DYNAMIC EFFICIENCY IN WORLD ECONOMY

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Abstract
Based on the AMSZ (1989) criterion, we exploit comprehensive datasets to estimate the dynamic efficiency of world economy. The results reveal that the representative economies conform to a "U-shaped pattern" in their evolution of capital accumulation. That is, a period of decreasing efficiency (over-accumulation) followed by increasing efficiency (de-accumulation). Contrary to previous evidence, the bias-corrected estimates show that major economies have been inconsistently dynamically efficient. As a prime example, China today is unquestionably in a state of severe dynamic inefficiency, and the inefficient status is likely to continue in near future. We also document the limitations of the AMSZ criterion and point out promising research directions in the efficiency literature.

Keywords: Dynamic efficiency, over-accumulation, cash flow criterion, interest rates, Pareto optimality
JEL Classification: E22, E43, O57

1. Introduction

In path-breaking research, Samuelson (1958) and Diamond (1965) build a model that violates the first fundamental welfare theorem[1]. By introducing overlapping generations, even in the absence of market failures and distortions, the equilibrium of a perfectly competitive market can be Pareto-suboptimal. That is, when there is surplus capital accumulation, the interest rate (r) falls below the economic growth rate (g). As a result, maintaining

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1 The theorem states that a market will tend towards a competitive equilibrium where the solution is Pareto-efficient, when the market maintains the following three attributes: (1) complete markets, (2) price-taking behaviour, (3) local non-satiation of preferences.

market equilibrium requires more investment (gK) than the economy actually produces (rK) (Fama and French, 2002; Weil, 2008). If over-accumulation holds, at the household level, increasing consumption today does not imply lower consumption in future. This inefficiency enables Ponzi schemes and leaves room for Pareto improvement. When capital stock exceeds the optimal level for maximizing social consumption, interest rates (r) become so low that financial approaches to transferring resources from one's youth to old age become unproductive. Under inefficient environments, instead of letting individuals save on their own, social planners can take advantage of the high economic growth (g) by redistributing resources from the youth to the elderly. Policy instruments such as the pay-as-you-go system (Aaron, 1966) and public debt (Diamond, 1965; Blanchard and Weil, 2001) can promote everyone's welfare in the Pareto sense.

Dynamic efficiency is a central topic in analyses of economic growth, corporate finance and welfare economics. Knowing the actual efficiency status is of great significance for policy implications. The rate-of-return criterion, which directly compares interest rates with economic growth, is the most commonly used approach in the field. Early evidence shows that in the US the gross capital return overwhelms the nominal growth rate, which indicates the absence of over-investment in the US (Feldstein, 1977; Poterba, 1998). Recent studies based on the rate-of-return criterion have reached similar conclusions (*e.g.*, Barbie *et al*., 2004; Homburg, 2014; Piketty, 2014). Therefore, it is tempting to conclude that dynamic inefficiency (over-accumulation) is merely a theoretical possibility rather than a real challenge to the world.

On the other hand, researchers find that real interest rates can even be negative and do not consistently exceed economic growth (*e.g.*, Mishkin, 1982). For instance, von Weizsäcker (2014) revisits the public debt issue and discovers negative real interest rates in OECD countries and China. Is the rate-of-return criterion empirically relevant? Above all, since there are too many "rates" to choose from, it is suspicious to believe any of the "rates" to be the best overall measure. Accordingly, the practical feasibility of the rate-of-return criterion remains questionable.

To overcome this shortcoming, Abel, Mankiw, Summers and Zeckhauser (1989; AMSZ hereafter) establish a cash flow efficiency criterion that is considered theoretically sound as well as empirically feasible. The AMSZ criterion is intrinsically equivalent to the conventional rate-of-return criterion. However, instead of comparing interest rates with growth rates (which emphasizes the essence of dynamic efficiency), the AMSZ criterion bases its judgement on a comparison between capital return and capital investment (which transforms the question into observing the outcome of dynamic efficiency). The cash flow criterion bypasses the complexity and selection bias in measuring interest

rates. Employing the cash flow criterion, AMSZ (1989) show that major OECD countries have been consistently dynamically efficient[2].

Empirical literature on dynamic efficiency has received little attention so far, partly due to the optimistic conclusions of AMSZ (1989) and because today's world indeed appears to be highly dynamically efficient[3]. Nevertheless, in recent years, the prevailing notion of "global saving glut" has raised numerous questions (*e.g.*, Bernanke, 2005). Is the world perfectly efficient, as suggested by previous evidence, or only partly efficient once we account for some measurement bias? Do major economies share a common pattern in their history of capital accumulation? Are emerging economies as efficient as developed ones? Which country has the lowest efficiency level? The remarkable progress of statistical systems achieved in the past decade also renews the interest in answering unresolved questions regarding efficiency estimates. In this study, we aim to fill the void in the efficiency literature by exploiting comprehensive datasets assembled to date.

The arrangement of this study is as follows. In the next section, we use the latest data to assess the dynamic efficiency of major economies and look into the evolution pattern of capital accumulation. In Section 3, we review the literature on statistical bias and present bias-corrected estimates for the representative economies. We also evaluate the dynamic efficiency of the world's 44 largest economies and discuss the severe inefficiency in the Chinese economy. In Section 4, the paper closes with brief concluding remarks and policy implications. Discussions of the practical and theoretical limitations of the AMSZ criterion are provided in the Appendix.

2. Assessing Dynamic Efficiency

In this section, we assess the aggregate- and corporate-level dynamic efficiency of major economies using comprehensive datasets assembled to date, based on the AMSZ (1989) criterion. We search for common patterns in the evolution of capital accumulation—a question that has rarely been explicitly formulated in the literature. Unlike the conventional rate-of-return criterion, the AMSZ (1989) criterion contends that dynamic efficiency can be captured by measuring the cash flow generated in the capital sector. To be precise, an economy is deemed to be dynamically efficient if gross capital gains outweigh capital

2 Employing the official statistics from the Bureau of Economic Analysis (BEA) and OECD, AMSZ (1989) find efficient states of the US in 1929–1985 and other major OECD economies (England, France, Germany, Italy, Canada, and Japan) in 1960–1984.

3 In recent years, the world-wide slowdown in both technological and demographic growths (especially for developed economies), relative to the stable long-term interest rate (about 5%), has contributed to the efficient status of world economy.

investment. Likewise, an economy is considered dynamically inefficient if capital investment exceeds gross capital gains.

