reflecting falling net leverage and rising cash holdings.[6] This trend is confirmed in most OECD countries

[4] Asset bubbles may occur in an overlapping generation framework, so our analysis is consistent with speculative fluctuations around the long term trend.

[5] Corrado and Hulten (2010b) define intangible capital as the capitalization of expert human capital invested in corporate knowledge, organizational capability, computerized information and internal software.

[6] The net financial position is defined as total liabilities net of total financial assets.

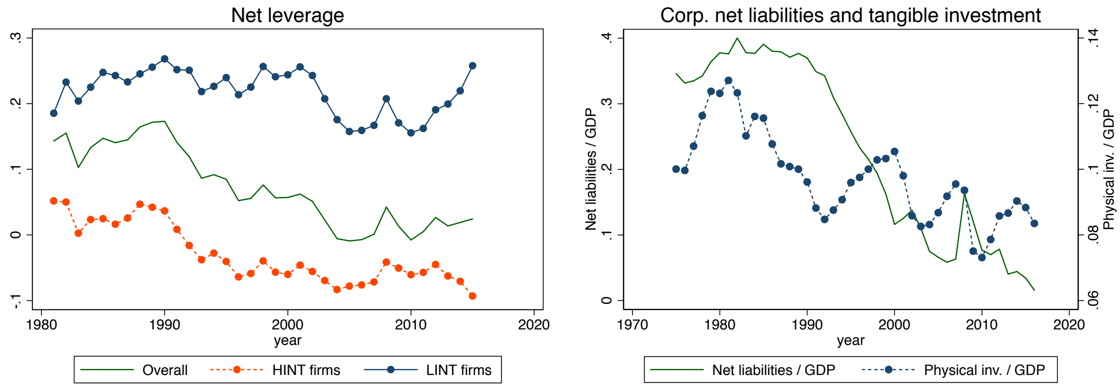

Figure 3: Net leverage and net liabilities of non-financial corporations

(Gruber, 2015). The right panel also shows falling physical investment scaled by GDP (from BEA data). The left panel of Figure 3 reports average Compustat leverage ratios, as well as their value for firms with intangible ratios above median (HINT) and below median (LINT).

HINT firms clearly led the decline, achieving a negative leverage ratio.[7] The fall in net corporate liabilities is not compensated by rising external equity, as US listed firms have seen net equity outflows since 1980 (Lazonick, 2015). Strikingly, the number of listed securities (a measure of investables for the general public) has also fallen sharply since 1980 (Doidge, Kahle, Karolyi, and Stulz, 2018).[8] This evidence is particularly puzzling at a time of falling real rates, but is consistent with a falling demand for physical investment and external corporate funding.

Allocation of credit Mortgage credit has grown sharply since 1980, and is now vastly above commercial credit across all OECD countries, as Figure 2 shows (Jordà et al., 2016), a rise that has continued even after a brief decline in the recent crisis. Such a generalized reallocation of credit suggests a common long term factor next to country-specific factors such as capital inflows or political choices.

Land and house prices Real house prices across advanced economies had been quite stable since 1870, but have risen sharply since 1980 across all countries (Knoll et al., 2017). Figure 4

[7]Leverage is here total net debt (DLTT + DLC - CHE) scaled by assets (AT). High intangible (HINT) firms are defined as the highest tercile of the intangibles ratio distribution, LINT firms are in the lowest tercile.

[8]The recent rise in high-fee private equity finance may reflect in this context both a rise in inequality and the rising importance of highly skilled investors.

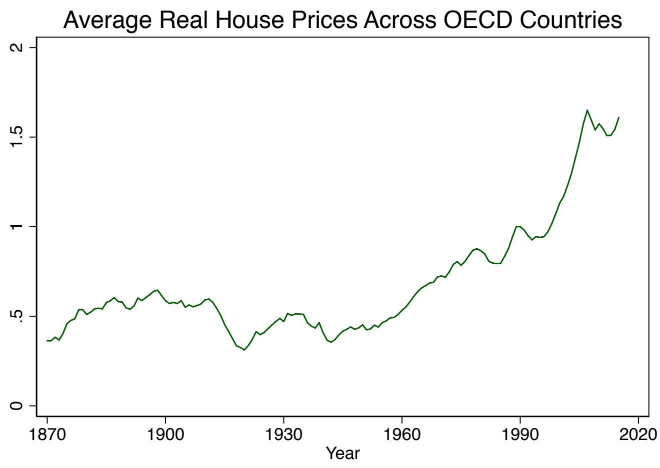

Figure 4: Average real house prices across OECD countries from Knoll et al. (2017).

shows the average real house prices series across OECD countries. As land supply is inelastic and local density is constrained by regulation, the trend is often attributed to rising demand and abundant credit.

Stock market capitalization U.S. stock market capitalization over GDP has risen from 50% in 1980 to well over 150% in recent years. Though profit rates have risen, the rise mainly reflects historically high price-earning ratios. The number of listed shares has sharply declined, while net equity flows have been negative for quite some years. Valuations have also been quite volatile, with the price-earning ratio ranging from 7 to over 44 in the period 1980-2016.

Rising wage inequality Survey data from the US Bureau of Labor Statistics show a sharp increase in relative earnings of skilled workers, a trend mirrored in other countries. The trend is widely interpreted in terms of a skill-biased technological change complementary with high cognitive skills, leading to automation replacing many low-skill functions (Acemoglu and Autor, 2011). Similar to the pre-1980 experience, labor wages have risen in industrializing countries where physical investment has been strong, reflecting diffusion of basic technology. While less precisely documented, there is much anedoctal and suggestive evidence on a rising innovator share (Garlenau and Panageas, 2017; Smith et al., 2017).

