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# THE ROLE OF INTANGIBLE CAPITAL IN THE TRANSFORMATION AND GROWTH OF THE CHINESE ECONOMY

Charles R. Hulten
Janet X. Hao

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## ABSTRACT

Investment in a broad array of intangible capital – R&D, organizational capital, worker training, and brand equity – has occurred in many of the most advanced world economies and has been found to be an important source of economic growth. This evidence suggests that intangible capital formation may play an important role in China's reform-driven transformation to a more market-oriented open economy. Though the literature on intangible capital is expanding, there has as yet been no general assessment of its role in China's rapid economic growth. This paper seeks to fill this gap by estimating how much intangible investment has taken place there over the last two decades. The importance of this capital as a driver of China's recent growth is then assessed using a growth accounting framework, and the results compared to similar findings for the U.S., Japan, the U.K., Germany, France, Italy, and Spain, as well as Japan during its high growth period. The paper also looks beyond the growth accounting framework to the role of saving rates and long-run convergence in shaping longer-term growth prospects. It also focuses on the problem of accurate economic measurement in an economy undergoing rapid transformation.

Charles R. Hulten
Department of Economics
University of Maryland
Room 3114, Tydings Hall
College Park, MD 20742
and NBER
hulten@econ.umd.edu

Janet X. Hao
The Conference Board
845 Third Avenue
New York, NY 10022
Janet.Hao@conference-board.org

The Role of Intangible Capital in the Transformation and Growth of the Chinese Economy

The reforms to the Chinese economy that began in 1978 have been a spectacular success. China has become a formidable producer and exporter of manufactured goods, with real Gross Domestic Product growing at or near double digit rates. At this pace, it will soon become the world's largest economy. At the same time, China remains a relatively poor country by world standards. According to World Bank estimates, GDP per capita in 2009 was $6,770 when adjusted for purchasing-power parity, but only $3,590 without this adjustment.

Recent Chinese reforms have aimed at raising incomes by capturing more of the value added by technology, a process that involves moving up the global supply chain from manufacturing to increased product and process innovation. A 2007 OECD assessment documented the acceleration in patents, engineers, research and development spending, and high technology exports (China has become the leading exporter of information technology products). However, successful innovation involves more than science and technology, and one of the objectives of the current study is to expand the frame of reference to include co-investments in product design and marketing, and in organizational capabilities and human capital (collectively termed "intangibles"). Investments in a broad array of intangible capital have occurred in many of the most advanced world economies, and in the U.S., the rate of business intangible investment has increased significantly over time and now surpasses that of tangible capital (Corrado and Hulten (2010)).[1] Intangible capital is also an important source of economic growth in many of these economies (van Ark, Hao, Corrado, and Hulten (2009)).

[1] The intangible investments in this paper are limited to the capital produced within business enterprises. We do not attempt to estimate the intangibles arising from investments in human capital or public sector

This evidence suggests that intangible capital formation may play an important role in China's reform-driven transformation to a more market-oriented open economy. The privatization of many state-owned enterprises requires an investment in new organizational capabilities and business models, as does progress along the global value chain to a more knowledge-intensive economy. Though the literature on intangible capital is expanding, there has as yet been no general assessment of its role in China's recent growth. This paper seeks to fill this gap by estimating how much intangible investment has taken place there over the last two decades, and assessing the importance of this capital as a driver of China's past economic growth using the model developed by Solow (1957) and Jorgenson and Griliches (1967), as extended to include intangibles by Corrado, Hulten, and Sichel (2009). In this "sources-of-growth" model, an increase in growth in output per worker is driven by two general factors: capital formation and total factor productivity.

This model has been employed extensively to gain insights into the growth process, and Krugman (1994) uses it to speak to the question of where a high-growth country is heading in the future. If a high rate of output growth is achieved primarily through capital formation, he argues that output growth will tend to slow over time because of diminishing marginal returns to capital (Krugman's growth by "perspiration"). On the other hand, if output growth is primarily driven by improvements in TFP, a high rate of growth is more sustainable (Krugman's growth by 'inspiration"). Our estimates allow us to explore the perspiration-inspiration dichotomy for the case of China using a concept of capital expanded to include intangibles, and then to compare

basic research, not because they are unimportant, but because their value is hard to calculate from the data available. Our enterprise intangibles differ from the accounting intangibles carried on enterprise balance sheets.

our results to those obtained by van Ark et. al. (2009) for the U.S., Japan, Germany, and other advanced economies. We also compare the recent growth experience of China to that of Japan during its high growth era using estimates from Nishimizu and Hulten (1978).

Perspiration and inspiration are unquestionably important determinants of whether China's high growth rates are sustainable, but they are not the only considerations. A country's growth rate may be high because it is in the early stages of convergence to a higher long-run growth path, and both the perspiration and inspiration effects may be exaggerated during this period. A higher rate of TFP growth may occur because of the inward diffusion of technology from other countries and because of the transitional effects of restructuring; a higher rate of capital formation is due, in part, to the feedback of rapid output growth on investment. The effects of both technological diffusion and restructuring diminish in importance as the economy matures and approaches the prevailing best-practice technology frontier, and the rate of capital formation declines as output growth slows and as diminishing returns to capital set in. Thus, China's current growth rates, impressive as they are, do not necessarily imply that its income per capita will overtake or surpass that of the more mature economies of the U.S. and other high income countries.[2]

The convergence-to-steady-state-growth model of Mankiw, Romer, and Weil (1992), provides a framework that looks through transitory convergence effects to the long-run growth path of an economy. Based on the Solow (1956) model of economic growth, this alternative

[2] The convergence effect underlies the forecasts of China's future growth shown in the recent World Bank report, *China 2030*. The growth rate of real GDP shown in Table 1 of that report is estimated to fall to 5.0 percent in the period 2026-2030, from the 9.9 percent average annual rate of the years 1995-2010. The report also notes the possibility that China might be caught in a middle-income growth trap, thought this is prospect is discounted.

approach shifts the focus of the empirical analysis away from the *historical* growth rates of the sources-of-growth model to the "reduced form" factors determining the *long-run levels* of output per worker that are the ultimate goal of economic development policy.  While not a crystal ball, the MRW model provides a well-organized conceptual framework for discussing the potential long-run effects of China's tangible and intangible investment rates, which are explicit arguments of the model as well as estimates of this paper.  The "parable" of long-run growth is also suitable for discussing the effects of restructuring of the Chinese economy and the effort to reduce the rate of population growth.