The efficiency criterion has abundant economic implications. Firstly, it is a benchmark for the "pie distribution" problem. That is, for social planners, the criterion presents the welfare principle on which Pareto-improving intertemporal redistribution is feasible. Secondly, the criterion is a generalization of the golden-rule condition addressed in Phelps (1961) and Diamond (1965), which suggests that efficiency status depends on the order of magnitude between interest rates and economic growth. Dynamic inefficiency signals over-accumulation under the neo-classical concept, since the capital stock has exceeded the optimal level for maximizing social consumption (the "welfare"). Thirdly, the criterion evaluates the investment returns, which guide enterprises to enter and withdraw from markets.

2.1 Dynamic efficiency in aggregate economy

The OECD has established the harmonized system of national accounts (SNA hereafter) for major economies covering the period 1970–2017. As a preliminary analysis, we measure the cash flow in the capital sector as the difference between gross operating surplus (GOS) and gross capital formation (GCF). The efficiency level is expressed in cash flow as a share of GDP, displayed in Figure 1. According to the results, the estimated efficiency varies over time and across countries. Several economies share an upward trend from 2005 onwards, which implies the increasing worldwide efficiency in the past decade. More importantly, capital investment has consistently produced greater income than expenditure, which satisfies the sufficient condition for efficient status by a wide margin. Accordingly, efficient status holds for all samples over the period 1970–2017.

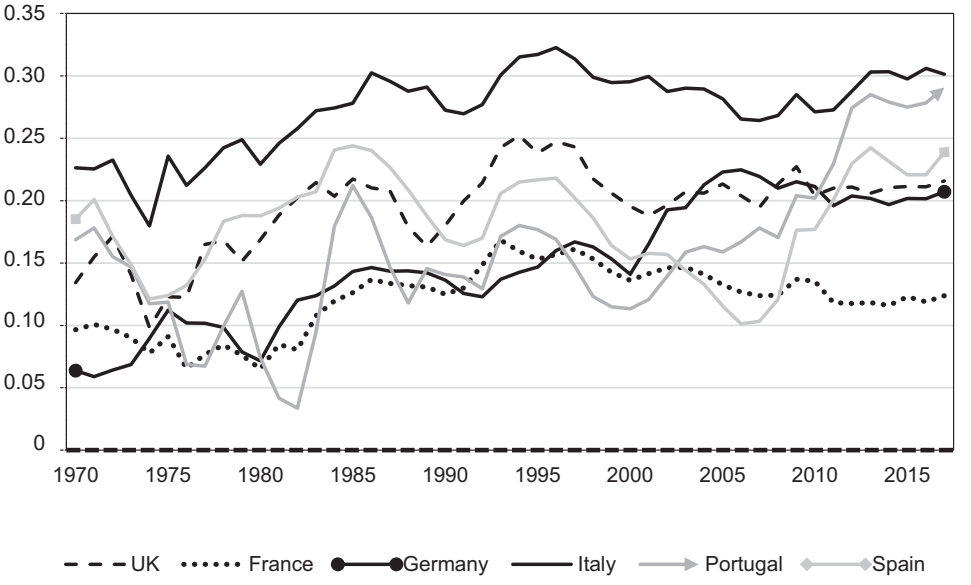
On the one hand, the above analysis will only take us so far due to its short observation period. For advanced economies, a time span of 47 years is far from adequate to capture the historical evolution of capital accumulation. However, since modern economic development began much earlier than the emergence of sophisticated statistical systems[4], the early stage of capital accumulation might be unobservable. On the other hand, longer is by no means necessarily better. As Piketty (2014) puts it, most countries have been severely plagued by two world wars and the subsequent political upheavals. As a result, statistical inferences derived from long-run historical data can be misleading (especially

4 It is generally considered that modern capital accumulation in the US was originated in the early 1870s (after the Civil War in the 1860s). For France, it started in the 1860s (the Second Industrial Revolution).

statistics for 1910-1950)[5]. As a matter of fact, at the end of World War II, the world was so heavily disrupted that global capital accumulation had to start all over again (*e.g.*, Piketty and Saez, 2003; Piketty, 2011, 2014). Quoting Piketty (2014, p. 275): "*In the twentieth century it was war, and not harmonious democratic or economic rationality, that erased the past and enabled society to begin anew with a clean slate.*" From an economic point of view, wartime shocks have reset the on-going evolution of capital accumulation. This unique setting provides feasible experiments to capture the otherwise unobservable evolution process.

Figure 1: Dynamic efficiency (percent)

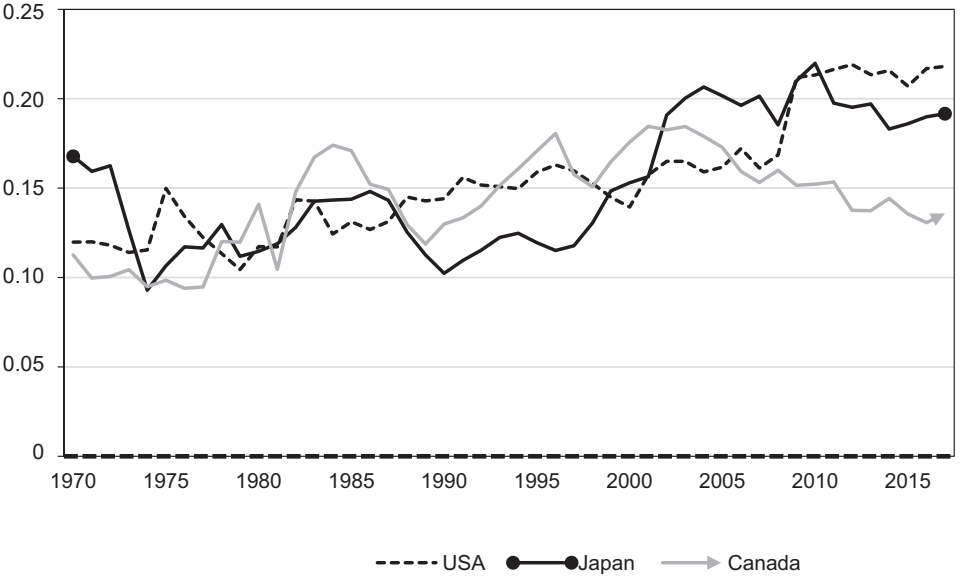
(1) European economies



5 A typical example is Kuznets' celebrated article on inequality. According to Kuznets' "bell curve" theory, the diminished US income inequality over the period 1913–1948 was achieved by rapid industrialization and innovation. However, there is ample evidence suggesting that the reduced inequality was essentially caused by wars and economic shocks in particular periods (*e.g.*, Elmendorf and Mankiw, 1999).