4. Model Setup

This section describes the baseline model environment and derives its equilibrium.

Time Time is discrete and runs from $t = 0$ to infinity. Overlapping generations live for two periods.

Goods There are two consumption goods, corn and land.[9] There is a fixed amount of land $\bar{L}$, infinitely durable as it does not depreciate. We denote by p_t the relative price of land in terms of corn.

Households Each generation consists of a unit mass of households. Households have a quasi-linear utility function $U(c_{t+1}, L_t) = c_{t+1} + v(L_t)$, where c_{t+1} denotes consumption of corn when old, and L_t are land holdings at the end of period t. The function $v(L)$ with $v'(L) > 0$, $v''(L) < 0$ captures the utility households achieve from living in their house. The initial old generation is endowed with all initial assets, such as firm shares and land. A fraction ϕ of households $(i = h)$ is born with high human capital and offers $\tilde{h}$ units of high-skill labor, while the rest $(i = l)$ provides $\tilde{l}$ units of manual labor. Both types of labor endowments are supplied inelastically.

Representative Firm There is an infinitely-lived representative firm in a competitive market, set up in the initial period with a mandate for value maximization. It has access to a nested CES production technology that uses as inputs physical capital K_t, highly complementary with manual labor l_t, as well as intangible capital H_t, complementary with high-skill labor h_t. Aggregate output thus equals

$$F(K_t, H_t, l_t, h_t) = A\left[\eta(H_t^{\alpha} h_t^{1-\alpha})^{\rho} + (1-\eta)(K_t^{\alpha} l_t^{1-\alpha})^{\rho}\right]^{\frac{1}{\rho}}. \tag{1}$$

where A reflects a common productivity factor, η measures the relative productivity of intangible capital and high-skill labor versus physical inputs, α is the capital share, and ρ is related to the elasticity of substitution between physical and intangible factors.

The firm can invest $I_{K,t}$ units of corn at t to install $K_{t+1} = I_{K,t}$ units of physical capital, to be used in production at $t + 1$. In contrast, intangible capital is created by innovative skilled

[9] We do not distinguish between houses and land, and will use the terms interchangeably.

workers. Both types of capital fully depreciate after production, and the firm starts with an initial stock (K_0, H_0). Households trade shares in the representative firm at the endogenous price f_t, which quantity is normalized to 1.

Intangible Capital The creation of intangible capital requires co-investment by the firm and its creative employees. Here we assume all intangible value is generated by a subset of skilled innovators at no monetary cost.[10] A fraction ε of high-skill workers can exert effort at a non-pecuniary utility cost of $C(I_{H,t}) = \frac{\psi}{2} I_{H,t}^2$, to create intangible capital $H_{t+1} = I_{H,t}$ next period.

Intangible capital creation requires creators to commit their human capital until production next period. As human capital is inalienable (Hart and Moore, 1994), innovators may leave before production, taking a fraction ω of intangible assets. Firm thus need to offer deferred compensation that pays after production at $t+1$, and innovators capture a significant fraction ω of intangible value, with firms appropriating the rest. As the value of innovation increases, the innovator share rises.[11]

Financial Claims All firm profits are verifiable, so the inalienability of innovative human capital is the only contractual friction. No claims may be issued at t against intangible value appropriated by innovators at $t+1$ (as opposed to the share captured by the firm).

In the basic setup there is no uncertainty nor other frictions, so firm equity and debt are equivalent. For illustration we refer to external financing as borrowing when backed by land or by physical capital, and as external equity for claims backed by the fraction $(1-\omega)$ of intangible capital that firms can appropriate and assign to investors. Households can thus invest in shares and corporate debt. As compensation to human capital is deferred, firms do not become financially constrained as their future return is fully pledgeable. Firms pay out all profits as dividends denoted d_t, though our results do not depend on their payout policy.

[10] In reality firms need to fund some intangible investment spending, such as advertisements, patent purchases and basic salaries. See Döttling et al. (2019) for a model in which firms need to incur some investment cost in intangible capital.

[11] In this setup any wage paid at $t=1$ does not restrict the ability of employees to leave at $t=2$.

4.1. Households

Households supply their labor endowment inelastically to the representative firm, receiving income when young. Labor income is $y_t^i \in \{w_t\tilde{l}, q_t\tilde{h}\}$ where w_t denote wages for manual workers and q_t are wages of high-skill workers. Households can buy a house L_t for own use, and sell it to the next generation when they are old, earning some utility plus any price appreciation. As households only consume in retirement at $t+1$, they use all wage income for house purchases and retirement savings.[12]

Next to housing, households can buy shares at a price f_t and corporate or mortgage debt D_t. We refer to households with $D_t \geq 0$ as lenders, and $D_t < 0$ as borrowers. While most households have no income when old ($y_{t+1}^i = 0$), innovators receive capital income from the intangible capital they created, $y_{t+1}^i > 0$.

The maximization problem of a household is:

$$\begin{aligned} &\max_{c_{t+1}, L_t, S_t, D_t} U(c_{t+1}, L_t) = c_{t+1} + v(L_t) \\ s.t. \quad & p_t L_t + f_t S_t + D_t \leq y_t^i \\ & c_{t+1} \leq y_{t+1}^i + p_{t+1} L_t + (f_{t+1} + d_{t+1}) S_t + (1 + r_{t+1}) D_t \\ & c_{t+1}, L_t, S_t \geq 0 \end{aligned} \tag{2}$$

The first two constraints reflect budget conditions for young and old respectively. At the optimum the budget constraints are binding, so housing demand is given by the first order condition w.r.t. L_t,

$$p_t = \frac{p_{t+1} + v'(L_t^i)}{1 + r_{t+1}}.$$

The price of housing reflects the discounted future house price plus its utility value. The relevant discount rate is either the borrowing interest rate (for a borrower) or the opportunity cost of investing (for a lender). In a competitive equilibrium they both equal r_{t+1}.