Any empirical attempt to understand China's recent and prospective macroeconomic performance is greatly hampered by uncertainty about the accuracy of the data.  Many past studies have had to grapple with this problem, which is summarized in detail in the recent study by Wu (2011).   China is a country in transition from pre-1978 economic structures (and accounting practices) toward an emerging modern economy, and aggregate data thus refer to different economic systems whose boundaries are shifting over time.  The measurement of intangible capital also poses significant measurement problems.  This form of capital has yet to be fully incorporated into national income accounting practice, and estimates must rely on the availability of other data sources and on assumptions about key variables.  This is a problem in data-rich countries like the U.S., and it poses greater difficulties in transitional countries like China whose data systems are less well developed.  This imprecision should be kept in mind when interpreting the results.

## II. ECONOMIC REFORM AND INTANGIBLE CAPITAL

The 1978 economic reforms have occurred in three stages, each recognizing the need to improve the organizational and technological structure of firms (Aizenman and Geng (2009)). During the first phase, from 1978 to 1984, most firms were state-owned enterprises (SOEs), initially under government control. The reforms of this period gave the SOEs' management more power to make decisions. In the second stage of the reforms, from 1984 to 1992, the government introduced more market-driven management, while retaining part of the central planning system. SOEs could sell their products in the market at a price up to 20 percent higher than the price in the central planning system. The third stage, from 1992 to the present, saw the privatization of many of the SOEs. Over this period, the number of SOEs fell from 74,066 in 1992 to 20,680 in 2007.[3]

Chinese economic policy continues to evolve, with an increased emphasis on science and technology. The 2007 OECD report cited the 2006 report "Medium to Long Term Strategic Plan for the Development of Science and Technology (2006-2020)" of the China State Council as setting out the "key priorities in science and technology" (page 17). The overarching goal is to make China an "innovation-oriented" society by the year 2020 and – over the longer term -- one of the world's leading "innovative economies" with an emphasis on the development of "indigenous" or "home-grown innovation" (page 17).

Whether this emphasis on innovation translates into a successful outcome in terms of technological leadership is another matter. China's economic prowess is built on its success in

3 Bai, Lu, and Tao (2008) and Aizenman and Geng (2009) stress that the shift from state ownership to "private" status is not an either-or affair, but involves varying degrees of independence from state control. The process was gradual and selective.

manufacturing goods, not on the design and marketing of these goods, and Breznitz and Murphree (2011) have argued that the country's technological strength currently lies in perfecting innovations created elsewhere, not in basic innovation.[4] Moreover, any success at moving up the global supply chain will bring Chinese firms into direct competition with the likes of Apple Computer, about which Michael Mandel (2006) has observed:

> "Grab your iPod, flip it over, and read the script at the bottom. It says: 'Designed by Apple in California. Assembled in China.' Where the gizmo is made is immaterial to its popularity. It is great design, technical innovation, and savvy marketing that have helped Apple Computer sell more than 40 million iPods."

The salience of this point is reinforced by the study by Linden, Dedrick, and Kraemer (2009) in which they found that "the iPod and its components accounted for about 41,000 jobs worldwide in 2006, of which about 27,000 were outside the U.S. and 14,000 in the U.S." However, "U.S. workers earned $753 million, while workers outside the U.S. earned $318 million" because the more highly compensated professional workers were in the U.S. In other words, much of the value-capture from the iPod accrues to the non-production activities of the company. It has also been argued that China does not capture much of the value created of the iPhones assembled there. According to Xing and Detert (2010), the wholesale cost of a phone shipped from China is $178.96, but the Chinese component of value added is only $6.50, or 3.6% of the total. The country's emphasis on the development of science and technology can be seen, in this light, as an

[4] In a recent interview about the book, *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China*, by David Barboza, one of the authors, Breznitz, observes that "China's companies are extremely efficient at creating new versions, often simpler, cheaper and more efficient, of technologies and products shortly after they are invented and marketed elsewhere in the world." He goes on to say that China is weak in "novel-product innovation," but suggests that this may change over time (New York Tines Economix article August 4, 2011).

attempt to move along the global value chain, in order to capture a greater share of the value added.[5]

Product design and marketing are not the only intangibles of importance for China's reform-driven growth. The country is undergoing fundamental structural changes in the organization of the economy, and the shift away from SOE's is evidence of the magnitude of the changes taking place. These structural changes involve fundamental changes in the way enterprises are managed: changes in the way decisions are made, changes in the structure of incentives and employee evaluation, and, more generally, changes in the "culture" of the firm. The critical importance of this kind of change for economic performance is stressed in the important paper by Prescott and Vissher (1980). They view the firm as essentially a store of organizational knowledge that defines the capabilities and future potential of the enterprise.[6] To realize this potential, the firm must make investments in the requisite operational procedures and infrastructural systems.[7]

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[5] The evolution of global supply chains has had a significant impact on the distribution of value-added across countries and the distribution of income within countries (see, for examples, Koopman et. al. (2010) and Timmer et. al. (2011), and the references contained therein). This is a large and complex topic with great importance for China's efforts to improve its position in the global value chain.

[6] This view provides an answer to the Coasian question of why firms *per se* exist at all in an environment in which the Invisible Hand is the ultimate efficient manager: the firm is the embodiment of the essential information infrastructure and operating procedures needed for effective decision making. This infrastructure platform, along with brand equity and intellectual property, is generally firm specific, though some parts can be outsourced.

[7] Such investments include expenses incurred for worker training and job-matching, and the development of management systems and business models. Lucas (1978), and Bloom and Van Reenan (2007), point to the importance of the management function, as does Lev (2001), who also stresses the importance of organizational capital in the formulation of business models. Brynjolfsson and Hitt (2005) point out that the organizational costs associated with the adoption of information technology greatly exceed, on average, the direct costs of the IT investments in hardware and software. When the value of a full range of intangible capital is measured at its production cost, it can explain the majority of the gap between the book value of a typical firm's equity and the corresponding market value (Hulten and Hao (2008) and

The organizational capital of an enterprise affects more than decisions about innovation. It touches every aspect of a firm's operations and planning. The importance of organizational efficiency for developing countries is underscored by Bloom et. al. (2010), who report "evidence that firms in developing countries are often badly managed, which substantially reduces their productivity (page 620)." They go on to say that recent work following Bloom and Van Reenan (2007, 2010) finds that "developing countries like Brazil, China, and India have significantly lower average management scores than firms in the United States, Japan and Western Europe (page 621)." These are essentially microeconomic findings, but they have important implications for the macroeconomic growth estimates of this paper.