Figure 1: Continuation

(2) Non-European economies



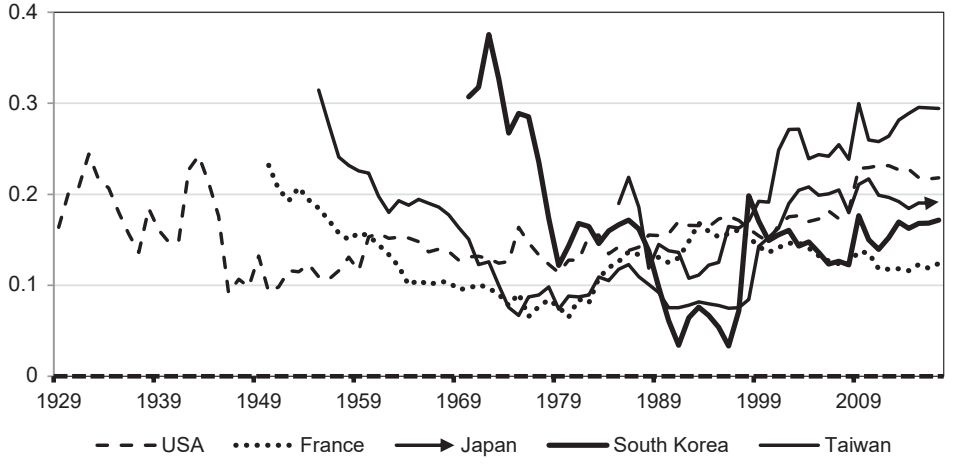
Note: The cash flow in the capital sector is calculated as the difference between the gross operating surplus and the

Source: Harmonized system of national accounts (OECD balance sheets) gross capital formation, expressed in fractions of GDP. That is, the percentage = Cash flow/GDP.

In this regard, 1950–2017 is not only a sufficient observation period for the research purpose but also a reasonable option for assessing the past and the present. We begin by gathering as extensively as possible the official datasets on advanced economies, focused on France, the US and Japan. These are representative developed economies involved in world wars and have well-established statistical systems.[6]

6 As the headquarter country and one of the founding members of the OECD, France established the earliest and most complete system of national accounts in 1950. As for Japan, the cabinet office built the national account system in 1955 in a manner corresponding to the conventional SNA68 standard, which enables us to capture the early phase of capital accumulation in post-war Japan. For the US, we employ the historical data of the National Institute of Pension Administrators (NIPA). The NIPA has been widely tested and advocated by researchers.

Figure 2: Dynamic efficiency in five economies (percent)



Note: In the estimates for France, Japan, South Korea and Taiwan, the cash flow in the capital sector is calculated as the difference between the gross operating surplus and the gross capital formation, expressed in a percentage of GDP. In the estimates for the US, the conventional GOS indicator is not available in the NIPA statistics until 1952, and the GCF indicator is not recorded until 1960. To extend the observation period, we follow the method presented by AMSZ (1989). We measure the gross capital flow as national income plus capital consumption allowance, minus employee compensation and 67% of proprietors' income.

Source: OECD SNA statistics for estimates for France and South Korea; BEA NIPA statistics for the US; SNA68 statistics (from the Cabinet Office of Japan) for Japan; and SNA statistics (from the National Statistics of Taiwan) for Taiwan.

Alternatively, it is illuminating to look into emerging economies such as the "four dragons of Asia". Studying emerging economies might suit the research purpose better because emerging economies are late starters in socio-economic development and capital accumulation. Accordingly, there is no need to rely on earlier data sources (note that "earlier" usually means "less reliable"). This feature enables the utilization of the harmonized system of national accounts (OECD balance sheets), which provides better accuracy and consistency in a statistical sense.

Employing the AMSZ criterion, Figure 2 displays the estimates of dynamic efficiency for France, the US, Japan, South Korea and Taiwan[7]. In every instance, the net capital return was relatively high at the beginning, which implies the relative scarcity of capital stock. The early stage corresponds to the well-known "pre-Lewis turning point", where rural labour surplus and capital shortage coexist. As the process unfolded, the net return

7 We have also estimated the dynamic efficiency for Hong Kong and Singapore and reached similar conclusions. The results are not reported here due to the limited observation period.

declined until it reached the nadir. There are roughly two explanations for the phenomenon. One apparent reason is the continuous accumulation of capital, which lowered the marginal product of capital investment. Another reason is that the way capital accumulated during post-war periods was generally extensive and ill-deliberated. For economic stability and market expansion, most countries chose a government-led investment pattern and specific anti-capital policies in their "golden ages" of economic development. Examples include progressive taxes on capital income, restrictions on house rent, economy collectivization and financial sector constraints – which have no doubt impaired the market effectiveness and investment efficiency. In the late stage, efficiency recovered due to technological progress, rational bubbles (valuation effects), financial liberation, privatization of state-owned enterprises (SOE) and structural reforms, and the net capital return flourished again. By and large, the estimated results are in line with historical experience.

The representative economies share a "U-shaped pattern" in their evolution of capital accumulation and evolve in a way consistent with the economic cycle. That is, investment expands at first and efficiency declines during economic booms; efficiency then reaches a low level and holds for some time; finally, efficiency rebounds when a way out of over-accumulation is found. This U-shaped pattern has many noticeable parallels in economics, such as the U-shaped industry concentration and the U-shaped lifecycle wellbeing. Another feature worth considering is that emerging economies have transitioned more dramatically, in both magnitude and direction, than advanced economies, consistent with the phenomenon of rapid transitions of economic development, demographic structures and income inequality in the developing world.

