8 Concluding Remarks on the Negative Natural Rate of Interest

Abstract

The Great Divergence: The period of production T is not rising anymore. The "waiting period" Z is rising over time with the rising standard of living and rising life expectancy, and this is the case worldwide. In the interest of full employment, the public debt period D has to compensate for this divergence: $T = Z - D$. Using an extrapolation procedure that we have developed and the available empirical data, we calculate total private wealth in the OECD plus China region. Net public debt already accounts for nearly half of private wealth today. COVID-19 increases the optimal steady-state public debt period. Both our theory and our empirical findings are increasingly confirmed by the work of other economists: for example, by Lawrence Summers' secular stagnation thesis and by the study of Jordà, Schularick and others on the secular evolution of private wealth.

8.1 The Great Divergence

In the first part of our book, we have found that almost one half of private wealth in the OECD plus China region consists of net claims on the state. Using our analytical method, we arrived at the conclusion, moreover, that there is a secular increase in the share of net public debt in total private wealth. We will first summarize the procedure that leads to this result. Given the numerous trees, this review is also intended to help the reader still to recognize the forest as such.

Our point of departure is the reflection that we can use the method of steady-state analysis that is commonly employed in capital theory. (Cf. Chap. 2 and Weizsäcker 2021.) Steady-state analysis has a long tradition in economic theory: starting with the Physiocrats, whose most important representative, François Quesnay, published the *Tableau Économique* (Quesnay 1758), and continuing through Adam Smith,

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who used the physics of Isaac Newton as his model, in order to derive the "natural prices" of commodities in his *Wealth of Nations* (Smith 1776). This tradition went on then via Ricardo, John Stuart Mill, Marx, Walras, Marshall, and Böhm-Bawerk up to Solow (1956) and Debreu (1959) and finally to the present day. But this sort of steady-state analysis or equilibrium analysis is also a pillar of every natural science. We can mention ecology as an example. Ecology is the science of equilibria in living nature. The concept of sustainability, which has become a key objective of government policy nowadays, is derived from it.

On the basis of a steady-state analysis, it is possible to recognize secular trends. We do this by using *two time concepts*: the period of production T and the waiting period Z. The equilibrium between supply of and demand for capital gets established via the real interest rate r and the public debt period D. The latter is the third time concept and it serves as the bridge between the first two: At the optimal interest rate $r = g$, the equation $T = Z - D$ corresponds to full employment equilibrium.

We find that the *Great Divergence* is a secular trend: Whereas the period of production, i.e., relative capital requirements, is almost constant over time, the waiting period Z, i.e., relative capital supply, has a secular tendency to increase. Over time, a gap thus comes into being: a growing divergence between Z and T. This has to be bridged by a growing public debt period D.

There are two reasons for the *Great Divergence*:

One is the limit to the "greater productivity of more roundabout production" (Böhm-Bawerk). We also call this the "*limit to the greater productivity of more complexity*." There is a danger of overcomplexity. There is the danger of excessive division of labor, of overspecialization. And it seems that an average time lag of a few years between the original input (labor and land) and the ultimate output (consumer goods) marks the degree of roundaboutness that maximizes the yield of the original factors of production. Beyond this point, productivity goes downhill again.

One of the reasons for this in turn—perhaps indeed the main reason—is technical progress: the increase in useful knowledge to which human civilization constantly gives rise. Due to this constant changing of our knowledge, the intermediate products comprising the real capital stock become outdated. Hence, they cannot be allowed to become "too old," and they are replaced. This is why there are limits to how much capital can be usefully tied up in the production process, and this is why *the capital coefficient tends to be constant over time*: which is to say, why *the period of production tends to be constant over time*. The low interest rates that have prevailed for some time now suggest that the OECD plus China economic area that we are examining is already close to the degree of roundaboutness of production that maximizes the yield of the original factors of production, labor and land.

The second reason for the Great Divergence also has to do with change or progress in our knowledge. This is the "*law of the increasing future-directedness of human action as prosperity increases*." The higher the level of prosperity, the greater is relative desired wealth: i.e., the ratio between planned wealth and current consumption. We call this ratio the *wealth coefficient*. This law of a growing wealth coefficient is the same as the law of a growing private waiting period Z. At the prosperity-maximizing rate of interest $r = g$, the overall period of production T is equal to the *overall waiting period* $Z - D$. The latter is the sum of the private waiting period Z and the public waiting period—D, which corresponds to the normally negative net asset position of the state. Since the period of production and the overall economic waiting period are equal in the optimum, we also call the corresponding equation $T = Z - D$ the *Fundamental Equation of Steady-State Capital Theory*. (Cf. Chap. 2 and Weizsäcker 2021.)

The rising private waiting period reflects the rise in *life expectancy* as prosperity increases. For nowhere in the world is there a parallel rise in the average retirement age. Hence, the time during which people receive retirement benefits is rising, and parallel to it, so too is the saving rate during their active working lives. The savings triangle gives graphic expression to these relationships (cf. Sects. 3.1 and 3.2). Despite the simplification it involves, it provides, for example, a good approximation of the facts for Germany.

Globally rising life expectancy is thus a key aspect of the Great Divergence. At the same time, it is also a side effect of the rising standards of living in many poorer countries: in particular, in developing countries. This is the part of the world that does not belong to the OECD plus China region that is the focus of our investigations. In the course of the twenty-first century, however, we can expect that private desired wealth in a significant number of countries in this part of the world will also come to exceed capital requirements. It is already the case today that more wealth is exported from these countries into the OECD plus China region than vice-versa (cf. Sect. 3.11).

8.2 Implicit Public Debt

Even today, the Great Divergence is far from being acknowledged as such by all economists. This is because up to now implicit public debt has not generally been recognized as public debt, including in the official statistics. As our investigations show, especially in Chap. 6, explicit net public debt for the OECD plus China region is merely the tip of the iceberg. Floating in the water underneath it is the far larger remainder of the iceberg in the form of implicit public debt. The latter is to a great extent a reflection of the welfare state that has been developed in this area.