Note that housing demand is independent of income, as borrowing enables all households to consume the optimal amount of housing.[13] Hence, we interpret borrowing as taking out a mortgage, which allows equalizing the marginal utility of housing across agents with heterogeneous income.

[12] The simplifying assumption rules out any savings response as rate change, as it is indeed the case empirically, but is not critical to our results.

[13] We consider borrowing constraints in the extension on mortgage default.

The first order condition w.r.t. S_t yields a pricing equation for shares:

$$f_t = \frac{f_{t+1} + d_t}{1 + r_{t+1}}. \tag{3}$$

Investments in capital markets follows as a residual $D_t^i = y_t^i - f_t S_t - p_t L_t$. Households with $y_t^i \geq p_t L_t + f_t S_t$ have enough income to buy their house and invest the remainder. In contrast, those with $y_t^i < p_t L_t + f_t S_t$ need a mortgage loan.

4.2. Firm Investment Choice

Firms employ labor l_t and h_t, and invest in physical capital K_t, so as to maximize the infinite stream of dividends d_t:

$$\max_{K_t, l_t, h_t} \sum_{t=0}^{\infty} d_t \tag{4}$$

To finance physical investment firms raise $D_t^f = I_{K,t}$ on capital markets, and pay the equilibrium interest rate r_t. Since innovators capture a fraction ω of intangible value, dividends can be written as

$$d_t = F(K_t, H_t, l_t, h_t) - w_t l_t - q_t h_t - [I_{K,t} - D_t^f] - (1 + r_t) D_{t-1}^f - \omega R_{H,t} H_t.$$

Under perfect competition, workers and suppliers of funding for physical capital are compensated according to their marginal productivity, $w_t = F_{l,t}$ and $q_t = F_{h,t}$. Since firms are financially unconstrained they can always scale up tangible investment until $1 + r_t = F_{K,t}$

4.3. Creation of Intangibles

After creating intangible capital, innovators can leave to re-deploy a fraction ω of intangible capital at a competitor firm. Their ex-post compensation needs to match this outside option of value $\omega R_{H,t+1} H_{t+1}$. This compensation must be paid after production takes place, where $R_{H,t}$ is the value of intangible capital. Under perfect competition, $R_{H,t} = F_{H,t}$. Innovators incur an effort cost $C(I_{H,t}) = \frac{\psi}{2}(I_{H,t})^2$, to create $H_{t+1} = I_{H,t}$ units of intangibles at $t+1$, so they scale up their intangible creation until

$$\omega R_{H,t} = \psi I_{H,t-1}. \tag{5}$$

As the ratio H/K rises, so does the innovator capital share.

The firm is never financially constrained, since its intangible capital is self-financed by deferred compensation to innovators. The production function has constant returns to scale, so factors are compensated according to their marginal productivity. Competitive firms earn profits on the fraction $(1-\omega)$ of intangible value they can appropriate:

$$d_t = (1-\omega) R_{H,t} H_t.$$

In the setup there is no risk. For illustrative purposes we refer to external funding for tangible capital as debt.

4.4. Equilibrium

A competitive equilibrium is defined as an allocation $\left\{c_t^h, c_t^l, L_t^h, L_t^l, D_t^h, D_t^l, D_t^f, K_t, H_t\right\}_{t=0}^{t=\infty}$ and prices $\{w_t, q_t, R_{H,t}, R_{K,t}, r_t, f_t\}_{t=0}^{t=\infty}$, such that given prices

- households maximize their utility (2),
- innovators choose intangible investment (5),
- final good producers maximize dividends (4),

and land and capital markets clear.

Market clearing in the land market requires $\int_0^1 L_t^i di = \bar{L}$. Since land can be fully pledged, mortgages allow for an efficient homogeneous allocation of land, with $L_t^i = \bar{L}$ for both high-skill and manual workers.

In the capital market, total net savings by households equal labor income earned by the young generation minus their house purchases, $D_t = w_t\tilde{l} + q_t\tilde{h} - p_t\bar{L}$. Net savings are invested in debt $D_t^f = K_t$ and stocks f_t. Using that $w_t(1-\phi)\tilde{l} + q_t\phi\tilde{h} = (1-\alpha)Y_t$, financial market clearing can be written as

$$(1-\alpha)Y_t = p_t\bar{L} + D_t^f + f_t, \tag{6}$$

Thus total savings supply equals the supply of investable assets, namely housing, corporate debt and equity. Lower income households use mortgage debt to buy their house, borrowing from higher income household.

4.5. The Allocation of Savings in Steady State

The left hand side of (6) shows that all labor income is directed to retirement savings income, since households only consume when old.[14]

On the right hand side, net investable assets include housing, corporate debt and equity. In steady state the value of these assets can be written as

$$f = \frac{(1-\omega)RH}{r}, \tag{7}$$

$$p = \frac{v'(\bar{L})}{r}, \tag{8}$$

$$D^f = K. \tag{9}$$

Consider the effect of a rising share of intangible capital, so that over time firms need less external finance. Some savings are absorbed by rising share prices, reflecting the firm share $(1-\omega)$ of intangible value.

At the same time, a rising capital share is not investable as innovators capture a fraction ω of the return to intangible capital. This results in a savings surplus that pushes down interest rates. As a result, the savings surplus is stored in higher long term asset values.