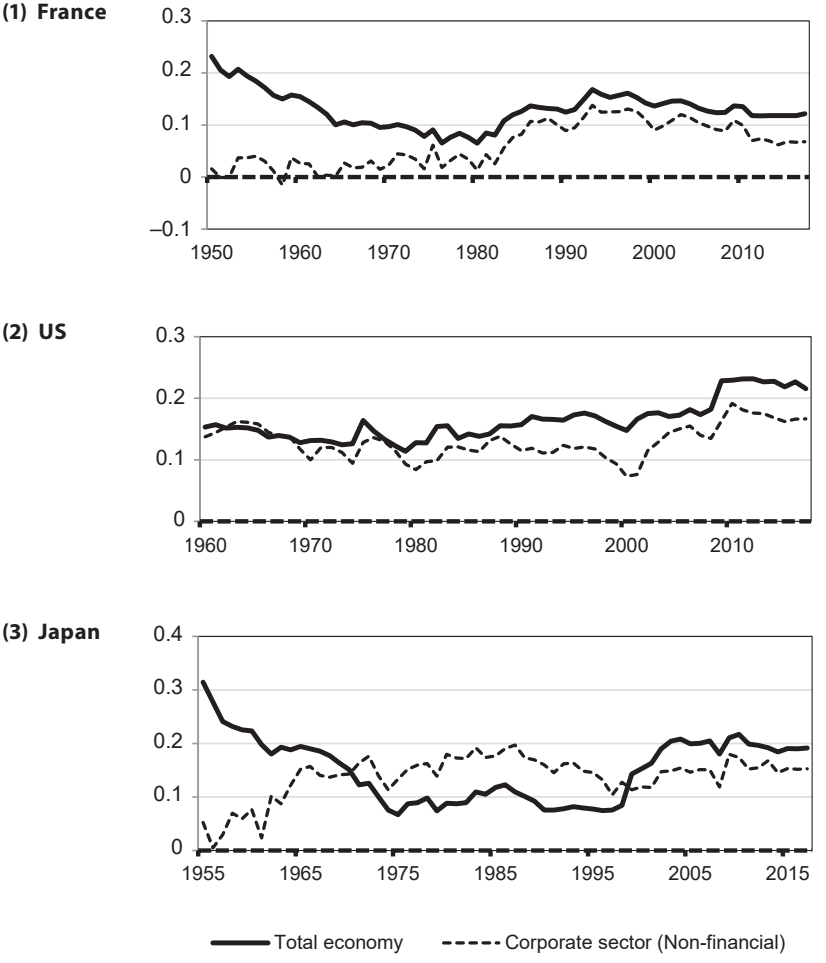
2.2 Dynamic efficiency in corporate sector

The previous subsection documented the evolution of dynamic efficiency for five representative economies. Nevertheless, aggregate economy is comprised of many components, of which some are highly competitive sectors while others are not. Theoretically, studying aggregate-level efficiency might be misleading since the efficiency criterion relies critically on the assumption of completely competitive markets. Based on this view, Desai *et al.* (2011) examine the cash flow in the US investment abroad and find that the foreign investment sector was dynamically efficient over the period 1950–2010, which reflects the efficient status of the US economy. In this subsection, we look into the dynamic efficiency of non-financial corporate sectors. This angle sheds light on the efficiency features of aggregate economy and its competitive components.

Following the methodology and data sources used in the previous subsection, we present estimates of corporate-level efficiency for France, the US and Japan. The estimates of both versions are demonstrated in Figure 3 to draw a comparison.

The results suggest that corporate- and aggregate-level efficiencies share a similar pattern. In most periods, the trends lie above the critical line by a substantial margin. Hence, corporate sectors also seem to be dynamically efficient.

Figure 3: Dynamic efficiency in corporate sector (percent)



Note: As the SNA (from the Cabinet Office of Japan) did not record the GDP of the corporate sector, we assume that the corporate sector accounts for 60% of the total GDP in the estimates for Japan. For the US corporate sector, the GOS indicator is not available in the NIPA. We measure the cash flow as the gross value added, minus compensation of employees and indirect tax paid by producers, reduced by producer subsidies. In short, GOS= GV-(IT-SU)-CE.

Source: Consistent with Figure 2.

Contrary to previous evidence[8], the estimates show that corporate-sector efficiency is lower than aggregate-level efficiency in the early stages of capital accumulation. Given the competitive essence of market economy, the net return (r) is not supposed to be either too high or negative on a steady-state growth path. That is, conditional on market effectiveness, the real interest rate of capital investment ought to converge to slightly positive values or oscillate around the critical line. This view is supported by the historical experience that the average asset return has been stable around 5% per annum, approximately 1/20 of the asset value. In this sense, the estimates seem to have captured the corporate-level efficiency properly.

On the other hand, dynamic efficiency also serves as an indicator of investment opportunities. Enterprises are profit-pursuing, whereas other sectors such as government and financial institutions are less interest-driven. Then, how to rationalize the fact that an imperfectly competitive entity (aggregate economy) achieves higher returns than its highly productive component (corporate sectors)? How can the net profit exceed 25% in specific periods? The contrast clearly warns of the potential overestimation in the aggregate-level efficiency. In the next section, we turn to the issue of measurement bias to derive more accurate estimates of dynamic efficiency.

3. Bias Correction in Efficiency Estimates

In Section 2, we estimated the aggregate- and corporate-level dynamic efficiency for the representative economies. Based on the AMSZ criterion, the results support the efficient status for all the samples covering the overall period. However, due to statistical bias, conventional SNA statistics are inclined to overstate the actual capital gains. Recall that the cash flow is calculated as the difference between capital gains and investments, the upward bias misleads researchers into becoming too sanguine about the real-world dynamic efficiency. In this section, we give a brief review of the statistical bias in applying the AMSZ criterion. We present bias-corrected estimates and a case study of dynamic inefficiency in China.

3.1 Bias correction

In the literature, three of the statistical biases have proven not only statistically significant but also empirically solvable:

8 AMSZ (1989) concluded that the levels and fluctuation of dynamic efficiency in the corporate sector were higher than in aggregate economy. Similarly, Kajitani (2012) found that corporate sectors in China have higher efficiency levels and volatility than the aggregate economy.

1. Bias related to labour income: The AMSZ criterion contends that dynamic efficiency can be captured by measuring the cash flow generated in the capital sector, calculated as the difference between capital gains and investments. Employing national accounts, researchers measure the cash flow as the difference between gross operating surplus and gross capital formation. Since early versions of SNA statistics fail to distinguish between mixed income[9] and gross capital income, the GOS has recorded both capital income and labour income from proprietors. An overstated GOS causes an upward bias in measuring capital returns.

In light of previous research in coping with the overstated capital income (AMSZ, 1989; Ahn, 2003; Kajitani, 2012; Geerolf, 2013), we take a conservative stance to assume the proportion of mixed income to GOS to be 10%[10]. We further refer to Christensen (1971), who reveals that labour income contributes about 2/3 to the total mixed income in the US unincorporated enterprises. Accordingly, 6.7% of the total GOS, which is by nature a kind of labour compensation, should be subtracted from the conventional GOS indicators.

2. Bias related to land rents: The AMSZ criterion is a benchmark of supply-side capital accumulation. Cash flow represents profit in the production sector, calculated as the difference between output and input in the production process. However, GOS indicators have recorded not only output of "productive capital" but also product from natural resources, such as land rent and output of forest resources. Land rent is essentially an output of non-reproducible resources. For countries with real estate bubbles and scarce land resources (such as Japan and France), land rent contributes a large percentage to the aggregate capital income. In this sense, SNA statistics have magnified the notion of "new investment", thus leading to an overestimation of capital income.