Social security protection for old age, illness and unemployment is a core component of the modern welfare state. The protection that citizens are afforded by social security is tantamount to protection by way of property ownership. Social security retirement benefits make this particularly clear. The retirement system creates property in the form of entitlements vis-à-vis the state. If, analogously to private insurers, the state had formed reserve funds to cover these entitlements, then the former would offset the latter and social security would not have led to additional net public debt. But in the overwhelming majority of cases, no such reserve funds have been formed. And for good reason, in our opinion. Such reserve funds would have caused a massive investment crisis in the OECD plus China region. They would have become a threat to the very people they were supposed to help. The market system would not have been able to cope with the investment pressure. Individual citizens would have found it difficult or downright impossible to plan for their futures. At best, considerable and prolonged inflation could have transformed *this* particular investment crisis into a *different sort of* investment crisis. Instead of an oversupply of capital, the high inflation would have made it impossible to secure the value of assets. Real capital would have flowed massively into economically unproductive investments.

8.3 The Natural Rate of Interest Is Negative

On our estimate, the net position of citizens vis-à-vis the state is about six times the annual consumption of the population in the OECD plus China region (cf. Sect. 6.2)—at a real discount rate of zero, in any case. We can infer from this that the natural rate of interest is negative. The natural rate is, after all, the real full-employment rate that would apply, if citizens did not have any net position vis-à-vis the state (cf. Chap. 1). At a real interest rate of zero and without any net position of citizens vis-à-vis the state, there would be an enormous excess of capital supply as compared to capital demand at full employment. This excess would put pressure on returns, which would thus fall into the negative.

It is pointless to speculate about how far into the minuses the real interest rate would slide. Once the real rate becomes clearly negative, peoples' investment behavior changes. High inflation changes their subjective perception of what a relatively safe investment is. So long as inflation plays no role or only a minor one, investment in financial assets like savings accounts, fixed term deposits or highly rated bonds is regarded as the safest investment. If investors are very conscious of inflation, then certain tangible assets, like gold or real estate, are regarded as the safer investments. The "flight to tangible assets" often leads to investments that do not only have a negative overall economic impact, but whose "best available" return for the investor is in fact negative as well. If the state does not offer a better alternative by way of a policy of stable money and public deficits, people's strong orientation toward the future comes to nothing, disappointments are a foregone conclusion, inequality in the distribution of wealth is exacerbated, and the market economy will be voted out at the ballot box. Paradoxically, this failure of government then drives people into the arms of "Big Brother." Like in times of need, their attitude toward the future gets transformed from that of carefully planning for far-off goals to "run for your lives!": from an attitude of personal responsibility and providing for one's family to an attitude of doing whatever it takes to survive even at the expense of one's fellow citizens.

Under these conditions, when the Great Divergence has already come about, it is pointless to speculate about where exactly the negative natural interest rate is situated.

8.4 The Distribution of Wealth

The conventional view of wealth that has prevailed up to now also means a distorted view of the *distribution of wealth*. For implicit wealth in the form of entitlements to future retirement benefits and healthcare services is obviously distributed differently than the wealth that has been hitherto considered.

In a cross-sectional view, the saving rate for voluntary saving rises with disposable income and already available wealth. This applies even if we take into account the "permanent income hypothesis." These observations hold for all the OECD countries and also for China. The facts they describe stabilize or exacerbate the unequal distribution of wealth. This is reinforced by the fact that, on average, greater wealth also generates higher returns due to a greater willingness to assume risks and to economies of scale in portfolio management (Piketty 2014, Chap. 12).

Progressive income, property and estate taxes dampen the tendency toward greater inequality (Krämer 2020). But the existence of tax havens creates opportunities for avoiding progressive taxation. It is, above all, the very wealthy who can make use of these opportunities. Persons whose wealth is medium-sized and is often tied up in a family-owned business have far fewer opportunities of this sort.

Entitlements to future retirement benefits are, however, much more equally distributed than the classical wealth that we have just discussed. We are not able to provide any data here on the Gini coefficient for entitlement assets in the OECD plus China region. Nonetheless, it is clear that it must be considerably lower than for conventionally defined wealth. Determining the overall distribution of wealth in the OECD countries and China is an important research project that remains to be done. We are aware, however, of a comparative study on Germany and the USA that refers to 2013 (Bönke et al. 2019). According to this study, the Gini coefficient for conventionally defined wealth is 0.889 in the USA and 0.755 in Germany. For all wealth, including public retirement benefit entitlements, the Gini coefficient is 0.700 in the USA and 0.508 in Germany.

Given the secular trend toward an increasing share of implicit wealth in total wealth, it cannot be ruled out that, contrary to the claims of many commentators (cf., for example, Piketty 2014), inequality in the distribution of wealth has not increased as much as is often presumed.

8.5 Private Wealth at a Real Interest Rate of Zero

In the context of our thesis of a negative natural rate of interest, we are especially interested in the situation of the smallest possible non-negative real interest rate: i.e., a real rate of zero. For, as Carl Christian von Weizsäcker has demonstrated in

Weizsäcker (2021), every equilibrium rate above the natural rate is connected to positive net public debt and every equilibrium rate below the natural rate is connected to negative net public debt (Weizsäcker 2021, Theorem 4). Hence, positive public debt at a real interest rate of zero means that the natural rate must be negative.