High house prices may push up the demand for credit by low-skill households to purchase a house. The steady state level of mortgage debt is given by:

$$m \equiv \max\left\{0, (1-\phi)(pL + fS - w\tilde{l})\right\}.$$

5. Explaining Secular Trends

This section considers alternative drivers behind long-term trends. In our setup, long-term trends may be due to either changes in factor productivity or changes in factor supply. Technological growth drivers are described by changes in aggregate productivity A as well as factor-specific factors such as η, ψ and α. The supply of labor, capital or savings may be affected by demographic change, globalization, capital flows and education levels.

The goal is to evaluate what growth drivers can best account for all major trends identified in Section 3, and represented by

$$\mathcal{T} = \left\{ r\downarrow, \frac{H}{H+K}\uparrow, \frac{K}{Y}\downarrow, \frac{m}{Y}\uparrow, \frac{p}{Y}\uparrow, \frac{f}{Y}\uparrow, \frac{q}{w}\uparrow \right\}.$$

[14] Our results do not rely on this assumption. What matters is that the elasticity of savings with respect to interest rates is not too high.

5.1. Growth Drivers

Each driver offers a parsimonious interpretation of recent growth. But which driver by itself best matches the observed evolution of moderate growth, shifting capital composition and rising asset prices in a long-run equilibrium allocation?

Clearly, a traditional Solow growth rise in the common productivity factor A would simply rescale the economy with no distinctive trends.

- A greater ease of innovation (a fall in ψ), e.g. due to an IT-induced reduction in the cost of producing intangible capital would increase its supply and may lead to higher rewards for scarce skilled labor. This technological growth driver is weakly redistributive, and does not imply lower productivity of physical factors. As a result also unskilled labor and physical capital benefits (in absolute, not relative terms) under even a modest degree of complementarity.

- A more radical technological shift (a rise in η) leads to higher productivity of intangible and innovative human capital and falling productivity for physical capital and labor. Such a shift is consistent with positive growth provided there is adequate skilled human capital. A falling absolute productivity of physical factors may be due to new technologies that replace labor and capital equipment, as well as by a shift in comparative advantage for physical production vis a vis emerging economies.

- A rising share of educated workers (an increase in ϕ) can explain the rise in intangible capital. It would also lead to more innovative capacity.

- A rising productivity of capital relative to labor would explain a historical fall in the labor share since the 1970s (Barkai, 2016). In the model it is described by a rising α.

- Radical changes in IT and internet technology may have led to an increased bargaining power for innovators over established firms, and can be described by a rising ω. Such a shift encourages intangible capital creation and can explain a decline in investable assets.

- Capital inflows from surplus emerging countries into the developed world offers a major contribution to a savings glut (Caballero and Krishnamurthy, 2009; Forbes, 2010). They are easily introduced as an exogenous savings boost. Let net foreign investment over GDP be x_t, so that the financial market clearing condition becomes

$$(1 - \alpha + x_t)Y_t = p_t\bar{L} + D_t^f + f_t. \tag{10}$$

The set of drivers $\mathcal{G} = \{\eta, \psi, \phi, \alpha, \omega, x\}$ have a direct representation in our model, while other formulations can be reinterpreted. In a model with a richer life-cycle structure a rise in longevity leads to higher savings. This effect can be captured in reduced form as an exogenous increase in savings x_t.

Globalization since 1980 has been a first order factor of economic evolution. Technological diffusion first affected traditional industries, inducing relocation of physical production. It may be represented in reduced form in two forms, either as a rise in (external) labor supply or as a loss of comparative advantage in physical production (a rise in η).

The setup cannot easily incorporate changes in concentration (observed in the US, Gutiérrez and Philippon, 2016), the emergence of winner-take-all competition and disruptive entry. Higher market power can explain high equity valuations and low investment. Analysing its effects on investment composition and relative wages would requires finer microfoundations beyond the scope of the model.

5.2. Analytical Results

This section assesses analytically whether changes in growth drivers $\mathcal{G}$ can predict all trends $\mathcal{T}$. It assumes an initial steady state around 1980 and a final steady state around 2015, and examines the comparative statics results for all drivers. We adopt here the nested formulation of Cobb-Douglas production (as $\rho \to 0$), while the general CES case is discussed in the Appendix A.

Specific changes in each driver can explain positive economic growth, as well as some trends. The main challenge is to explain the combination of a falling corporate borrowing $\frac{D^f}{Y}$ and physical investment $\frac{K}{Y}$, even during a phase of falling rates r. To see this, consider the steady-state interest rate:

$$1 + r = \alpha(1 - \eta)\frac{Y}{K}, \tag{11}$$

In a steady state equilibrium, a fall in the interest rate is associated with a rising ratio $\frac{K}{Y}$, unless either η rises or α falls. The second possibility is inconsistent with evidence on the falling labor share (e.g. Dorn, Katz, Patterson, Van Reenen, et al., 2017). If productivity shifts to non-investable capital as η rises, both $\frac{K}{Y}$ and r may drop. All other growth drivers produce a falling $\frac{K}{Y}$ only if rates increase. This leads to the main analytical result:

Theorem. *Among all growth drivers in $\mathcal{G}$, only a strongly redistributional technological progress that shifts productivity from physical to intangible factors (an increase of η) can simultaneously produce a fall in r and $\frac{K}{Y}$. Hence, it is the only candidate driver that may individually explain all observed trends in $\mathcal{T}$.*

This result establishes that only a structural decline in the productivity of physical factors at the technological frontier can explain why traditional investment and borrowing falls along its price r.

Why do other individual drivers fail in explaining some secular trends? Drivers associated with an increase in savings include capital inflows, or (outside our model) an ageing population. Such drivers are able to explain falling interest rates, but cannot explain why excess savings did not flow to firms to fund physical investment.