To avoid the complexity in measuring land value[11], AMSZ (1989) follow previous literature and assume that land rent contributes 6.7% to the total GNP in the efficiency estimate for the US. Similarly, for lack of reliable data, Ahn (2003) conservatively assumes the proportion to be 2% in the estimates for Asian economies. Piketty and Zucman (2014)

9 Mixed income is the surplus or deficit accruing from production by unincorporated enterprises, which consists of both capital income and the labour income of proprietors.

10 Time series data for mixed income are only available for several economies during specific periods, according to which the ratio of mixed income to GOS ranges from 15% to 40% across countries and over time. While not determinable, these estimates help to draw an initial impression of the magnitude of mixed income. To avoid over-correction, we assume the ratio to be 10% in the following analyses.

11 When referring to the market value of vacant land, the price reflects not only the "pure land value" that represents its capacity in the production process, but also the infrastructure around it and the geographical advantages distinguished by aggregate investments and construction. These features make it almost impossible to quantify the land value.

propose that the pure land value should be less than half of the national income, which infers a land rent/GNP ratio of 2.5% (if the asset return is 5%).

On the other hand, it is more effective and meaningful to measure land rent as percentage of GOS, because the plus-minus of efficiency estimates depends on the order of magnitude between GOS and capital formation. In this vein, Geerolf (2013) refers to the evaluation of Goldsmith (1985) and Davis and Heathcote (2007), which indicate that land value contributes 25% to the total value of tangible assets in the US. Accordingly, 25% of the GOS should be subtracted if land resources and other assets have identical interest rates. We assume the ratio to be 25% in the estimate for the US. For the sake of conservativeness, the ratio is set at 20% in the estimates for Japan and France[12].

3. Bias related to production tax: As noted, GOS denotes the pre-tax gross capital income, which includes taxes in the production process. However, production taxes defined in the SNA standards consist not only of the duties and tariffs on capital gains but also of taxes on labour income (He *et al.*, 2007; Geerolf, 2013)[13]. Since capital gains have included part of the employee compensation, we need to disentangle labour income tax from pre-tax capital income. To address this issue, we follow the method presented by He *et al.* (2007) to assign the ratio of labour income tax to total production taxes as the ratio of total employee compensation to gross capital income. Note that the actual labour income tax is likely to be lower than the estimates. Cautious readers should be aware of the potential over-correction and treat the estimates as a lower bound of the actual efficiency.

In summary, the bias correction process can be simplified in the following equation:

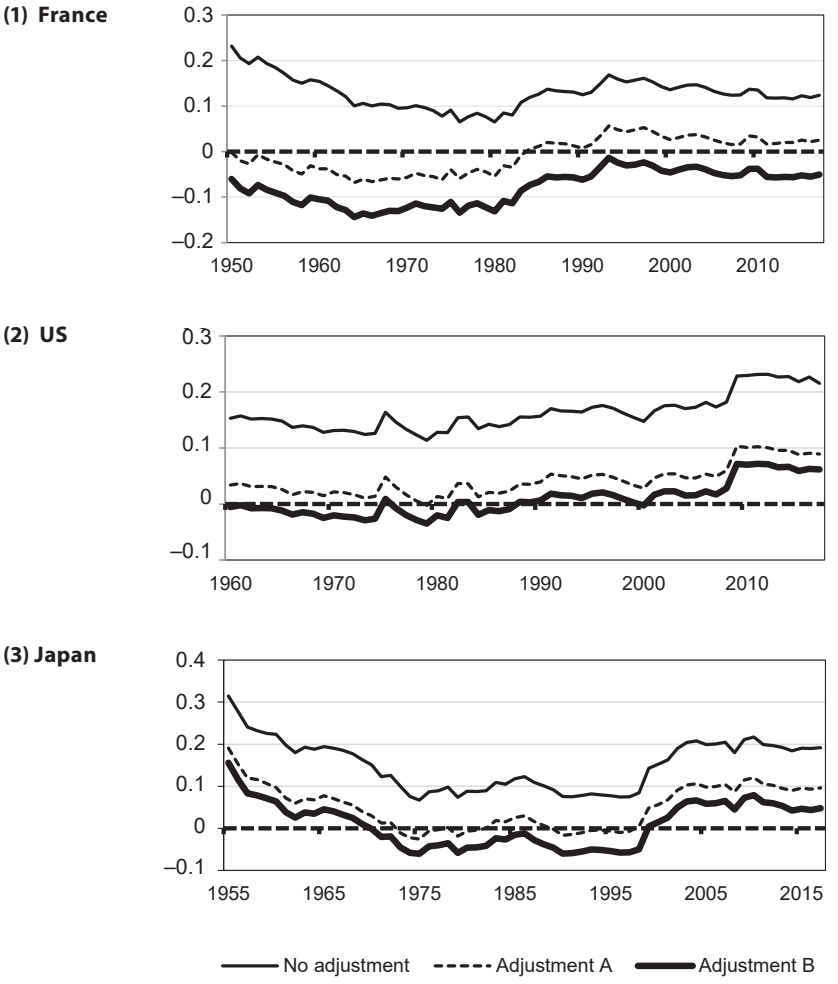
$$\text{Bias corrected GOS} = \left(\text{GOS} - \frac{2}{3}\text{Mixed income} - \text{Tax on labour income}\right) \times \left(1 - \frac{\text{Land value}}{\text{Total asset value}}\right)$$

$$\text{Level of dynamic efficiency} = \frac{\text{Bias corrected GOS}}{\text{Gross domestic product}}$$

12 According to the OECD database (SNA 2008 standard), in 2011, the land value/GDP ratio in France skyrocketed to 290 percent, and the ratio of land value to the total value of nonfinancial capital is above 44 percent in France (45 percent in Japan; see Homburg, 2014).

13 According to the SNA standards established by the OECD (available on the OECD homepage), taxes on production and imports consist of taxes payable on goods and services when they are produced, delivered, sold, transferred, or otherwise disposed of by their producers, plus taxes and duties on imports that become payable when goods enter the economic territory by crossing the frontier, or when services are delivered to resident units by non-resident units. They also include other taxes on production, which consist mainly of taxes on the ownership or use of land, buildings, or other assets used in production or on the labour employed, or compensation of employees paid.

Figure 4: Bias-corrected estimates (percent)



Note: "No adjustment" denotes the aggregate-level estimates displayed in Figure 3. "Adjustment A" denotes the estimates after the correction for biases related to labour income and land rent. "Adjustment B" denotes the estimates after the correction for biases related to labour income, land rent and production taxes.

Source: Consistent with Figures 2 and 3.