In Chap. 6 on private wealth in the form of net public debt, we were able to provide a fairly reliable estimate of public debt at a zero real interest rate using a second degree Taylor approximation. This extrapolation from a real interest rate of three percent per year to a real interest rate of zero percent was possible, because the statistical offices of the European Union member states have reported present values of retirement benefit entitlements not only for a real discount rate of three percent per year, but also for four percent and two percent. In an excursus in Chap. 6, we showed how, on the basis of this data, a second-order Taylor approximation can be used to estimate the value at a real interest rate of zero. The result for the OECD plus China region is that if we take the sum of explicit public debt and the zero interest rate value of assets in the form of entitlements to public retirement and healthcare benefits, the total comes to 6.26 times annual consumption in this area.

We stress that this is only an estimate. The level of entitlements as a function of the steady-state real interest rate is not a quadratic function. Hence, a second-order Taylor approximation always deviates from the real values. Experience has shown, however, that the approximation error in an extrapolation over only two percentage points (from 2% annually to zero percent) is not very big.

We are not able to undertake a similar approximation for real capital and land, the other components of private wealth, because the relevant data is not available. In both cases, however, we are able to make other estimates by way of a more detailed analysis of the facts.

Let us start with land. The valuation of land sometimes includes natural resources it contains, like coal, oil, natural gas and ores, among other things. The estimate of a value of land amounting to 1.94 times annual consumption is based on official national figures on land value. The latter are derived from transaction prices when property changes hands. We presume that these valuations correspond to a real interest rate of two percent or three percent per year. In what follows, we assume that the official land value figures thus correspond to an interest rate that is equal to the growth rate in the OECD plus China region: i.e., $r = g$. We can expect higher values to result, if we use a risk-free real interest rate of zero. We undertook an estimate in Sect. 5.1.11. The following point is important here: The risk premium α on land is higher, the lower the risk-free rate of interest. This is because the lower the risk-free rate of interest is, the greater is the valuation risk due to possible interest rate changes. Thus, in our mathematical example in Sect. 5.1.11, the risk premium rises from 5.7% per year at a risk-free interest rate $r = g$ to 7.2% per year at a real interest rate of zero. It follows that in moving from $r = g$ to a zero real interest rate, the valuation of land in the OECD plus China region rises by 30%—and thus amounts to 2.52 times annual consumption instead of 1.94 times.

Similarly great revaluations are not to be expected in the case of real capital. It is useful to recall here that when $r = g$, the capital coefficient (= real capital divided by steady-state annual consumption) is equal to the period of production T (cf.

Sect. 2.5). Now, it is of interest to know how the period of production reacts when the interest rate changes. There are two conflicting effects here. On the one hand, there is a substitution effect. Using the concept of the coefficient of intertemporal substitution ψ, Carl Christian von Weizsäcker has shown in Weizsäcker (2021) that, as a result of a substitution effect, the period of production has the tendency to rise when the interest rate is falling (Weizsäcker 2021, Chap. 3, Sect. 2). Since, however, the period of production is calculated using present values, changes in interest rates also have a valuation effect on it. This valuation effect (which, by the way, has something to do with the Sraffa school's "Wicksell effect," but is not identical to it) goes in the opposite direction: With a falling interest rate, and bracketing the substitution effect, the period of production falls. (See Weizsäcker 2021, Chap. 2, Sect. 5.)

It is conceivable that these two effects exactly offset each another, so that the period of production T turns out to be constant. As shown in Weizsäcker (2021), this is not a far-fetched assumption: a Solow production function with a constant intertemporal coefficient of substitution ψ entails that, *empirically*, this ψ must be around 1 (Weizsäcker 2021, Chap. 3, Sect. 7). This is connected to the fact that, as discussed here at numerous points, the capital coefficient does not exhibit any secular trend. But precisely if this is so, then it is also the case that T is no longer dependent on r: that the substitution effect and the valuation effect neutralize each other. The relevant Solow production function runs as follows:

$$Tf(k) = k\{1 + \ln \bar{k} - \ln k\}$$

Here, k is the capital stock per worker (or the capital intensity). In the case of Harrod-neutral technical progress, k refers to a labor "efficiency unit." The variable $\bar{k}$ is the value of k at which labor productivity is maximized. T is the period of production, which is a constant in this case. The marginal productivity of capital is zero when $k = \bar{k}$. Now, let $k*$ be the value of k at which the marginal productivity of capital is equal to the growth rate of the economy. Let $c*$ be consumption per worker when $r = g$. Now, $rT = f'(k)T = (\ln \bar{k} - \ln k)$ is thus $gT = (\ln \bar{k} - \ln k^*)$. It follows that

$$ln\bar{k} = lnk^* + gT \text{ or } \bar{k} = k^* e^{gT}$$

In Chap. 4, we found that $k*/c* = 4.03$. By the Böhm-Bawerk formula in Weizsäcker (2021), however, this is equivalent to the period of production T (Weizsäcker 2021, Chap. 2, Sect. 3). The growth rate of the economy is set at three percent per year. This results in a value of $gT = 0.1209$ or, rounded, 0.12. Thus, at $r = 0$, we have the following approximation for the capital stock:

$$\bar{k} = k^* e^{012} \approx k^*(1 + 0.12) = k^* 1.12$$

Hence, at a real interest rate of zero, we obtain an addition to the real capital stock of around 12%, bringing its number to 4.51 in units of annual consumption.

If we take the sum of the two estimates for the values of real capital and land at a real interest rate of zero, we thus obtain *4.51 + 2.52 = 7.03 annual consumption units*, whereby consumption is here consumption at a zero real interest rate.

8.6 The Shift in Optimal Public Debt After COVID-19

As we have seen, the optimal public debt period D equals the difference between the waiting period Z and the sum of the production period T and the land value period L, all three evaluated at the optimal risk free rate of interest $r = g$. How does the COVID-19 pandemic influence Z, T and L? How does COVID-19 thereby influence the optimal level of D? The answer comes from a steady-state analysis, which differs from the analysis of the optimal stabilizing fiscal policy. The latter is important for short-term fiscal operations. However, steady-state analysis provides guidance on the likely path of long-term real rates of interest. This guidance is necessary for the optimal stabilizing fiscal policy.