## III. China's Investment in Business Intangibles

The practical problem with measuring intangible capital arises from an important asymmetry between tangible and intangible capital. Unlike tangible capital, the bulk of the intangible capital used in the business sector originates within firms, and there are thus no market transactions with which to value the investment. Intangibles must therefore be imputed from data outside the available accounting frameworks, or from assumptions and approximations. Another important asymmetry arises from the fact that many intangibles lack a physical embodiment (hence the name) because they represent the organization or control over certain types of knowledge. Because knowledge is nonrival, it can often be appropriated by competitors to the detriment of the innovator (though not necessarily at zero cost). The fact that many private companies do have R&D programs is, however, evidence that they are successful in capturing

Hulten, Hao, and Jaeger (2010)). See also McGrattan and Prescott (2010) for a different approach to valuation.

some value from their investment. Our estimates attempt to measure this value as it is reflected in the cost of making the investment. They therefore refer to the *commercial* value of this investment and thus exclude the broader social value.[8]

Our estimates of the cost of China's intangible capital are shown in Table 1. This table follows the classification system developed in Corrado, Hulten, and Sichel (2005, 2009) as closely as possible to enable a comparison (the corresponding aggregate time series are shown in Table 6, as part of a comparison of tangible and intangible investment time trends). Table 1 gives estimates of the rate of intangible investment as a fraction of GDP for the total economy and the market portion of the economy.[9] The overall results indicate a substantial effort at investment in intangible capital (7.47 percent of GDP for the total economy in 2006, and 7.06 percent of GDP for the market sector). Moreover, the rate has increased over time, from 3.79 percent in 1990 to 7.47 percent for the total-economy estimate. The 7.47 percent rate for 2006 is distributed across three main categories in the following proportions: computerized information (software), 25 percent; innovative property, 51 percent; and economic competencies, 24 percent. The market economy results are similarly distributed. The subcomponents of the three categories also show a degree of diversity. One implication of these estimates is that the scope of intangible investment is much broader than R&D spending alone, which accounts for only18

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8 This approach assumes that firms are willing to invest in intangible assets up to the point that the discounted present value of the expected income stream just equals the cost of producing or acquiring the marginal asset. This assumption is symmetric with the usual treatment of tangible capital (e.g., Jorgenson (1963)).

9 The GDP estimates in this table are expanded to include the value of the internal intangible investment produced. The separate market economy estimates are made for purposes of comparison with the intangible investment rates estimated for various countries, but they are provided only for 2006 because of the availability of the required input/output tables. Data sources are described in a data appendix available from the authors.

percent of the total–economy intangible rate.  This point should be kept in mind when interpreting the various OECD science and technology indicators available for China, which tend to focus more narrowly on the technology aspects of the innovation process.

China's intangible investment rate is substantial and growing, but how does it compare to other countries?  To address this question, we examine the experience of China in light of the corresponding rates of intangible investment in the world's largest economies, which we obtain from the study by van Ark, Hao, Corrado, and Hulten (2009).  The result is shown in Table 2, which shows that China's 7.06 percent investment rate (market economy) is comparable to the estimates for Germany and France, as well as Italy and Spain, but well behind the three leaders. It seems reasonable to conclude, on the basis of these estimates, that China's commitment to building a knowledge-based economy is roughly consistent with the corresponding efforts in the world's leading economies, in so far as that commitment can be proxied by the intangible investment rate.

Whether this investment in innovation translates into a successful outcome in terms of technological leadership is another matter.  Half of the intangible investment rate in China is due to two categories:  software and architectural and engineering design.  These two items are tied to investments in tangible capital (ITC and residential structures), and a more focused measure of organizational and product/process innovation would exclude them.  The result of this exclusion is shown in the last row of Table 2.  The adjusted rate for China is only 3.56 percent for 2006, substantially less than the corresponding adjusted U.S. rate of 8.61 percent, 6.78 and 6.65 percent for Japan and the U.K., respectively, and 5.21 and 5.20 percent for France and Germany.

## IV. INTANGIBLE CAPITAL IN THE ANALYSIS OF PRODUCTION AND GROWTH

Formal models of economic growth are usually based on the assumption that a stable aggregate production function exists that relates output, $Q_t$, to labor input, $L_t$, and to the stock of tangible capital, $K_t$. In the form used in the empirical growth models of Solow (1957) and Jorgenson and Griliches (1967), a multiplicative (Hicksian) efficiency term, $A_t$, is added in order to allow for costless changes in the efficiency with which the inputs are used, resulting in a production function of the form $Q_t = A_tF(L_t, K_t,)$. The $Q_t$ variable is an index of the volume of the total output of consumption and the two types of investment (see equation (4) below). The term $A_t$ is typically associated with costless technological and organizational change, over and above any investment in R&D, such as the diffusion of technology developed elsewhere and the reallocation of resources from less to more productive firms.

Firms invest in intangible capital in order to increase future profits, suggesting that this form of capital does not play a role in the production of contemporaneous output. On the other hand, intangible investment uses resources that might have been devoted to other uses and is thus a valid part of the contemporaneous output mix. This conceptual issue can be resolved by reformulating the problem in terms of profits, and treating the implied meta production function as a process that includes product development and sales (Hulten (2012)). In this reformulation, output is interpreted as the volume developed, produced, *and* sold, providing a rationale for including non-production intangible inputs and outputs in the structure of production.[10] The resulting meta production function has the following form:

$$(1) \qquad Q(C_t, I_t, N_t) = A_t F(L_t, K_t, R_t).$$

The output index $Q_t$ now includes intangible investment, $N_t$, and the list of inputs includes the net stock of accumulated intangible capital.

Aggregate production is typically assumed to take place under constant returns to scale to capital and labor in neoclassical formulations of production and growth. A competitive equilibrium is also assumed in which labor and capital are paid the value of their marginal products. Under there circumstances, the following accounting identity can be derived directly from the production function:

$$(2) \qquad P^C{}_t C_t + P^I{}_t I_t + P^N{}_t N_t = P^K{}_t K_t + P^L{}_t L_t + P^R{}_t R_t .$$

Applied to the aggregate economy, this is an expanded form of the well-known identity between GDP and Gross Domestic Income (GDI) on which national accounting practice is based. Because these accounts have traditionally omitted most intangibles from both sides of the accounting identity, their inclusion has the effect of increasing GDP as conventionally measured. Moreover, when both side of this identity are divided by the current value of (expanded) GDP, the identity can be expressed as

$$(2') \qquad s^C{}_t + s^I{}_t + s^N{}_t = s^L{}_t + s^K{}_t + s^R{}_t = 1.$$

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[10] In many earlier formulations, R&D capital and software were treated as current inputs to the production function, but not as outputs. This includes much of the literature on endogenous growth. Corrado, Hulten, and Sichel (2009) were the first to treat these items symmetrically in the growth accounting context.