Figure 4 displays the bias-corrected estimates of the aggregate-level dynamic efficiency for France, the US and Japan. The estimate for France is considered more reliable than the others, as mixed income is directly available from the OECD database

for 1950-2017. In the early stage of post-war capital accumulation, unincorporated enterprises played an important role in the French economy with "mixed income" contributing over 25% to the total GDP. The bias correction concerning mixed income and land rent leads to a 10-20% reduction in the efficiency level, and the correction for overall biases leads to a 25% decrease. The results clearly point out that France has not been consistently dynamically efficient, especially in 1950–1985 – the post-war recovery period and the early phase of modern capital accumulation. Turn to the estimates for the US and Japan. As expected, neither country has been in an efficient status consistently over the observation period. Japan in its golden periods of economic development and the US during its economic booms might have encountered capital saturation and the consequent over-accumulation.

Are these estimates empirically relevant? Recall that in inefficient environments where capital has accumulated beyond the optimal level for maximizing social consumption, lowering investment today does not necessarily reduce social consumption in future. According to the OECD balance sheets, the capital formation ratio (GCF/GDP) in France had been declining noticeably from 29 to 21% over the period 1974–1984, whereas the consumption ratio (FCE/GDP) had been stable at 54% from 1974 onwards. Similar tendencies can be observed for the US and Japan. The efficiency estimates verify the objective existence of over-accumulation, which suggests that dynamic inefficiency is more than a theoretical possibility and should never be shelved in the library of impractical economic theories.

3.2 Dynamic efficiency in world economy

The findings in the previous subsection suggest that developed economies have experienced inefficient states in the middle stage of post-war economic development. Opposite to Bernanke's (2005) caveat that a "global saving glut" prevails in the 21st century, the "U-shaped pattern" indicates that the world today appears highly efficient (even after bias correction)[14]. In today's world, is there any country dynamically inefficient? Which country has the lowest efficiency level? To have an ex-ante understanding of these questions, one can refer to the causes and manifestations of dynamic inefficiency. Literature along this line suggests that over-accumulation is closely associated with the following attributes: (1) a large share of monopoly enterprises, (2) a high level of government intervention, (3) market imperfection and distortion, (4) speculative bubbles, (5) excess savings and consumption stagnation, and (6) rapid economic growth. Intuitively, Asian and socialist economies stand out as potential candidates for the victims of over-accumulation.

14 Fischer (2017) developed a generalization of the AMSZ criterion and revealed that dynamic efficiency always prevails. The author found signs of increasing efficiency in major OECD economies in 1990-2010.

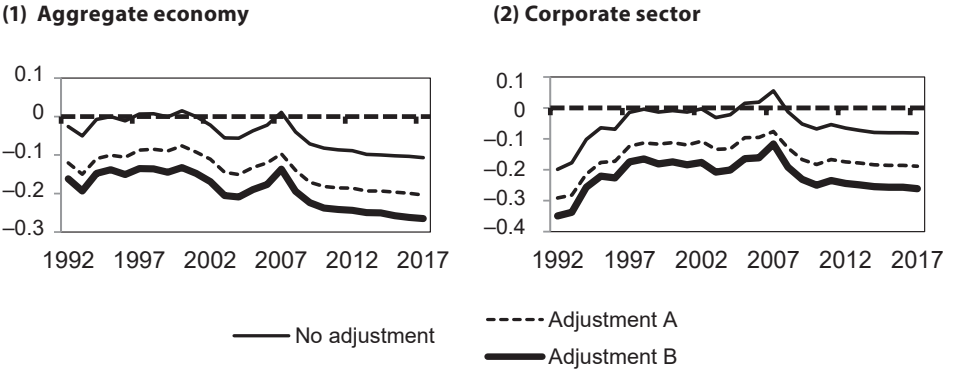
Table 1: 21st century dynamic efficiency (percent; without bias correction)

GDP Ranking	Country	Dynamic efficiency	Averaged over	GDP Ranking	Country	Dynamic efficiency	Averaged over
1	**USA**	18.56%	2000–2017	**28**	**Austria**	16.38	2000–2017
2	**China**	–4.97	2000–2017	**31**	**Norway**	21.17	2000–2018
3	**Japan**	19.27	2000–2017	**34**	**Israel**	19.51	2000–2017
4	**Germany**	20.10	2000–2017	**35**	**Denmark**	12.84	2000–2017
5	**UK**	20.49	2000–2017	**39**	**South Africa**	23.67	2008–2017
6	**France**	13.03	2000–2017	**40**	**Ireland**	27.62	2000–2017
7	**India**	9.65	2000–2017	**43**	**Columbia**	35.35	2000–2017
8	**Italy**	28.60	2000–2017	**44**	**Chile**	32.47	2003–2017
9	**Brazil**	21.54	2010–2016	**45**	**Finland**	17.41	2000–2018
10	**Canada**	15.89	2000–2017	**47**	**Portugal**	20.11	2000–2017
11	**Korea**	14.95	2000–2017	**50**	**Greece**	24.98	2000–2017
12	**Russia**	17.63	2011–2017	**51**	**Czech Republic**	22.61	2000–2017
13	**Australia**	14.58	2000–2017	**53**	**New Zealand**	22.18	2010–2017
14	**Spain**	16.71	2000–2017	**58**	**Hungary**	18.47	2000–2017
15	**Mexico**	44.61	2003–2017	**66**	**Slovak Republic**	27.18	2000–2017
17	**Turkey**	32.15	2009–2017	**76**	**Luxembourg**	20.18	2010–2017
18	**Netherlands**	19.80	2000–2018	**77**	**Costa Rica**	24.15	2012–2016
19	**Switzerland**	15.55	2000–2017	**86**	**Slovenia**	11.12	2000–2017
22	**Taiwan**	10.65	2000–2017	**88**	**Lithuania**	26.59	2004–2017
23	**Sweden**	10.25	2000–2018	**100**	**Latvia**	19.15	2000–2017
24	**Poland**	28.28	2000–2017	**105**	**Estonia**	12.43	2000–2017
25	**Belgian**	16.29	2000–2017	**112**	**Iceland**	11.68	2000–2017

Source: SNA (2008) statistics (from the National Statistics of Taiwan) for Taiwan; statistics on employee compensation used to compute GOS are not available for India at the aggregate level, we instead use the statistics on the non-financial corporate sector as a substitute, obtained from the Ministry of Statistics and Program Implementation of India; data for other countries are obtained directly from the OECD database. For Brazil, statistics on acquisitions minus disposals of valuables used to compute gross capital formation are not available in the OECD database; we instead use the statistics on gross fixed capital formation as a substitute, which might to some extent overstate the efficiency level.