Due to the pandemic, for any given r we expect the steady-state level of Z to shift upward and the steady-state level of T and of L to shift downward. We then should observe a higher steady-state optimal public debt period D.

We first discuss steady-state Z. The pandemic is an unexpected shock for effective demand and for effective supply. On average, people have lost money and welfare. Their “animal spirits” adapt to a world of substantially higher uncertainty. This should raise the ratio between wealth and annual consumption to which they aspire. But, at a real rate of interest $r = g$, this ratio equals the waiting period Z. In short, the pandemic induced shift in animal spirits raises the waiting period Z. A different way of expressing the same conclusion is as follows. Due to the pandemic, the representative consumer expects a lower level of future well-being, mainly because of a higher subjectively felt uncertainty regarding developments to come. The representative consumer thereby restricts present day consumption. He or she will only come back to the old level of consumption after having accumulated additional reserves.

What about a shock to T? The pandemic provides a heavy push toward digitalization. Home office is an example. “Amazonization” of shopping habits is a second example. A substantial portion of this digitalization push will remain after the pandemic has receded.

The secular trend toward increased digitalization is technical progress. In this respect, economists interpret it analogously to the industrial revolution of the last 250 years. Like the latter, digitalization steadily, step by step, changes our lives; and, most of the time, in hindsight, we do not want to go back by repeating the steps in reverse.

Does technical progress in the case of digitalization have a bias? And if so, is it labor-saving or is it capital-saving technical progress? If, on the macrolevel, we use the Solow production function, the answer is not clear. To put it differently, it is difficult to find out whether, on average, digitalization is neutral or labor-saving or capital-saving according to the Hicks definition of these terms.

However, as we will now show, the answer is very clear for the Harrod definitions of bias in technical progress. The Harrod approach fits our Neo-Böhm-Bawerkian theory. Using our theory, we can show that digitalization is capital-saving and land-saving.

We separate the production system of the economy into two sectors: sector 1 is the "analog" sector; sector 2 is the digital sector. We may then construct a two-by-two input/output matrix, showing the input/output coefficients from one sector to itself and to the other sector. Both sectors also have labor-input coefficients and land-input coefficients. In addition, the sectors are characterized by a period of production T_1 or, respectively, T_2. And there is a "direct labor + land-input period of production" τ_1 or, respectively, τ_2. The direct labor + land-input period of production of a sector shows the average time lag between the direct labor and land inputs and the sector output. In our Neo-Böhm-Bawerkian model, we work with continuous time. Let a_{ij} be the steady-state input/output coefficient of industry j for input i. Let b_i be the direct labor and land-input coefficient of industry i. We then obtain the following system of linear equations for the two industry-specific periods of production

$$T_1 = b_1\tau_1 + a_{11}T_1 + a_{21}T_2$$

$$T_2 = b_2\tau_2 + a_{12}T_1 + a_{22}T_2$$

We should note that the steady-state coefficients b_i and a_{ij} are not the technical coefficients of a Leontief input/output system, although they are related to the latter. The best way to understand them is by considering them as the economic value of the deliveries from workers and landowners to the industry per value unit of industry output (for b_i) and, respectively, from industry i to industry j per unit of output of industry j (for a_{ij}). This means that these coefficients also depend on the rate of growth g of the system and on r, the rate of interest. (Remember that the period of production defined in Chap. 2 and in Weizsäcker 2021 also depends on the steady-state rate of interest.) But for our present purposes, we do not have to go into the details of that dependence on g and on r, the rate of interest.

We also want to point out that the "direct labor and land inputs" b_i are not the same as those in the Leontief input/output system. There, they can be identified with the direct labor inputs of the firms in sector i. In a Leontief system, one frequently uses discrete time periods and then models the economy as if the inputs would have to be available exactly one period earlier than the corresponding outputs. Here, in our system, the direct labor and land input coefficient b_i is the ratio between the "wages and land rents" paid in sector i and the output value of the sector. Correspondingly, the industry specific period of production τ_i is the average time lag between the labor and land input in this sector and the final output of the sector. Thus, if for example, the sector would comprise the economy at large, the "direct" labor and land-input period of production τ_i would be equal to the period of production of the economy at large, T. The mix of labor and land inputs is no problem in this set-up. The direct period of production τ_i is a weighted average of the direct labor period of production and the land period of production. The weights are the values of these two inputs, expressed as present values. Indeed, since both labor inputs and land inputs are heterogeneous goods anyway, the same weighing procedure has already been implicitly applied for an aggregate of the labor period of production and of the land period of production.

Above, we have a system of two linear equations with the unknowns T_1 and T_2 and the given direct labor and land-input periods of production τ_1 and τ_2. The solution then is this

$$T_1 = \frac{b_1\tau_1(1-a_{22}) + a_{21}b_2\tau_2}{(1-a_{11})(1-a_{22}) - a_{12}a_{21}}$$

$$T_2 = \frac{b_2\tau_2(1-a_{11}) + a_{12}b_1\tau_1}{(1-a_{11})(1-a_{22}) - a_{12}a_{21}}$$

The period of production for the production system as a whole is then

$$T = (1-\delta)T_1 + \delta T_2$$

with δ symbolizing the value share of the digital sector 2 in the production system in terms of its final output (consumption goods).