Tables 1 and 2 focused on the size of the intangible investment share, $s^N$. As we shall see, the size of labor's income share, $s^L_t$, is also an issue of major importance for the analysis of China's growth.

The prices in the accounting identity (2) refer to the corresponding quantity variables. Those on the left-hand side are product prices, but only the first two prices are determined by market transactions because the bulk of intangible investment is produced within the firm. Its price must be interpreted as a shadow value and imputed, and finding an appropriate imputation procedure is one of the most unsettled issues in the emerging literature on macro intangibles. The prices on the right-side of (2) are input prices, with $P^L_t$ denoting the wage and $P^K_t$ and $P^R_t$ representing the Jorgensonian user costs of capital (imputed as per Jorgenson (1963) and Jorgenson and Griliches (1967)). Under the competitive market assumptions of the model, the input prices are equal to the corresponding value of marginal product, and the shares are therefore equal to the corresponding output elasticities.

## A. The Sources-of-Growth Model

The investment rates of Tables 1 and 2 indicate the scale of the commitment to future economic growth. The historical importance of intangible capital as a source of past growth is a separate question, one which has traditionally been addressed by the Solow-Jorgenson-Griliches sources-of-growth model. This empirical model is based the production function (1) without intangibles, under the assumptions of constant returns to scale and competitive equilibrium. In this conventional case, the shares $s^K_t$, $s^R_t$, $s^L_t$, can be used as proxies for the corresponding output elasticities. Output per worker can then be decomposed into the growth rates of tangible and intangible capital stocks, also expressed in per worker terms and weighted by the respective shares. The residual portion of the former not explained by the latter is the total factor productivity growth (TFPG) residual:

$$(3)\quad TFPG_t = \frac{\dot{A}_t}{A_t} = \langle\frac{\dot{Q}_t}{Q_t} - \frac{\dot{L}_t}{L_t}\rangle - s_t^K\langle\frac{\dot{K}_t}{K_t} - \frac{\dot{L}_t}{L_t}\rangle - s_t^R\langle\frac{\dot{R}_t}{R_t} - \frac{\dot{L}_t}{L_t}\rangle .$$

The growth rate of output in this formulation is the sum of the share-weighted growth rates of the constituent outputs:

$$(4)\qquad \frac{\dot{Q}_t}{Q_t} = s_t^C\frac{\dot{C}_t}{C_t} + s_t^I\frac{\dot{I}_t}{I_t} + s_t^N\frac{\dot{N}_t}{N_t} .$$

The variables involving dots are the annual growth rates of the variables in the production function (1).

TFP growth is measured as a residual in (3), and under the assumptions of the conventional model without intangibles, it is equal to the growth rate of the shift term, $A_t$ of the production function. However, it is at this point that the price paid for extending the conventional production framework to incorporate intangibles, as per (1), becomes an issue. It is shown in Hulten (2012) that the optimal investment decision about firm-specific intellectual capital involves monopolistic elements, with the important implications that prices are no longer equal to the value of the marginal products. As a result, the income shares are no longer equal to the corresponding output elasticities and the sources-of-growth model (5) yields a biased estimate of $A_t$.[11] While a monopolistic bias is not surprising given the firm-specific nature of

[11] The approach to non-current inputs advocated in Hulten (2012) is based on the model of advertising developed by Nerlove and Arrow (1962), expanded in the 2011 paper to include R&D, and is explicitly a non-competitive model with a mark-up of price over marginal cost. This leads to the problem studied by Hall (1988), who shows that the existence of a mark up of price over marginal cost, and the resulting disconnect between shares and elasticities introduces a bias in the link between TFP and $A_t$. This is the

intellectual property, the size of the bias may not be all that large because of the nature of the technological competition for market share and the implied pricing strategies.

The conventional model of productivity analysis treats technological change as both autonomous and costless ("Manna from Heaven"). The introduction of intangibles into the analysis allows for a higher degree of endogeneity in the innovation process, but TFP does not disappear when corrected for the presence of intangibles. The residual contains factors other than innovation, such as variations in capital utilization, shocks to the economic systems, the effects of changing the policy environment, omitted variables like human and infrastructure capital, and errors in measurement.

Two components of the TFP residual deserve special attention. First, it captures the effect of reallocating resources from lower to higher productivity producers. This is potentially an important effect of the Chinese reforms, given the diminished importance of state-owned enterprises (Bai et. al. (2008) and Hsieh and Klenow (2009)). The cross-sectional survey by Dollar and Wei (2007) found evidence of unequal returns to capital among firms and that the SOE's had systematically lower returns, suggesting potential benefits from further reallocation. Second, TFP embodies the technology captured by users other than the original innovator. This capture is not costless, but is generally less costly than the full development costs of the original innovation. This is potentially an important source of TFP growth for countries like China that

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price paid for the internal consistency of the sources-of-growth meta model when expanded to include intangibles. However, the bias in the shares does not invalidate the adding-up condition (2').

start with lower levels of technology.[12] Both the diffusion and reallocation effects suggest a significant role for TFP in the growth of China, at least in the near term.

TFP competes with capital formation as a source of growth in Equation (3). The dichotomy between the two for any given rate of growth in output per worker is important for understanding the path ahead, for the reasons pointed out by Krugman (1994) with his distinction between perspiration and inspiration. As noted in the introduction, China's high rate of output growth is generally thought to be more sustainable if it is driven by the latter more than the former, if capital accumulation is subject to diminishing returns to scale. However, there is a major caveat to the perspiration-inspiration dichotomy. To the extent that China's TFP growth is driven by reallocation and diffusion, inspiration *cum* TFP is itself not immune from the diminishing-returns problem. The productivity-enhancing benefits of reallocating economic activity to more productive firms is likely to diminish as the relative importance of the SOEs declines. Moreover, opportunities for appropriating best-practice technology via diffusion decline as the best-practice technology frontier is approached.