Drivers that directly boost the rate of innovation can explain the increase in intangible assets, and include a falling cost of creating intangibles (falling ψ), an increase in education (rising ϕ), or an increase in the income appropriated by innovators (rising ω). However, under these drivers physical factors benefit indirectly, by general complementarity between factors (see further discussion in Section 6).

5.3. Stronlgy Redistributive Growth

Under what conditions can rising η generate all other trends in $\mathcal{T}$? A direct effect is that the ratio of intangible to physical increases, due to its direct effect of the relative productivity of intangible capital in the production function (1). Similarly, a rising η directly produces a rising income inequality $\frac{q}{w} = \frac{\eta}{1-\eta}\frac{\tilde{l}(1-\phi)}{\tilde{h}\phi}$.

As long as ω is not too small and output growth modest, a change in η can indeed replicate all trends $\mathcal{T}$. We describe next the key results, all derived in Appendix B. The intuition is that by general factor complementarity, growth also stimulates physical investment. As long as the effect of η on growth is not too strong, the direct negative effect on factor productivity dominates, resulting in a falling equilibrium ratio of $\frac{K}{Y}$:

Lemma 1. *If* $\frac{dY/d\eta}{Y} \leq 1-\eta$*, then rising* η *results in falling* $\frac{K}{Y}$*:*

$$d\left(\frac{K}{Y}\right)/d\eta \leq 0$$

The financial market clearing condition (6) illustrates the effect of a falling K/Y on the equilibrium allocation of savings. As retirement savings are inelastic to rates, the direct effect of a lower K/Y is a boost in house and/or share prices as alternative savings vehicles:

$$(1-\alpha) = \frac{p}{Y}\bar{L} + \frac{f}{Y} + \frac{K}{Y}.$$

As long as ω is sufficiently large, excess savings reduce interest rates and are re-directed towards housing:

Lemma 2. *Suppose the direct effect of* η *dominates (as in Lemma 1). Consider the limit as the innovator share* $\omega \to 1$*. When growth is positive, a rising* η *results in falling interest rates* r *and rising house prices relative to income* p/Y*:*

$$dr/d\eta \leq 0$$

$$d\left(\frac{p}{Y}\right)/d\eta \leq 0$$

When ω is large most intangible value is not investable, so excess savings are not fully absorbed by higher share prices. In this case η is able to explain all trends, as confirmed by the quantitative exercise in the next section.

Steady state share prices can be written as

$$\frac{f}{Y} = (1-\omega)\frac{\alpha\eta}{r}. \tag{12}$$

Firm equity value increases in η via a direct effect of an increase in intangible value captured in share prices, and indirectly by lower interest rates. House prices over income $\frac{p}{Y}$ also rise as rates fall since land is in fixed supply. Excess savings enable to fund a higher mortgage credit demand. For the case of a positive demand for mortgages, the steady state value of $\frac{m}{Y}$ is:

$$\frac{m}{Y} = (1-\phi)\frac{p}{Y}\bar{L} - (1-\alpha)(1-\eta). \tag{13}$$

Clearly, with $\frac{p}{Y}$ rising, higher η results in more mortgage credit.

5.4. Shifts in the labor and capital share

A rise in the relative productivity of intangible versus physical assets generalizes the redistributive results in the labor literature concerning the impact of automation and IT progress on skilled and unskilled wages. A rise in η leads to a rising skill premium, and potentially to a decline in absolute labor wages. Such a productivity shifts can also account for changes in the capital income share, reallocating value from investors to innovators.

The steady state return on intangible capital captured by innovators (scaled by GDP) can be written as

$$\frac{\omega H R_H}{Y} = \omega \alpha \eta,$$

It is immediate to see that it rises as η increases.

To summarize, as long as output growth is positive but not too strong and ω is sufficiently large, K/Y and r indeed both fall in response to rising η. Under these conditions a rising η also predicts the direction of all major trends in $\mathcal{T}$. A rising η can uniquely reproduce large redistributive effects within both the labor and capital income share, as well as on the reallocation of credit and the rise in household leverage.

Clearly, in reality no driver alone explains long-run economic change. Our goal is to show how a redistributive technological shift does offer a consistent and parsimonious interpretation for the combination of falling interest rates and investment as directly reflecting a falling marginal productivity of capital assets that can be funded externally.

The next section uses a simple calibration to assess further how well alternative formulations of the growth process can match observed trends in a numerical exercise.

6. Empirical Assessment

The long-term framing of our overlapping generation model aims to capture low frequency trends, rather than higher frequency oscillations. The time frame of the model assumes that all capital depreciates in one period and agents live only two periods, so its quantitative evaluation cannot match shorter frequency cycles. Moreover, some growth drivers considered are hard to measure and slow moving. In reality markets do not operate under full information and no financial constraints. The period since 1980 has seen high uncertainty and major fluctuations driven by real and financial shocks as well as asset bubbles which a full foresight model cannot aspire to match.

This section assesses the plausibility of each growth interpretation in explaining long-term trends. Our numerical exercise presumes an initial steady state in 1980 and a final steady state in 2015. We use these endpoints to extract an implied change for each growth drivers by calibrating the growth in the intangible capital ratio. We then compare the predicted direction and scale of unmatched major trends for all drivers.

The results indicate that a shift in η explains not just the sign but the rough magnitude of trends, particularly after controlling for external factors such as capital inflows.