We now investigate the following special case: the relative "digital content" of the consumption goods is the same as the relative "digital content" of all intermediate goods, including intermediate digital goods. This assumption implies the following equations for the input/output coefficients. For some common value $\mu \geq 0$ we have

$$a_{11} = \mu(1-\delta)^2;\ a_{12} = \mu(1-\delta)\delta$$

$$a_{21} = \mu\delta(1-\delta); \quad a_{22} = \mu\delta^2$$

Moreover, the "labor" coefficient b_i of sector i must fill the gap between unity and the costs of the intermediate inputs: remember that the coefficients are expressed in money units, and the "labor" coefficients include land rents, as well as profits beyond the interest costs of the capital employed. Thus

$$b_1 = 1 - a_{11} - a_{21} = 1 - \mu(1-\delta)$$

$$b_2 = 1 - a_{12} - a_{22} = 1 - \mu\delta$$

Using these equations, by some straightforward calculation, we can obtain the following three results.

For $\delta = 0$ we obtain $T = \tau_1$. For $\delta = 1$ we obtain $T = \tau_2$.

For $\delta = \frac{1}{2}$ we have $T = \frac{\tau_1 + \tau_2}{2}$.

This looks like a linear relation between δ and T. We may then approximate other values of T by linear interpolation. The equation then is

$$T \approx (1 - \delta)\tau_1 + \delta\tau_2$$

We now show that τ_2 is substantially smaller than τ_1.

Output of the digital sector mainly consists of software and a little bit of associated hardware like smartphones, PCs and fiberglass communication lines. The overwhelming part of the workforce employed in sector 2 produces and manages software. And thus the main part of the capital employed consists of software. One thing is important: the production function of software is quite different from the production function of hardware.

The main part of physical capital produced in sector 1 (the “analog” sector) consists of buildings, which tend to be long-lived. The construction cost of a single building is roughly half the construction cost of two buildings of the same size; and it is roughly one percent of the construction cost of one hundred buildings of the same size. Due to wear and tear and due to obsolescence, maintenance costs are unavoidable, if the owner wants to keep the building functional. These annual maintenance costs are a rather small fraction of the original construction costs. The annual service value provided by a building (like, e.g., annual rental of residential buildings) is a small fraction of its original construction costs. This is the main reason why any product requiring a large fraction of its total costs in terms of building services is associated with a high capital intensity and thus with a high period of production.

The service provided by standardized software (like operating systems, programming languages, apps, etc.) has a completely different cost structure. Once the software program is written, it can be used with negligible marginal cost in a very large number of devices like smart phones, PCs, etc. Software has a cost structure similar to that of patented inventions obtained by research and development. Once available to the market, the marginal cost of the service provided to an additional user is quite small.

This difference in the cost structure has decisive implications for maintenance costs: in particular, with respect to the rate of obsolescence. Obsolescence occurs everywhere; but in the case of buildings, it results in a rather slow speed of degradation. In a year’s time, buildings that are more modern can replace only a very small fraction of existing ones. On the other hand, new software, once available, threatens to replace existing software everywhere. Just as in the case of medical drugs: A new and better performing medical drug can replace the earlier one with every patient. To maintain the market position of given software, its owner has to undertake great efforts to modernize it all the time.

The very successful firms of Silicon Valley and other places are a good example. Their original programming effort to provide a product turns out to be quite small in comparison with their later effort to maintain and expand their position in the market. Their customers receive a steady flow of upgrades.

Compatibility with other software is important for the market success of any given software product. However, this other software is changing all the time. Therefore, the effort involved in maintaining compatibility is quite substantial. Without this effort, the software product rapidly becomes obsolete due to a lack of compatibility.

Similar results obtain if we look at the protection of the functionality of the item under consideration. Burglary is an attack on the functionality of a building. Its owner thus spends resources to protect the building against burglary. The likelihood of burglary is small whenever the owner spends a reasonable amount of money to protect against such attacks. The main reason for this minute likelihood is the cost structure of the burglary business: To break into two houses is about twice as expensive as to break into one house. To break into one hundred houses is approximately one hundred times as expensive as to break into one building. The production function for making a virus intruding into pieces of standardized operating software is quite different. After the setup cost of developing the virus, spreading it over many of its users is almost independent of their number. This is particularly the case for a virus, which, like in a pandemic, is automatically sent on from one software user to all of his or her correspondents. There are then huge economies of scale in manufacturing viruses designed to attack users of standardized software. The incentive to enter this business of virus manufacturing thus rises with the number of users of a given piece of standardized software.

Therefore, the manufacturer of such standardized software needs continually to employ a large amount of skilled labor, in order to protect the software against successful intrusion by viruses.

The upshot of all this is the quite high rate of obsolescence of capital in the digital sector. This indicates a low value of τ_2.

However, we have to consider two further consequences of a higher production share of digitalization. They work in opposite directions.

First consequence: Interaction between different users of software generates a strong incentive to use the same software product. Everybody uses “Word” from Microsoft. Text thereby can be sent from one user to the next one and changed to be sent back to the first user—without any compatibility problems. The “quality” of such a software product thus rises with the number of its users. Similar effects apply to the Google search engine. This “frequency of use -> quality” effect generates a very high profitability for the original developer of this kind of software. Shares of these firms exhibit very high Tobin’s Q values. In relation to their annual turnover, their balance sheet shows low values of their real capital. On the other hand, their market value is a high multiple of their reported equity. This high Tobin’s Q is not so much the result of hidden reserves. Rather, it signifies a substantial level of market power. Given that these companies are traded on the stock market, every citizen can buy into this market power. To the extent that a higher level of digitalization raises the opportunity to buy into market power, this effect raises investment opportunities for citizens and thereby works to dampen the loss of investment opportunities due to the reduced period of production T.