### B. The Sources of Growth and Labor's Share of Income

It is not surprising that a large literature has evolved in the sources-of-growth tradition, given the size and importance of China's economy.[13] The literature is too extensive to review here, but Wu (2011) provides a good summary and, in particular, one that draws out two key

[12] The 2007 OECD report can be read as suggesting that China is a major beneficiary of technological diffusion (e.g., more emphasis on the "D" part of R&D), and, as noted previously, Breznitz and Murphree (2011) have argued that China's strength currently lies in perfecting innovations created elsewhere, not in basic innovation. Moreover, the contribution of technological diffusion to TFP growth is not solely a matter of technology, but also has an important management dimension (Bloom et. al. (2010)).

[13] This literature includes Chow (1993), Borensztein and Ostry (1996), Woo (1998) , Qian (2000, 2003), Chow and Li (2002), Young (2003), Maddison (2007), Bosworth and Collins (2008), Brandt and Zhu (2010), and Wu, (2011).

issues. First, there is substantial disagreement about the true size of China's labor share, $s^L_t$, which is low by international standards. The study by Bai and Qian (2010) reports that the share fell from an average of just under 60 percent for the period 1978 to 1998 to around 48 percent after 2004. That was the year in which a substantial accounting change occurred, which explains about one half of the overall decline. This change involved the way the income of SOEs, collective farms, and individual business owners was divided between labor and capital. The rest was attributable to structural shifts in the economy.

The pattern reported by Bai and Qian has an important implication for growth accounting. Since labor's share of income is a proxy for the corresponding output elasticity in the sources-of-growth framework, and since the shares sum to one, the larger the labor share, the smaller is the share associated with capital. A look at equation (3) shows that capital's share leverages the growth rate of the corresponding capital stock, so the larger the share, the greater the impact of the associated capital growth and, other things equal, the smaller the share left over for the TFP residual (see, for example, Hulten and Isaksson (2007) for the magnitude of these impacts across countries). This issue is particularly important for China, given the extraordinarily high investment rates and rapid growth in the capital stocks.

The paper by Gollin (2002) shows that China's lower measured labor share is by no means the exception among lower and lower middle income countries. However, he attributes the lower labor share in these countries to the misattribution of much of the income accruing to proprietors and the self-employed to capital. When imputations are made that reclassify part of this income to labor, Gollin finds that labor's share (in the early 1990s) rises significantly in the lower income countries, from 47 percent to the 65-75 percent range. This result has been taken as justification for using a labor share at or above 60 percent regardless of the data obtained from official accounts.[14] A 60 percent labor share is used by Bosworth and Collins (2008) in their study of Chinese growth. Wu (2011) also uses this figure as one of the alternatives he considers in this study, along with the 40 percent labor share used in Chow (1963), and the share as actually measured. This procedure is a welcome and appropriate acknowledgement of the problem, and it allows the reader to see the range of estimates and choose among the alternatives.

C. Estimates of China's Sources of Growth

The problem of data accuracy goes beyond the question of labor's share. Wu also points to problems with other variables that enter the sources-of-growth model, and makes alternative estimates of real output, capital, and labor. In many cases, these estimates diverge considerably from the corresponding official data. He finds, for example, that his alternative estimate of real output grew at an average annual rate of 9.4 percent over the period 2001 to 2008, versus the "official" rate of 10.5 percent. The gap is much wider in the preceding period 1991 to 2001, 7.0 versus 9.9 percent. Wu also finds a gap between the "official" estimates of labor and capital and his estimates. As a result, the rate of TFP growth computed as per (3) is significantly lower using his alternative measures. When combined with the effects of different assumptions about

[14] Gollin's results make a valuable contribution to this difficult problem. They point to the need for improving official data and suggest a way to proceed until improvements are made. However, there is a deeper conceptual problem. The division of self-employment income into the return to either labor or capital (tangible and intangible) may be an appropriate accounting convention for a modern industrial economy, but it is not necessarily appropriate for the economic activity originating in the informal, or traditional, sectors of a low income economy. On any given work day, a self-employed person may be simultaneously both a proprietor/manager/entrepreneur and a worker. It is thus unclear how to isolate the separate marginal products of labor and capital required for the growth accounting exercise (if they even exist, given the high degree of jointness in the use of time). Nor is it clear that the marginal product of labor, if it can be clearly defined, is approximately equal to the wage the proprietor might earn in the next best labor force alternative in the informal sector.

labor's share, TFP's contribution to the growth in output per worker is found to range from a low of 13 percent to a high of 45 for the period 2001-2008, and -26 percent to 50 percent for the period 1991 to 2001.[15]

## D. Intangible Capital as a Source of China's Growth

The range of plausible TFP estimates is far too large to have any confidence about its role in the growth process, or to settle the associated perspiration-inspiration problem. However, the main focus of this paper is on the role of intangibles as a source of growth. Proceeding in the spirit of Wu's multiple alternatives, we show results for two assumptions about the labor share: in our first variant, we use the average factor shares of the countries included in the van Ark et. al. study (the "EIB shares"), and compare these results to the outcome obtained directly from the data ("China shares"). We use the "official" data from the NBS which, though probably biased upward, provide a baseline for comparison with a broader range of cross-national studies.

Table 3 shows our results, both with and without intangibles, for the years 2000 to 2008. In both cases, the introduction of intangibles in the analysis leads to a restatement of the relative importance of the various sources. The contribution of intangible capital is around one-sixth of the growth in output per worker using either factor-share assumption, where its implicit contribution was previously zero. Put differently, the omission of intangibles exaggerates the importance of the other traditional sources. One implication is that while TFP continues to be a

[15] In other words, whether or not TFP growth is a significant factor in China's growth depends on how you measure it. This finding recalls the earlier "Tyranny of Numbers" debate between Young (1995) and Hsieh (12999, 2002) about the role of TFP in the growth of the Asian Tigers. In that debate, the role assigned to TFP (and to perspiration versus inspiration) turned on whether TFP growth was measured using quantities, as in equation (3) of this paper, or formulating the problem in terms of prices (the "dual" to (3)).

significant source of growth, the perspiration-inspiration debate is tilted towards overall capital, although the assumption about the size of labor's share continues to matter (both with and without intangibles). Finally, the introduction of intangibles does little to change the growth rate of real GDP per worker (compare the columns 1 and 2 in the first row to columns 3 and 4).