6.1. Calibration to 1980

We calibrate the initial values of parameters $\alpha, \bar{L}, A, \phi, \rho, \eta, \beta, \tilde{h}$ and $\tilde{l}$, whenever possible to actual 1980 data. The capital share is set $\alpha = 0.33$ (a standard value in the literature) while ϕ is set at the share of the population with a Bachelor degree in 1980, namely $\phi = 0.2$. We assume a log utility for housing consumption $v(L) = \ln(L)$. The value of ρ is calibrated from the estimated elasticity of substitution between skilled and labor workers from the literature (Acemoglu and Autor, 2011), obtaining an elasticity at the center of the estimated range at 1.7. Building on calculations in Eisfeldt and Papanikolaou (2014) the value of ω is set to 0.55, so that human capital appropriates around half of intangible value. The value of x is set to 0, in line with a balanced U.S. current account in 1980. Values for $\bar{L}, A$ and ψ are set to one. We choose $\tilde{h}$ and $\tilde{l}$ such that the aggregate supply of skilled labor is equal to the aggregate supply of unskilled labor, $\phi\tilde{h} = (1-\phi)\tilde{l} = 10$. The remaining free parameter η is set to $\eta = 0.45$, so as to match the observed intangible ratio in Compustat data in 1980 at $\frac{H}{H+K} = 0.4$.

We next evaluate how well each driver matches the direction and relative scale of observed trends over 1980-2015, implying the change in each drivers by matching economic growth and the change in the intangibles ratio. We then compare how well the trends produced by these drivers match those observed in the data.

We start from assessing the quantitative prediction for a strongly redistributive productive shift in η, then consider alternative explanations.

Data

	Intangible Ratio	Net corp. liabilities / GDP	Real rate	Mortgages / GDP	Land values / GDP	Stock mkt. cap / GDP
Δ 1980 - 2015	50%	-86.2%	-72.3%	86.2%	37.1%	201.1%

Model

	H/(H+K)	K/Y	r	m/Y	p/Y	f/Y
$\eta \uparrow$	50.4%	-43%	5.1%	278.9%	0.8%	46.6%
$\eta \uparrow (\omega = 0.9)$	50.8%	-42.2%	-1.5%	349.3%	7.3%	67%
$\eta + x \uparrow$	50.6%	-41.8%	-36.5%	780.1%	63.5%	160.5%
$\eta + A, x, \phi \uparrow$	50.1%	-42.8%	-45.8%	695.5%	39.9%	280.7%

Table 1: Relative changes across steady states implied by changes in η.

6.2. Redistributive Growth

In Table 1, the top panel reports the relative change in the key trends over 1980-2015 in the data, taken from Section 3. In this phase the intangibles ratio has grown from around 0.4 to 0.6 (see Figure 1), while net corporate liabilities and real rates have fallen by around 86% (Figure 3), and 72%, respectively. We calculate the increase in mortgage credit to GDP using Flow of Funds data.[15] Land values are taken from Davis and Heathcote (2007), and scaled by nominal GDP.

The lower panel shows the value implied by the implied changes in η. Specifically, the first row of the lower panel allows only changes in η so as to generate an increase in the intangibles ratio of 50%, keeping all other parameters constant as in the baseline calibration. In this calibration, η alone explains the direction of all trends except the interest rate (red numbers indicate an incorrect trend prediction). The second row shows η alone can generate a modest fall in rates under a larger value $\omega = 0.9$, where almost all intangible value is captured by innovators. A strongly redistributive growth just by itself generates the right sign for all trends only in case of a large loss in investables that pushes down interest rates, in line with the analytical result in Lemma 2.

A necessary adjustment for a model of US saving supply are massive capital inflows rising over time. During the credit boom years 2002-2007 the US received 7.8 trillion dollar, a

[15] Mortgage credit is defined as the total amount of home mortgage debt outstanding by households and nonprofit organizations in the Flow of Funds.

most significant funding boost (Forbes, 2010). Once we adjust x to reflect this large inflow of savings by BEA data on the U.S. net international investment position (from 0 to 0.4), η can explain the sign for all observed trends even at a smaller number $\omega = 0.55$, as the savings glut helps pushing down interest rates further. However, note that by itself a savings glut cannot explain why extra funding did not flow into physical investment, so the rise in η along x is still necessary.

The fourth row adds the change in education level. The fraction of skilled households ϕ rises from 0.2 to 0.3.[16] This adjustment affects both intangible creation and savings supply. The adjustment for the common factor A of 40% is based on an annual TFP growth of around 1% over a 35-year time span. Relative to capital inflows, these adjustments do not change the overall performance too much.

6.3. Alternative Drivers

Table 2 examines other drivers. A technological interpretation is a greater ease of innovating (a falling cost of producing intangibles ψ). This driver boosts the scale of valuable intangible capital and can result in falling rates. However, lower rates would induce an increase in K/Y and a drop in land values. The driver would predict even higher growth in K/Y when accounting for foreign capital inflows.

Technological change driven by general purpose IT technology may have enhanced the ability of innovators to capture a rising share of capital returns, and thereby boost the supply of intangibles. The third and fourth rows of Table 2 suggest that this effect is relatively weak. In fact, once we also account for capital inflows, a rise in ω even leads to a fall in the intangible ratio. The key insight is that the supply of innovation is not very elastic to its price, so a rising return does not lead to a large expansion in innovative capital. Moreover, the indirect effect of a higher ω is a reduction in investable assets, and thus interest rates, which favors physical investment. We observe similar effects for rising education levels ϕ in rows 7 and 8.

A rising income share of capital α is consistent with the observed rise in the overall capital share, and can replicate the rise in intangibles and their value (fifth and sixth rows). However, it results in falling savings supply from workers and rising productivity of physical capital, implying rising equilibrium interest rates. The first effect may be reversed by wealth

[16]This is measured by the evolution over 1980-2015 in the US population with a Bachelor degree.