Second consequence: Digitalization is not only capital-saving technical progress, but also land-saving technical progress. Our measure of the period of production is a weighted average of the time lag between labor and final output and the time lag between land and final output. The weights are the values of their respective services. Due to digitalization, the use of land is substantially reduced. We only have to mention the increased use of home–office labor and the higher share of mail-order purchases, led in particular by Amazon. In both cases, one labor year does not only use a reduced number of square meters of office space and/or shopping space: In addition, and this is perhaps quantitatively more important, digitalization replaces expensive office space and shopping space by much cheaper building space—away from the expensive inner city locations. Digitalization increases the space of possibilities of where one can work. The competition between locations rises: to the benefit of consumers and workers, but at the expense of landowners. We have discussed land in Chap. 5. We are aware of the fact that land enters the value of real assets twice: first—as it were, looking backwards—as a part of the historical cost of real capital and thus as a contributing part of the period of production T; second—as it were, looking into the future—as land value discounting future land rents. A higher level of digitalization thus not only reduces the period of production T, but also the relative discounted value of future land rents, L.

Given that land is a real asset for investment, its diminished value (at a given rate of interest) reduces the share of private wealth that can be invested in real assets. This raises the optimal public debt period.

8.7 Real Assets in Comparison with an Estimate by Jordà et al. (2019)

Our estimate of the value of real assets is somewhat higher than the estimate for 31 December 2015 that Jordà et al. (2019) have presented in their study on rates of return from 1870 to 2015 (Jordà et al. 2019, Fig. 4 in the appendix, p. 63). The value of real assets is given there as around three times annual GDP. This is the equivalent of approximately four times annual consumption. The estimates for the period from 1870 to 2015 are made assuming the prevailing interest rate level. If we use our extrapolation factors to calculate for a hypothetical real interest rate level of zero, then, starting from the Jordà et al. (2019) estimate, we obtain real assets worth around five years of total consumption. This is less than our estimate of 7.03 years of total consumption. This difference cannot be attributed to the fact that the area that we are examining includes China, whereas China is left out in Jordà et al. (2019).

Further research is required to explain this discrepancy. We suspect that both groups of researchers have tried to be conservative in their estimates. Our focus is the thesis of the need for high net private claims on the state. In this case, a conservative approach could lead us to overestimate alternative ways of investing wealth. Jordà et al. (2019) want, among other things, to point to the great significance of home ownership for growth in the wealth coefficient. A conservative approach would thus lead them perhaps to underestimate real estate ownership as a component of wealth.

8.8 Total Private Wealth at a Real Interest Rate of Zero

On the assumption of a zero interest rate, in addition to their real assets, private persons have entitlements vis-à-vis the state amounting to 6.26 annual consumption units. On this calculation, the value of the real assets, consisting of land and real capital, is 12–13% greater than the net financial claims on the state.

At a steady-state real interest rate of zero, total private wealth in the OECD plus China region thus adds up to 7.03 + 6.26 = 13.29 or around 13 annual consumption units. 47.10% of this sum comprises private net claims on the state; 33.94%, private real capital; and 18.96%, privately owned land. We can also write that approximately 7/15 is net public debt, 5/15 or one-third is private real capital and 3/15, i.e., one-fifth, is land and the mineral and energy reserves it contains.

8.9 Recent "Secular Stagnation" Literature: An Example

Even if Carl Christian von Weizsäcker can claim to have already made similar observations in earlier publications (Weizsäcker 2010, 2011, 2014), it was, above all, thanks to public statements by the former US Secretary of the Treasury and well-known economist, Lawrence Summers, that the secular stagnation thesis became a subject of academic reflection again. Summers (2013, 2014), and Rachel and Summers (2019) should be mentioned, in particular. Thanks to Olivier Blanchard's Presidential Lecture on "Public Debt and Low Interest Rates" at the 2019 AEA Annual Meeting (Blanchard 2019), positions that are clearly related to the position on the Great Divergence that we have argued for in this book have become almost mainstream in the USA.

As already touched upon in Sect. 8.1 above, the description "secular stagnation" does not reflect our fundamentally optimistic attitude to the economic future of the world. (On the debate on secular stagnation, also see Chap. 7 and Kurz 2021.)

The robust optimism that is apparent in the UN's population forecasts and especially its forecasts of life expectancy is more reflective of our attitude. It is true that the Great Divergence, which we have described in Sect. 8.1 above, requires wise economic and financial policy. If we can depend on the latter, however, the Great Divergence appears as a journey into abundance from an economic point of view: less and less onerous labor combined with a constant or even increasing material standard of living.

Our approach is based on steady-state capital theory and its empirical anchoring is provided by the careful examination and adaptation of data on the components of private wealth, such as one can find in the official statistics. We consider a particular *point in time*: namely December 31, 2015 or the average values for 2015. We thus abstain from undertaking an econometric time series analysis. We examine the situation from the vantage point of the hypothetical natural rate of interest that would be compatible with full employment in the steady state without net public debt. Our comparative empirical analysis involves comparing different hypothetical steady states on the date in question, whereby we *extrapolate*, in particular, from the interest rates that are implicitly or explicitly used in the official statistics to a real interest rate of zero. (For a summary, cf. Sect. 8.5 above.) Using this analysis based on steady-state properties, we find that net public debt at a real interest rate of zero is very substantial for the OECD plus China region. We derive the thesis of a negative natural rate of interest from this finding. The temporal depth dimension of our approach is, *firstly*, the narrative concerning *the exhaustion of the greater productivity of more roundabout production* and, *secondly*, the narrative concerning *the increase in relative desired wealth as prosperity increases*—or, expressed in formulas, the narrative about the secular constancy of the period of production T and the narrative about the secular rise in the private waiting period Z. (In general on narratives, also see Shiller 2017.) We do *not* connect these two narratives to an econometric time series analysis. Nonetheless, the UN world population forecast up to 2100 provides "quasi-empirical" *future-oriented* backing for our thesis of the rising private waiting period Z; just as the empirical constancy of the capital coefficient over time provides *past-oriented* backing for our thesis of the exhaustion of the greater productivity of more roundabout production. The fact that our starting point is a steady-state analysis based on capital theory allows us to use a "meta-model." This has the advantage of allowing us to do without many specific assumptions: especially about the production sector, but also about the consumption sector.