The sources of growth results for China are compared to the leading economies of the world in Table 4. Again, it is not a surprise that the Chinese growth rates dominate the corresponding rates in other countries. However, while the share-weighted growth rate of China's intangibles is more than twice that of the other countries, its relative *percentage* contribution is the smallest for every other economy except Japan's, where it is essentially the same. In the U.S., intangibles contribute 30 percent of the 2000-2006 growth rate, while the Chinese rate is only half of the U.S. figure. China's continued reliance on tangible capital growth suggests a continued emphasis on manufacturing production.

The comparisons in Table 4 refer to countries at different stages of development. China is seemingly a country in the earlier stages of reform-induced development and is therefore not directly comparable to the other countries in Table 4, which are at a more mature position in their respective economic evolution. A more apt comparison would be between China's recent growth and that of Japan during its high growth era.[16] This comparison is shown in Table 5 using results from Nishimizu and Hulten (1978), in which the sources of Japanese growth were estimated for the years 1955-71. This study did not include intangible capital, but did use two estimates of tangible capital and a common labor share of 45 percent. The comparison between

[16] This comparison is made, for example, in a 2010 article in the Economist magazine, which also discusses some of the deeper issues involved in the comparison.

the high-growth era of Japan and the recent experience of China reveals a similarity not present in the preceding table. Labor productivity growth rates are similarly large, and the growth in capital per worker played an important role, as did the growth of TFP. A look back at Table 4 shows that Japan's rapid growth rate has abated as its economy began to experience some of the problems of mature economies. Income per capita in Japan is currently only about 70 percent 0f the corresponding U.S. figure.

## V. THE CONVERGENCE HYPOTHESIS

### A. The Mankiw, Romer, Weil Model

The patterns in Tables 4 and 5 do not prove that China is following a similar path to that of Japan. However, China cannot grow forever at 8 to 10 percent per year, as the World Bank report *China 2030* notes, and the comparison of Japan in these tables is instructive in light of the "Japan as Number One" claims made during that country's high growth era. The patterns of these tables are consistent with the hypothesis that China is in the early stages of convergence to a higher, reform-induced, growth path of the sort described by Barro (1991). If so, the convergence hypothesis predicts that its growth must ultimately slow.

To examine this possibility and its implications, we use a variant of the convergence model developed by Mankiw, Romer, and Weil (1992). This model is particularly useful in the current context because it connects the investment rates of Table 1 and the output elasticities to long-run outcomes. It is based on the steady-state growth model of Solow (1956), and is composed of two parts: a steady-state equilibrium and a convergence path to that equilibrium.[17]

[17] This model, and its close cousin, the neoclassical optimal growth model, start by assuming that capital in the production function exhibits diminishing marginal returns. This is the mechanism through which the steady state is achieved. The "AK" model of endogenous growth offers a competing vision in which the presence of externalities offsets the direct effects of diminishing marginal returns and convergence

In the first part, a steady-state value of output per person is derived from an aggregate Cobb-Douglas production function

$$(1') \qquad Q_t = A(X)\, K^{\alpha}_t\, R^{\beta}_t\, (e^{\lambda t} L_t)^{\gamma} \ .$$

The parameters α, β, and γ, are the Cobb-Douglas output elasticities (now constant), and they indicate the percentage impact on output generated by an increase in the respective input. The A(X) indicates the general level productive efficiency, as before, but now it is made an explicit function of a set of externally determined "state" variables, X. These state variables are included in the shift term A(X) under the hypothesis that environmental, institutional, and cultural variables affect the efficiency of production. The X's are treated as exogenously determined, and are thus not choice variables under the control of the individual enterprises that underlie the production function.[18]

The production function provides a snapshot of an economy's output-generating capacity at any point in time. Over time, output grows because of three factors in the model: (a) labor, which grows at the rate η; (b) capital, which is formed at the gross rate $s^I_t$ (adjusted for depreciation at the rate δ); and (c) technical efficiency, which grows at the rate λ. These

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does not occur. The endogenous growth model has the attractive feature that it provides one way to incorporate R&D and human capital into the growth process, rather than treating innovation as a purely exogenous process. However, this advantage is attenuated when intangibles are introduced into the Solow and optimal growth models as both an output and an input. Moreover, while the divergence feature of the endogenous growth model may help explain the growing gap between rich and poor countries, it is not an attractive model to apply to the cases with a sudden acceleration in growth, followed, in the case of Japan, by a subsequent slowdown.

[18] The MRW production function includes human capital, but not intangibles. We do not have a good measure of the stock of human capital, though Table 6 does show annual expenditures for schooling as a fraction of GDP, and, since our focus is on business intangibles, we have omitted this variable for our analysis. The state variables in the efficiency term are implicit in the MRW model.

variables are assumed to be fixed and exogenously determined, as are the saving rates, $s^I_t$ and $s^N_t$. Given these last assumptions, MRW show that the economy evolves toward a steady-state growth path along which output per worker converges to a fixed value

$$(5) \qquad (Q/L)^*_t = e^{\lambda t}\left[\frac{A(X)\ (s_I^{\alpha})(s_N^{\beta})}{(n+\lambda+\delta)^{\alpha+\beta}}\right]^{(1/1-\alpha-\beta)} .$$

The long-run prosperity of a country is determined, in this formulation, by its frugality (as reflected in the rates of saving), its innovativeness (as represented by the variable λ), its population growth (the variable *n*), and the effectiveness of its institutions, as embodied in the index A(X). A higher rate of investment in either type of capital increases the level of output per worker, but higher population growth has the opposite effect. An increase in the rate of costless technical change, on balance, increases output per worker.