Previous evidence indicates that Japan, South Korea and Taiwan might have once encountered inefficient states (*e.g.*, Ahn, 2003; Geerolf, 2013), while little is known about emerging economies in Asia and other regions. Based on the AMSZ criterion, we exploit the comprehensive datasets to evaluate the 21st century dynamic efficiency of the world's 30 largest economies ranked by GDP and other OECD participants, presented in Table 1[15]. For lack of sophisticated data, we do not conduct bias correction in this part. According to previous estimates, the efficiency level can be systematically overestimated by 15–25% under the criterion; thus, it is reasonable to label the economies with efficiency levels under 15% as potential victims of over-accumulation. These economies are: China (−4.97%), India (9.65%), Sweden (10.25%), Taiwan (10.65%), Slovenia (11.12%), Iceland (11.68%), Estonia (12.43%), Denmark (12.84%), France (13.03%), Australia (14.58%) and South Korea (14.95%).

Figure 5: Bias-corrected estimates for China (percent)

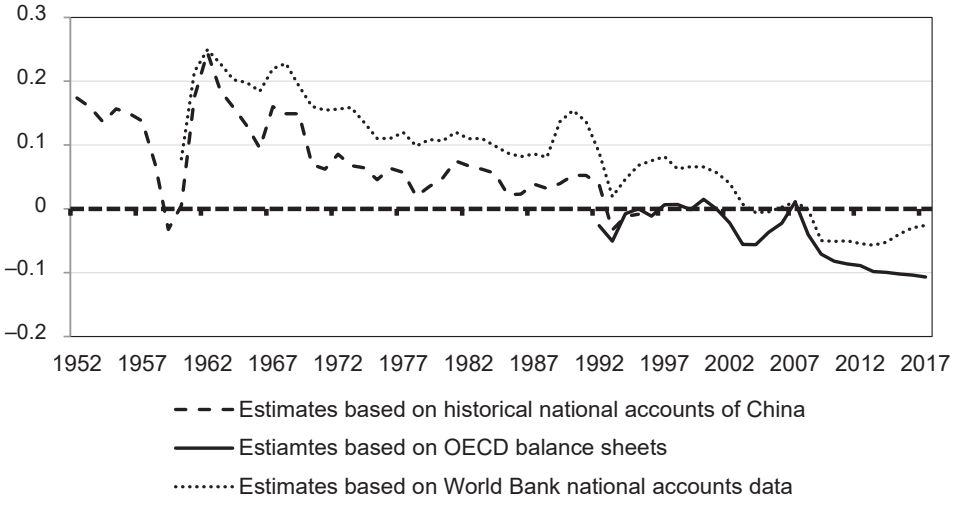


Source: Harmonized system of national accounts (OECD balance sheets)

Among the observations, China has undoubtedly been in a state of severe dynamic inefficiency in the past decade. Figure 5 displays the bias-corrected estimates for China's aggregate- and corporate-level dynamic efficiency (based on the OECD balance sheets). The results come as no surprise, because even the estimates without bias correction suffice to verify China's over-accumulation over the period 1992–2017. The bias-corrected estimates lie well below the critical line, which sets a record for inefficiency estimates obtained in the literature.

15 Among the Top 30, we drop the observations of Indonesia, Saudi Arabia, Argentina, Thailand, Iran and the United Arab Emirates, as official statistics for these countries are not up to the standards for applying the AMSZ criterion.

Figure 6: Dynamic efficiency in Chinese economy (percent; without bias correction)



Note: We calculate the GOS/GDP ratio of China using the OECD balance sheets and find that the ratio fluctuates from 35 to 40% during 1992–2017. The GOS indicator is not available in the World Bank national accounts data and the historical national accounts of China. For the sake of conservativeness, we assume the ratio to be 40% in using the World Bank national accounts data and the historical national accounts of China.

Source: Estimates for 1992–2014 are based on the OECD balance sheets. Estimates for 1960-2017 are based on the World Bank national accounts data. Estimates for 1952-1995 are based on the historical national accounts of China, conducted by the State Statistical Bureau of China (SSBC) and the Institute of Economic Research of Hitotsubashi University.

To depict the evolution of capital accumulation in China, we extend the observation period to the 1960s and 1950s by referring to the World Bank national accounts data and the estimation of historical national accounts of China. Figure 6 displays the sequences of efficiency estimates. The three sequences demonstrate similar patterns and overlap closely in the period 1992–2017, which confirms the good quality of the data and consistency of results. According to the estimates, China experienced a highly efficient status in its early stage of capital accumulation, consistent with the "U-shaped pattern" documented in Section 2. However, the efficiency level has been declining gradually ever since, resulting in a severe inefficiency today. The continuous deterioration is broadly in line with China's history of socio-economic development over the period 1950-1990, during which the market efficiency was impaired significantly by the government-led investment pattern and production disruption (*e.g.*, the "great leap forward" strategy, the "great famine" in China and the "the cultural revolution").

If the "U-shaped pattern" holds, an inescapable fact is that China today is in its middle stage of capital accumulation, where capital saturation and an alarming level of inefficiency prevail. Given previous findings on the long duration of middle-stage economic transitions (see Figure 2), China is likely to sustain the inefficient status in near future. Faced with these challenges, the capital-extensive investment pattern is difficult to continue, and it is imperative for governments to reform the growth model to improve the allocative efficiency in Chinese economy.

4. Concluding Remarks

This study aimed to document the evolution of capital accumulation in the world economy from the perspective of dynamic efficiency. Section 1 briefly introduced the theoretical background and previous literature on dynamic efficiency. In Section 2, we exploited comprehensive datasets to estimate dynamic efficiency for major economies based on the AMSZ (1989) criterion. The results show that the representative economies exhibit a similar "U-shaped pattern" in their evolution of capital accumulation. That is, the efficiency swings from high to low in the early stage, holds for some time in the middle stage, then rebounds from low to high in the late stage of capital accumulation.

In Section 3, we reviewed the literature on statistical biases in measuring dynamic efficiency and presented bias-corrected estimates. Contrary to previous evidence, the results imply that France, the US and Japan have been inconsistently dynamically efficient, especially in the early phases of capital accumulation and during the golden periods of economic development. The following analysis suggested that China today is, at any rate, in a state of severe dynamic inefficiency. The level of excess capital is extremely high, and the inefficient status is likely to continue in near future. It is imperative for Chinese governments to reform the growth model to improve the allocative efficiency. Likewise, for economies that confront moderate inefficiency (*e.g.*, India), it will be mostly harmless and reasonable to stimulate consumption, lower the capital/labour ratio, raise interest rates and reduce idle capital. The key message is that making full use of policy designs (such as pension systems and public debt) is not only the most beneficial option to obtain "free" welfare gains[16] but also the ultimate solution to the saving glut.