We want here again to compare our approach with the study by Rachel and Summers (2019). The latter consists of a theoretical and empirical analysis of the evolution of the neutral rate of interest or, in other words, the real equilibrium rate over the past five decades. Like in our approach, the authors try to cover a large geographical area, in order to be able realistically to work with a model of a closed economy. In their case, the countries examined comprise the members of the OECD. The situation circa 1970 is the point of reference. A number of time series are now introduced, in order to establish causal relationships between the different variables. The main interest is the evolution of the neutral interest rate. The latter has fallen by a few percentage points over these nearly five decades. Nonetheless, a number of variables whose rise economists expect to push the interest rate upwards have increased. Thus, for example, the conventionally measured public debt ratio in the OECD countries has increased from around 20% of GDP in 1970 to around 70% today. If we assume, based on the econometric analysis, that a rise in the debt ratio by one percentage point (e.g., from 30 to 31% of gross domestic product) raises the equilibrium interest rate by 3.5 basis points, the increase in the public debt ratio from 20 to 70% will have raised the neutral interest rate by 1.75%.

The authors examine a number of other factors that have an influence on the neutral rate. These include factors of a demographic nature, factors related to income distribution and, finally, policy-related factors: in particular those, as in the case of the public debt ratio, that are affected by fiscal policy and social policy, with special attention being given to the funding of the healthcare system. The model created with these variables serves to estimate the influence of the various parameters on the neutral interest rate using time series analysis.

The point estimates of Rachel's and Summers' model suggest that change in the directly policy-related variables has pushed up the neutral interest rate by around 4% (Rachel and Summers 2019, p. 13). Given that the neutral interest rate is today much lower than four percent, the authors conclude that were it not for the change in the directly policy-related variables, the neutral rate would be negative.

Now, it should be added that the reference point, the neutral rate in 1970, was higher than the natural rate at the time, i.e., the hypothetical neutral rate with zero public debt. Hence, the results of Rachel and Summers (2019) provide all the more reason to conclude that the natural rate must be negative today.

A brief comparison of the two approaches follows. The two most important points are the same in both cases, viz. the following qualitative points: 1. The natural rate of interest today is negative; 2. The natural rate is falling over time. Neither approach attempts to make a precise estimate of the negative natural rate. The analytical methods of the two approaches are complementary. The econometric time series approach of Rachel and Summers (2019) is able—also by drawing on numerous prior studies by other economists—to provide a graphic representation of the downward trend in the neutral interest rate while holding the public policy parameters constant. We mention here just two related studies: the above-cited paper by Jordà et al. (2019) and Eggertsson et al. (2019). But Rachel and Summers are conscious of the fact that the confidence intervals are very large. The "real" trend parameter of the neutral interest rate while holding the public policy parameters constant may be quite different from their point estimate. To this extent, our simplified illustration using the savings triangle is no less instructive than the parameter estimates of Rachel and Summers (2019)—especially since it matches the reality for employees covered by the German social security system very well.

Our meta-model-based approach does not require such special assumptions as the approach of Rachel and Summers (2019). Thus, in specifying their model, they use a Cobb–Douglas production function with Hicks- and Harrod-neutral technical progress from the outset. They thus find, like practically all such models, that there is a secular decline in technical progress. By contrast, our meta-model can also cope with the hypothesis that technical progress has not decreased at all, but is merely directed nowadays toward reducing the "disutility of labor" that is ignored in the conventional way of measuring technical progress.

Our "*Fundamental Equation of Steady-State Capital Theory*" ($T = Z - D$) (or also: $Z = T + L + D$) provides insight into secular trends, without our having to enter into complicated time series analyses that are fraught with uncertainty. There is no doubt, however, that by using such econometric methods, it is possible to answer more specific questions that cannot be answered by way of steady-state analysis.

It thus seems to us that the two approaches are complementary. It could prove worthwhile to try to combine them.

8.10 Sensitivity Analysis on the Negative Natural Rate of Interest

Our finding that the state has substantial net debt vis-à-vis its citizens at a zero real interest rate is sufficient to prove that the natural rate of interest is negative. In fact, we do not need any estimate of citizens' real assets in the zero interest rate scenario. We have, nonetheless, undertaken such an estimate, in order, among other things, to call attention to the robustness of our thesis. Purely hypothetically, we could well have imagined that net public debt at a zero interest rate only represents a small fraction of citizens' total wealth. We would have had then to show that people's desired wealth could not also have been completely covered by real assets. Just a small error in estimating real assets would then have been sufficient to call into question the positive result for the zero interest rate estimate of net public debt. As an example: If up to 90% of privately desired wealth could be covered by real assets, miscalculating real assets by 20% would be enough to arrive at a situation in which real assets in the zero interest rate scenario are greater than desired wealth. In this case, the natural rate of interest would be positive, since net public debt would not be needed to satisfy the desired level of wealth.

But at real interest rates of zero, the desired wealth of the population is almost twice private real assets. In order then for desired wealth to be exclusively covered with private real assets, we would have to consider the possibility that the estimate of real assets is too low by a factor of two. This seems very unlikely—especially since other estimates come to even lower figures (Jordà et al. 2019).

Moreover, a further fact has to be kept in mind here: We have not even undertaken any direct estimate of relative desired wealth. All we have done is to make it plausible that relative desired wealth rises with rising life expectancy. This is the main message of the "savings triangle." Apart from that, we have relied on the measured private wealth coefficient roughly corresponding to relative desired wealth. The background to this is the consideration that the government will intervene in compensatory fashion to stabilize employment, if desired wealth is considerably greater than actual private wealth. If desired wealth massively exceeds actual wealth, then voluntary private saving is significantly greater than private investment. Without government intervention, however, this means recession or even depression. If, in this case, interest rates cannot be cut any further, because they have already reached the lower bound, then the state will have to ensure, by way of additional “dis-saving,” that aggregate saving is brought into line with aggregate investment (cf. Chap. 7). This increases the net position of citizens vis-à-vis the state and thus desired wealth and actual wealth come together again.