Two of the logical properties of this formulation deserve special attention. A higher rate of saving leads to a higher level of long-run output per worker, other things equal, but does not affect the long-run rate of growth. In fact, the steady-state rate of growth of capital per worker is zero in this model. The sources-of-growth results shown in Tables 3 and 4 should be viewed with this in mind. Moreover, because the steady-state growth rate of the capital-labor is zero, a steady-state version of the sources-of-growth decomposition (3) assigns no weight to capital formation, leaving the exogenous rate of technical progress, λ, to explain all of the growth in output per worker. In other words, it's all about inspiration in the long-run. [19]

[19] The nature of the technical change variable, λ, also requires special mention. In Solow's 1956 steady-state model of growth, the variable λ is the rate of labor-saving (Harrodian) change. In the Solow's 1957

The second part of the MRW model involves the transition to the steady-state path described by equation (5) above. At any point in time, the actual level of output per worker. $Q_t/L_t$, differs from the steady-state value (Q/L)* and is generally presumed to be below the latter). In the MRW model, the gap between $Q_t/L_t$ and value (Q/L)* is assumed to be closing at a rate μ [=(n+λ+δ)(1-α-β)] from a starting point

$$(6) \qquad \frac{\dot{Q}_t}{Q_t} - \frac{\dot{L}_t}{L_t} = \mu \; [\ln(Q/L)^* - \ln(Q_t/L_t)].$$

The growth rate of an economy depends, here, on the size of the gap between its current position on the convergence path and its steady-state target, and thus differs from the formulation in the growth accounting equation (3) (though the two are consistent). The larger the remaining gap to close, the higher the rate of growth, explaining why economies in the early stages of convergence have higher rates of growth, and why these rates gradually decline. One important implication is that a larger contemporaneous growth rate in output per worker in one country versus another does not imply that the former will necessarily end up on a higher steady-state growth path with a higher level of prosperity. It may simply have started from a much lower initial level of output per worker. It might be recalled, here, that the current gap between output per worker in the U.S. and China is around six to one.

B. Reforms and Convergence

The structure of the Solow/MRW growth model is far too simple to capture the complexity of the events that have taken place in China since 1978, and economic growth in the

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sources-of-growth formulation, TFP refers to the Hicks'-neutral rate of technical change, i.e., the growth rate of $A_t$. The two rates are connected by the formula $\lambda = TFP/s^L$.

real world does not proceed automatically according to a prescribed formula (recent events are a reminder that there is a demand side to the growth problem). Indeed, there is something other-worldly about any model in which the course of events unfolds smoothly and predictably into a distant future. The steady-state framework is best regarded as a parable that illustrates certain points, and the steady-state growth parable does capture some of the main economic mechanisms of the post-1978 Chinese reforms. It also provides a useful way of organizing data and interpreting data. For example, the move toward a more market-oriented economy open to global trade can be thought of, in MRW terms, as influencing the state variables X in the efficiency function A(X) in order to initiate convergence to a higher steady-state value of output per worker.

The transformation of the Chinese economy to achieve a more efficient framework for production is a key aspect of the reform process, and certainly one that will play a major role in the long-run prosperity of the country. A reduction in the rate of population growth via the one-child policy is another factor in encouraging higher long-run labor productivity, albeit one with other cultural and structural implications. Changes in the saving rate also boost the steady-state level of output per worker in the MRW framework (but, again, not its long-run rate of growth). The rate of costless technical change, $\lambda$, has offsetting effects on the steady-state solution in (5), but, on balance, is a positive factor. It is treated as externally determined, an assumption with greater credibility when intangible capital is added to the model.

## VI. SAVING AND CONVERGENCE

### A. Chinese Saving Rates

Table 6 shows the rates of saving/investment for various categories of tangible and intangible capital, as well as the rate of expenditure on education, for the years 1995-2008. The total rate for intangible investment, as measured by Gross Fixed Capital Formation (GFCF), and expressed as a fraction of expanded GDP, rose from 32 percent 1995 to 38 percent in 2008. Moreover, this growth rate accelerated significantly in the second half of the period. GFCF includes both business fixed investment and investment in residential real estate, which we impute to be around half of the total in the period 2001-2008. The rate of intangible capital grew rapidly over this period (6.6 percent per year), but the growth of the core intangibles rate (without software and design), was significantly slower (3.7 percent). The table also shows that the expenditure rates for ITC equipment and education have increased.

These rates are put into an international context in Figures 1, 2, and 3. Figure 1 compares the rates of intangible investment, $s^N_t$, across countries with labor productivity, $Q_t/L_t$, which is closely related to income per capita. The countries included in the comparison are based on the larger economies studied by van Ark et. al. (2009). The results for the large economies are generally consistent with Barro (1991), who shows that countries with larger rates of tangible investment exhibit higher income per capita. China is possibly such an outlier, but this is hard to tell because of the absence of low and middle income countries in the comparison.

Table 2 shows China has a relatively high rate of intangible investment, so its position in Figure 1 is due in large part to its significantly lower labor productivity. One explanation for this result is that China is in the earlier stages of the convergence process, so a higher reform-induced intangible investment rate would be consistent with a relatively low labor-productivity ratio, when compared to other economies further along in the convergence process. However, the observed patterns in Figure 1 could also reflect convergence to different steady-states paths, since other parameters besides the investment rates are important. A comparison of Japan and the U.S. shows that mature economies can have roughly the same rates of intangible investment, but different levels of labor productivity.

The picture changes somewhat when the core rate of intangible investment on the last row of Table 2 is used in place of the gross investment rate. This comparison is shown in Figure 2, where the association between $s^N_t$ and $Q_t/L_t$, is seen to be stronger, with the U.S. the unambiguous leader. While China is still an outlier, and continues to be roughly at the level of Italy and Spain, it is now at distinctly below the level of the other countries. The U.S. lead also widens.

The pictures changes quite a bit in Figure 3, where the rate of *tangible* investment is compared to the output per worker across countries. Here the position of China is so different that it is hard to explain solely in terms of the early stages of the convergence process, or even as convergence to a higher growth path. There is, however, another possibility. China's outlier status here, and in the preceding figures, may be the result of investment rates that are inflated by a policy designed to encourage or force rapid economic growth. This kind of policy may reflect an initial "big push" to get the economy launched on the new reform-induced steady state path. In this regard, Young (1995) observed that investment rates in Singapore and South Korea rose to rates comparable to China's (47 and 40 percent, respectively) during their "Asian Tiger" growth period, while the Taiwanese rate rose to 27 percent. Hong Kong was the exception with a constant rate.

### B. The Composition of China's Investment Rates

Another look at Table 6 reveals an important aspect of China's investment patterns: while China's rate of intangible investment is comparatively high relative to the other countries in the comparison, the ratio of intangible to tangible investment is relatively low. This last finding is of interest because of its implications for the structural transformation of China from manufacturing toward a more innovation-intensive economy. If the U.S. experience is any guide, this involves a shift in emphasis from investment in tangible capital toward intangibles.[20] Moreover, Figure 4 reveals a positive association between this ratio and labor productivity, with the U.S., the U.K., and Finland showing intangible/tangible ratios above one. France is just below this value, while Germany, with its greater orientation to manufacturing, is around 0.7. China is again an outlier with respect to the other countries, but its intangible/tangible ratio of around 0.3 is among the lowest in the countries shown in the figure. Despite substantial investments in intangible capital, China still appears strongly oriented to its manufacturing base.