In the Appendix, we look into the practical and theoretical limitations of the AMSZ criterion. We argue that the shortcomings of the AMSZ criterion do not devalue its

16 Dynamic inefficiency represents "the future devours the current" state (Piketty, 2014; p. 571), which leaves room for Pareto improvement through intertemporal redistribution. In a $g > r$ environment, policy designs such as the pay-as-you-go system can promote everyone's welfare in the Pareto sense. Governments can roll over public debts forever to improve social welfare since there are always emerging investors to replace the former.

feasibility and versatility, and that the advantages of the method vastly exceed its limitations. This study explores a brand new angle for investigating the evolution of capital accumulation. Some of the findings might be helpful to reconcile the mixed conclusions of recent studies, and we look forward to breakthroughs in efficiency criteria and improvements in statistical systems.

Appendix

A.1 Unresolved statistical biases

With the exception of the statistical biases discussed in Section 3, some causes of biases are of significant importance in the application of efficiency criteria but remain unresolved due to limitations of statistical systems.

1. **Bias related to monopoly rents:** As noted, the AMSZ criterion pivots on the assumption of perfectly competitive markets, in which capital always obtains its marginal returns. In the real world, there are monopoly rents, decreasing returns, market failures and other distortions. These factors indicate the potential upward bias in measuring real capital returns. For this problem, Tobin's q (Tobin, 1969)—the ratio of a firm's market value to its book value—can be useful in assessing the degree of monopoly rents[17]. Numerous studies suggest that the aggregate-level Tobin's q is greater than unity, which manifests the objective existence of monopoly rents and market distortions in today's world. However, since market ineffectiveness is a complicated multi-dimensional issue that is unlikely to be quantified by any single unidimensional index (*e.g.*, Tobin's q), further research is needed before we can account for the monopoly bias in efficiency estimates.

2. **Bias related to capital formation and time adjustment:** In assessing dynamic efficiency, gross capital formation represents immediately available capital ("productive capital") in the production sector, including vantage capital and other crucial components. In this sense, the assumption of full depreciation adopted in AMSZ (1989) is empirically irrelevant, and the problem will be aggravated in empirical assessments due to the rough measurement of capital depreciation in statistical systems. Moreover, there is ample evidence indicating the time adjustment and gestation period of capital formation (*e.g.*, Anderson, 1993; Fakin, 1998). In other words, it takes time for the capital formed to be "operative", which causes a time asymmetry between the recorded and actual capital formation. Accordingly, the year-by-year approach tends to underestimate the efficiency level for economies where the production sector is expanding. On the other hand, immature

17 Geerolf (2013) has made explicit attempts to correct for the monopoly bias by referring to the estimated values of Tobin's q.

statistical systems tend to overstate capital formation due to artificial errors[18]. In summary, the upward bias in measuring capital formation can lead to underestimated efficiency levels, especially in the case of emerging economies.

3. **Bias related to informal services and tax evasion:** The current statistical systems have difficulty separating informal financial services and intermediations from capital investment. These hard-to-quantify labour incomes generally account for 2–5% of GDP (Bullard and Russell, 1999; Geerolf, 2013; Piketty, 2014), which could lead to non-negligible upward bias in efficiency estimates. On the other hand, tax evasion and wealth concealment have become significant socio-economic issues in recent years[19]. Zucman (2013) reveals that in 2010 about 8% of global private capital, mostly owned by Europeans and Americans, was held in "tax havens". The "missing income" due to tax evasion can cause downward bias in efficiency estimates, especially for advanced economies.

A.2 Theoretical limitations of the AMSZ criterion

Empirical literature has exhibited the feasibility and versatility of the AMSZ criterion in assessing dynamic efficiency. However, the long debate over "the best overall efficiency criterion" has never been settled, since neither the AMSZ nor the rate-of-return criterion is immune to theoretical limitations. As a major critique, the theoretical basis of AMSZ (1989) virtually underlies a sufficient condition for (interim) Pareto optimality, for which the required assumptions seem too strong for assessing dynamic efficiency (*e.g.*, Zilcha, 1990; Barbie *et al*., 2004). As a result, the AMSZ criterion is inclined to underestimate the actual efficiency[20].

In addition, the AMSZ criterion is frequently challenged because it requires the net dividend to hold positive on all paths (including future) under efficient environments, which is a demanding and unverifiable assumption. However, it is noteworthy that other efficiency criteria such as the rate-of-return criterion also confront the same limitation—the interest

18 According to Xu (2008), statistical systems in China tend to record the capital investment of "big projects", which are generally operated for more than five years, as capital formation in the starting year of the project. Moreover, due to the understatement of social consumption, statistical systems in China might have substantially overstated capital investment (*e.g.*, Zhang and Zhu, 2015; Liu *et al*., 2016).

19 The core concept of tax evasion is the strategy of "transfer pricing." A prime example is "tax havens": large multinational companies report most of their profits as earned by their subsidiaries located in countries such as the Cayman Islands (tax havens), instead of their European subsidiaries that actually produce the profits (where tax rates are higher).

20 For instance, Chattopadhyay (2008) found that dynamically efficient economies can be identified as inefficient under the AMSZ criterion.

rate is evaluated over the "entire horizon". The AMSZ criterion is intrinsically equivalent to many others. The only distinction is that the AMSZ criterion bases its judgement on the net dividend, while other criteria focus on marginal product and real interest rates. Overall, the critique on the definition of "future earnings" is a replay of the "Cambridge capital controversy" in the 1960s, and the question is a minor theoretical limitation rather than a reason to turn a blind eye to the advantages and versatilities of the AMSZ criterion.

In the literature, the lack of microeconomic basis is widely perceived as the actual limitation of the AMSZ criterion. In AMSZ (1989), the mathematical proof follows conventional methods in addressing social welfare in a typical planner's problem. An implicit utility function is employed in computing the first-order conditions, whereas the derived propositions do not rely on the conditions because all the allocations and market prices in equilibrium are *assumed* to satisfy individual constraints as well as the first-order conditions. In this sense, the AMSZ criterion does not necessarily obtain essential micro foundations, including the generality of consumer preferences, intergenerational risk sharing and existing transfer mechanisms (Chattopadhyay, 2008; Weil, 2008; Schoonbroodt and Tertilt, 2010)[21]. Overall, the characterization of aggregate-level efficiency cannot provide complete answers. It is of equal importance to understand the efficiency implication from microeconomic perspectives.

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21 In fact, many of the shortcomings of the AMSZ criterion (including statistical bias, theoretical limitation and shortcomings in mathematical proof) were firstly raised by AMSZ (1989).

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