Data

	Intangible Ratio	Net corp. liabilities / GDP	Real rate	Mortgages / GDP	Land values / GDP	Stock mkt. cap / GDP
Δ 1980 - 2015	50%	-86.2%	-72.3%	86.2%	37.1%	201.1%

Model

	H/(H+K)	K/Y	r	m/Y	p/Y	f/Y
$\psi\downarrow$	49.5%	0.4%	- 12.5%	24.9 %	- 4.3 %	21.3%
$\psi\downarrow + x\uparrow$	50.5%	20.7%	-51.5%	456%	57.1%	119%
$\omega\uparrow$	10.5%	7.5%	-19.4%	-4%	15.8%	-86%
$\omega + x\uparrow$	-2.4%	28.9%	-54.1%	418.5%	93.9%	-75.9%
$\alpha\uparrow$	50.7%	-19.8%	158.4%	4%	-16.1%	-41.4%
$\alpha + x\uparrow$	50.3%	3.8%	113.7%	405.2%	44.2%	-17.9%
$\phi\uparrow$	40.1%	0.4%	-10.2%	-70%	-3.5%	16.9%
$\phi + x\uparrow$	26.1%	21.7%	-48.4%	35.5%	60.6%	100.1%

Table 2: Relative changes across steady states implied by different drivers.

accumulation over time by high earners, but the effect on capital investment would persist, contradicting the evidence.

6.4. Cross-country evidence

According to the model, excess savings may arise as intangible use by firms reduces credit demand. We further examine this empirical relationship in a panel of OECD countries, seeking to account for the evolving national share of mortgage credit to total credit shown by Jordà et al. (2016) in terms of the national rate of adoption of new technology. The exercise is aimed at establishing a correlation and has no ambition to claim any empirical validation for the interpetation.

The intangible capital measure across OECD countries is drawn on National Accounts, available through the INTAN-Invest project (see Corrado, Haskel, Iommi, and Jona Lasinio, 2012). As an alternative measure we use Compustat Global firm data, estimating intangibles by capitalizing R&D and SG&A expenditures as in Peters and Taylor (2016).[17]

Table 3 presents the results of pooled OLS regressions using both intangible ratio measures,

[17]For details see Döttling et al. (2017). Compustat Global data coverage is from 1989 to 2015, the INTAN-Invest series from 1995 to 2010. These measures are strongly correlated, with an average of 0.82.

Table 3: Cross country evidence on mortgage credit and intangible investment

Mortgage Ratio is the ratio of mortgage to total credit. *Intangibles Ratio* is the ratio of intangibles to total assets. Reported t-statistics based on errors clustered at the firm level. ***, **, * indicate significance at 1%, 5%, and 10% level. All independent variables are lagged one year.

	(1)	(2)	(3)	(4)
	Mortgage Ratio	Mortgage Ratio	Mortgage Ratio	Mortgage Ratio
Intangibles Ratio (INTAN-Invest)	0.777^{***}	0.706^{***}		
	(5.00)	(4.05)		
Intangibles Ratio (Compustat)			0.299^{***}	0.432^{***}
			(3.29)	(3.34)
Log GDP per capita		0.00360		-0.870
		(0.04)		(-1.70)
Current Account		0.00175		0.00928
		(0.40)		(1.37)
Year Fixed Effects	No	Yes	No	Yes
Observations	263	263	264	264
Adjusted R^2	0.402	0.392	0.152	0.270

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

controlling for GDP per capita and capital inflows. In all specifications, a higher intangibles ratio is significantly associated with more mortgage credit and its impact is of economic significance.[18]

The cross-country correlations confirm US evidence (Dell'Ariccia et al., 2017) that rising intangible capital results in reduced funding demand by firms, inducing their banks to increasing mortgage lending.

6.5. Rising Default Risk and Policy Issues

A natural question is whether a growing supply of mortgage credit may compromise financial stability (Jordà, Schularick, and Taylor, 2015), as it increases household leverage (their mortgage debt to income ratio), as a redistributive growth path produces a rising ratio of house prices to unskilled labor income. Intuitively, a rise in household leverage produces more frequent mortgage defaults even with a constant risk factor. In an earlier working paper version, we assess the effect of time-invariant uncertainty in house prices, by introducing "weather shocks" that may damage a house (Doettling and Perotti, 2017).

In this extension, mortgage default rates rise as η increases wage inequality along house prices, and labor workers end up with a higher loan to value ratios. However, as long as mortgage default is just an ex-post transfer with no aggregate welfare loss, there is no inefficiency that needs to be addressed by a Pareto-improving policy intervention, since the economy is dynamically efficient. However, such a policy does have interesting side effects. Limiting mortgage debt restricts the ability of of young home buyers to bid up house prices. This further decreases interest rates, and shifts some savings towards physical investment. In general equilibrium both output and labor wages grow because of the indirect subsidy to production. On the other hand, the old generation suffers a capital loss. An LTV limit benefits most those for whom the borrowing constraint becomes binding (unskilled labor), a consequence of lower equilibrium land prices and the subsidy to physical investment.

This result mirrors Deaton and Laroque (2001), who show how introducing land in an OLG growth model absorbs savings, so that there is generally an under-accumulation of capital. It also relates to empirical evidence in Chakraborty, Goldstein, and MacKinlay (2018), who find

[18] A one percentage increase in the intangibles ratio raises the share of mortgage credit by 0.3 and 0.78 percentage points.

that the housing boom in the 2000s crowded out real investment. Our model highlights that such effects may be stronger in a knowledge economy where technology leads to an excess of savings over investment.

7. Conclusion

We offer a neoclassical view of redistributive growth, driven by a form of technological change that favors skilled labor and intangible factors. Our goal is to offer a parsimonious explanation for the main driver of major long term trends in developed countries in the last decades. The key challenge is to account for a persistent excess of savings over productive investment in a phase of falling interest rates, often defined as "secular stagnation".