We can ask, furthermore, where underestimates of real assets primarily come from. The official statistics may have underestimated the actual value of firms and hence the value of citizens’ shareholdings. But this can only concern shares that are not traded on the stock exchange. Statistical agencies make certain estimates of the value of shareholdings by inferring the value of firms that are not listed on the stock exchange from known market values. But it cannot be ruled out that underestimates occur when using this method.

It is possible that the “true” value of all firms that are not publicly traded is, on average, greater than the equity reported in their balance sheets. The latter is already taken into account on the liabilities side of the balance sheet in calculating real capital (Chap. 4) and the value of land (Chap. 5). What is at issue is thus the valuation of “family businesses.”

If their value is, on average, underestimated, then we have also underestimated the value of real assets. But this does not have any great impact on our estimate of net private claims on the state. For in the overwhelming majority of cases, such businesses stay “in the family.” In other words, they are inherited. And, as we have shown in Sect. 3.6, the wish to leave wealth to one’s descendants has a one-to-one effect on increasing desired wealth. At least as an approximation, we can thus assume that an underestimation of the value of non-publicly traded firms entails an equivalent underestimation of desired wealth. The difference between privately desired wealth and private real assets that is bridged over by public debt thus remains practically untouched by possible errors in estimating the value of shares in non-publicly traded companies.

Thus, in short:

> The thesis of a negative natural rate of interest proves to be extremely robust.

8.11 A Summary of the Results of Our Empirical Estimates

Table 8.1 provides a final overview of our empirical estimates of the components of private wealth—real capital, land and public debt—in the OECD plus China region, as presented in Chaps. 4, 5 and 6.

Table 8.1 Overview: results of our main empirical estimates

Composition of private wealth in the OECD plus China region, 2015					
In years of total consumption					
With a positive real interest rate					With zero percent interest rate
	USA	Germany	OECD	OECD plus China	OECD plus China
Real capital	3.70	2.76	3.59	4.03	4.51
Land	1.42	1.54	2.02	1.94	2.52
Public debt	4.22	5.03	4.31	3.95	6.26
– Explicit public debt	0.98	0.70	0.92	0.75	0.75
– Implicit public debt (retirement)	2.34	3.64	2.75	2.63	4.94
– Implicit public debt (health insurance and care insurance)	0.90	0.69	0.64	0.57	0.57
Total	**9.34**	**9.33**	**9.92**	**9.92**	**13.29**

Note Health insurance: Public health insurance
Care insurance: Public nursing care insurance
Source Authors' own calculations

Real Capital
When calculated using a positive real interest rate, real capital in the OECD was equivalent on average to 3.59 times total annual consumption in 2015. The USA is above the OECD average at 370% of total annual consumption, while Germany is below the average at 276% of total annual consumption. In Chap. 4, we estimated real capital wealth in China, which is as high as 554% of China's total annual consumption—well above the OECD average. For the OECD plus China region as a whole, we estimate real capital wealth to be about 4.03 times total annual consumption. Applying our calculation method using a real interest rate of zero percent, we estimate private real capital wealth to be 4.51 times total annual consumption for the OECD plus China region as a whole.

Land
On average, the value of land in the OECD countries is twice total annual consumption. If China is added, the average private land wealth in the OECD plus China region is 194% of the consumption of the region as a whole. Germany and the USA are below the OECD average at 1.54 and 1.42 times their annual consumption, respectively. If we apply the zero interest rate, this results in a land value of 252% of total annual consumption for the OECD plus China region in 2015.

Public Debt
Using a positive discount rate, we arrive at the following results: In 2015, private citizens' net claims on the state accounted for the largest share of private wealth. In the USA it's value was at 422% of total annual consumption. As we argued in Chap. 6, pension and retirement benefit entitlements, as well as public health and

nursing care insurance, give rise to implicit public debt. At 234% of total annual consumption, implicit public debt from retirement benefit entitlements deriving from social security retirement schemes accounted for the largest share of private citizens' claims on the state in the USA. The structure of claims vis-à-vis the state (explicit and implicit debt) is similar in Germany. At 364% of total annual consumption, implicit public debt from retirement benefit entitlements is even higher in Germany.

Using a positive discount rate, we estimate that total public debt (the sum of explicit and implicit public debt) is 4.31 times total annual consumption in the OECD and 3.95 times total annual consumption in the OECD plus China area. Explicit debt, calculated as net public debt, accounts for a relatively small fraction of these totals at 0.92 times (OECD) and 0.75 times (OECD plus China area) total annual consumption. According to our estimates, in 2015, implicit public debt was 339% of total annual consumption in the OECD and 320% of total annual consumption in the OECD plus China region. Implicit public debt is thus much more significant for the claims of private individuals on the state in these regions.

As we argued earlier, in a world with zero interest rates, we also need to calculate the present values of expected future income flows using a zero discount rate. The last row in Table 8.1 shows the results of our estimates for the three private wealth components. Public debt amounted to 626% of total annual consumption in the OECD plus China region in 2015. By far the largest contributor is implicit retirement-related public debt, which, according to our calculations, came to 494% of total annual consumption. Implicit retirement-related public debt thus accounts for nearly 80% of total public debt.

Total Wealth

Using a positive discount rate, total private wealth amounted to 9.92 years of total annual consumption in 2015 in the OECD countries and also in the OECD plus China region. Using a discount rate of zero percent, private sector wealth in the OECD plus China area totaled 13.29 years of total consumption. One-third of this was private wealth in the form of real capital (machinery, equipment, buildings), one-fifth was land, and just under half (more precisely: 7/15) was comprised of net financial claims on the state.

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