The analytical results suggest that a rising return to intangible capital that produces modest positive growth cannot compensate for declining productivity of physical factors, so firms decrease physical investment and leverage despite their falling cost. The resulting savings surplus is stored in increasing house and share prices, while more credit flows to mortgage credit to meet a rising demand. The model accommodates a redistributive shift in factor productivity and capital shares along with the redistributive shift documented in the labor share (Acemoglu and Autor, 2011).

Our result on the implied evolution of relative factor productivity in developed economies is certainly reinforced by their growing specialization in high intangible industries, while some physical production is relocated to emerging markets.

The long term setup offers a clear interpretation of major trends in labor, capital and asset markets in terms of technological change and the changing role of human capital. While it is unsuited for a high-frequency calibration exercise, we show that a simple quantitative exercise can roughly explain the scale of major economic changes. Ultimately, a redistributive growth interpretation needs to be validated by more granular empirical work on its specific channels. Closely related evidence is offered by Dell'Ariccia et al. (2017), who show that as U.S. firms increase their share of intangibles, their creditor banks shifts to more real estate funding.

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Appendix A General case

In the more general CES case (not restricted to Cobb-Douglas), the steady-state interest rate (11) can be expressed as

$$1 + r = A^{\rho}\alpha(1-\eta)\frac{Y^{1-\rho}}{K^{1-\alpha\rho}}l^{(1-\alpha)\rho} \tag{A.1}$$

Relative to the Cobb-Douglas case, the interest rate still depends on $\frac{K}{Y}$, though not linearly. The new parameters that show up are ρ, A and l. A decrease in A or l could also explain simultaneously falling $\frac{K}{Y}$ and r. However, this would also lower output, while on average US real GDP has grown by more than 2% a year since the 1980s. The effect of ρ on the secular trends is ambiguous, but changing complementarity between intangible and tangible capital seems an implausible driver behind the relevant secular trends.

Appendix B Strongly Redistributive Growth

This appendix elicits that as long as rising η results in positive but not too extreme growth such that $\frac{1}{1-\eta} \geq \frac{dY}{d\eta} \geq 0$, then it can produce all trends $\mathcal{T} = \left\{r\downarrow, \frac{H}{H+K}\uparrow, \frac{K}{Y}\downarrow, \frac{m}{Y}\uparrow, \frac{p}{Y}\uparrow, \frac{f}{Y}\uparrow, \frac{q}{w}\downarrow\right\}$. As a first step we collect the relevant equations and evaluate them in steady state. The steady-state equilibrium for the variables r, R_H, K, H, f, p and Y is defined by the following set of equations, together with the production function (1):

$$1 + r = \alpha(1-\eta)\frac{Y}{K} \tag{B.1}$$

$$R_H = \alpha\eta\frac{Y}{H} \tag{B.2}$$

$$H = \frac{\omega}{\psi}R_H \tag{B.3}$$

$$f = \frac{(1-\omega)R_H H}{r} \tag{B.4}$$

$$p = \frac{v'(\bar{L})}{r} \tag{B.5}$$

$$(1-\alpha)Y = p\bar{L} + f + K \tag{B.6}$$

As a first step, Lemma 1 shows under what conditions K/Y falls in response to η.

Proof of Lemma 1 Focusing on $\omega \to 1$, by (B.4) $f \to 0$. Using this, the market clearing condition (B.6) simplifies to

$$(1-\alpha) = \frac{p}{Y}\bar{L} + \frac{K}{Y} \tag{B.7}$$

Proof. Plugging (B.5) and (B.1) into (B.7), and solving for $\frac{K}{Y}$ yields the following expression:

$$\frac{K}{Y} = \frac{1-\alpha}{1 + \frac{v'(\bar{L})\bar{L}}{\alpha(1-\eta)Y}}$$

Clearly, $d\left(\frac{K}{Y}\right)/d\eta \leq 0$ if and only if $d[(1-\eta)Y]/d\eta \leq 0$. Evaluating

$$\frac{d[(1-\eta)Y]}{d\eta} = -Y + (1-\eta)\frac{dY}{d\eta} \leq 0$$
$$\Leftrightarrow \frac{dY/d\eta}{Y} \leq 1-\eta$$

□

Next, Lemma 2 shows that rising η additionally results in falling interest rates, as long as output growth is positive.

Proof of Lemma 2

Proof. Note that falling $\frac{K}{Y}$ implies rising $\frac{p}{Y}$ by market clearing (B.7). With $\omega = 1$, house prices must rise to absorb excess savings. Observe that from (B.5)

$$\frac{p}{Y} = \frac{v'(\bar{L}}{rY}.$$

Hence, an increase in $\frac{p}{Y}$ implies a drop in rY. As long as $dY/d\eta \geq 0$, it therefore follows that $dr/d\eta \leq 0$ □

From Eq. (13), it is clear that with $\frac{p}{Y}$ and η rising, it must also be that mortgage credit $\frac{m}{Y}$ rises.

Wage inequality depends on η and the relative supply of skilled and unskilled workers, and increases in response to η:

$$\frac{q}{w} = \frac{\eta}{1-\eta}\left(\frac{\tilde{l}(1-\phi)}{\tilde{h}\phi}\right)$$

Finally, to see that share valuations rise, use Eqs. (B.4) and (B.2) to write them as

$$\frac{f}{Y} = (1-\omega)\frac{\alpha\eta}{r}.$$

Clearly, with falling rates, an increase in η must result in rising share values. This completes the proof for all trends in the set $\mathcal{T}$.