## VII. CONCLUSION

Intangible capital in its various manifestations - human capital, technology, organizational development, product design and marketing - is the foundation on which modern economies are built. The architects of current Chinese economic policy, in government and in

[20] The rate of tangible investment in the U.S. has been relatively constant over time (1950 to the present) while the rate of intangible investment has increased significantly and now exceeds tangible investment (Corrado and Hulten (2010)).

business, are well aware of this reality and have promoted a high rate of investment in intangible capital. Its impact is apparent in the estimates of this study, which, despite all the problems and ambiguities with the data, finds that intangibles have played a significant role in China's recent growth. This role is, however, not nearly as great as in the U.S. economy, and investment rates in China appear to be dominated by a commitment to tangible capital, both residential and non-residential. This, in turn, raises questions about the country's progress along the global value chain to greater affluence.

Given the current momentum, there is every reason to expect that intangible investment will continue to play an important, and perhaps an increasingly important, role in the future, given the recent trend in the country's science and technology indicators. Though the macroeconomic evidence is ambiguous and the perspiration-inspiration issue is left unresolved, China appears to be moving to a higher long-run level of output per worker, regardless of which of the saving rates or capital output elasticities reported in this study are assumed to prevail in the long run. Indeed, the experience of Japan appears to be a reasonable model on which to base guesses about the path ahead. However, this may be a long march, particularly if the objective is to catch up to, or exceed, the U.S. The current income gap between the two countries is quite large, with output per person in China only 16 percent of the U.S. number in 2007. A rough "development accounting" calculation suggests that, even after controlling for intangible capital formation, the differential in TFP was responsible for 40 to 53 percent of this gap, depending on the assumption about the size of capital's income share. Filling the gap may prove challenging, particularly the TFP "inspiration" part of it, but is certainly not impossible.

REFERENCES


Aizenman, Joshua, and Nan Geng, 2009. *Adjustment of state owned and foreign-funded enterprises in China to economic reforms, 1980s-2007: a logistic smooth transition regression (LSTR) approach.* NBER Working Paper 15274 National Bureau of Economic Research.

Bai, Chong-En, and Zhenjie Qian, 2010. "The Factor Income Distribution in China: 1978-2007," *China Economic Review*, 21, 650-670.

Bai, Chong-En, Chang-Tai Hsieh, and Yingyi Qian, 2006. "The Return to Capital in China," *Brookings Papers on Economic Activity*, 2006, 61-88.

Bai, Chong-En, Jiangyoung Lu, and Zhigang Tao, 2008. "How Does Privatization Work in China?" *Journal of Comparative Economics*.

Barro, Robert J,, 1991. "Economic Growth in a Cross Section of Countries," *The Quarterly Journal of Economics*, 106, May, 407-443.

Barboza, David, 2011. *"Moving China Up the Value Chain"*, Economix, NewYork Tines, August 4.

Bloom, Nicholas, and John Van Reenen, 2007. "Measuring and Explaining Management Practices Across Firms and Countries," *Quarterly Journal of Economics* 122 (4), 1351-1408.

Bloom, Nicholas, and John Van Reenen, 2011, "Why Do Management Practices Across Firms and Countries," *Journal of Economic Perspectives*, 24 (1), 2010, 203-224.

Bloom, Nicholas, Aprajit Mahajan, David McKenzie, and John Roberts, 2010. "Why Do Firms in Developing Countries Have Low Productivity?" *American Economic Review*, 100, 2, May, 619-623.

Breznitz, Dan and Michael Murphree, 2011. *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China*, Yale University Press, May 31.

Bosworth, Barry and Susan Collins, 2008. Accounting for growth: comparing China and India. *Journal of Economic Perspectives*, 22(1), 45-66.

Borensztein, Eduardo and Jonathan Ostry, 1996. Accounting for China's growth performance, *American Economic Review*, Vol. 86, 224-228.

Brandt, Loren and Xiaodong Zhu, 2010. *Accounting for China's growth*. IZA Dicussion paper No. 4764.

Brynjolfsson, Erik., and Lorin M. Hitt, 2005. "Remarks," In *Measuring Capital in the New Economy*, C. Corrado, J. Haltiwanger, and D. Sichel, eds., Studies in Income and Wealth, Vol. 65. Chicago: The University of Chicago Press, 567-575.

China State Council, 2006. *Medium-to-Long-Term Strategic Plan fore the Development of Science and Technology* (2006-2020).

Chow, Gregory C., 1993. Capital Formation and Economic Growth in China. *The Quarterly Journal of Economics*, Vol. 108 (3), 809-842.

Chow, Gregory, and Kui-Wai Li, 2002. China' economic growth: 1952-2010. *Economic Development and Cultural Change*, Vol. 51, 247-256.

Corrado, Carol and Charles Hulten, 2010. “How do you measure a ‘technological revolution’?” *American Economic Review*, May, 99-104.

Corrado, Carol, Charles Hulten, and Daniel Sichel, 2005. “Measuring Capital and Technology: An Expanded Framework.” In *Measuring Capital in the New Economy*, C. Corrado, J. Haltiwanger, and D. Sichel, eds., Studies in Income and Wealth, Vol. 65. Chicago: The University of Chicago Press, pp.11-41.

Corrado, Carol, Charles Hulten, and Daniel Sichel, 2009. “Intangible Capital and U.S. Economic Growth,” *Review of Income and Wealth*, 55, 3, September, 661-685.

Economist Magazine, 2010. “China's economy, Not Just Another Fake: The similarities between China today and Japan in the 1980s may look ominous. But China’s boom is unlikely to give way to prolonged slump,” *The Economist*, January 14.

Economist Magazine, 2011. *Privatisation in China: Capitalism Confined*, *The Economist*, September 3, 67-70.

Economist Magazine, 2012. *Special Report: China’s Economy*. May 26.

Dollar, David, and Shang-Jin Wei, 2007. *Das (Wasted) Kapital: Firm Ownership and Investment Efficiency in China*, NBER Working Paper 13103, National Bureau of Economic Research, May.

Fukao, Kyoji, Tsutomu Miyagawa, Kentaro Mukai, Yukio Shinoda and Konomi Tonogi, 2009. Intangible Investment in Japan: Measurement and Contribution to Economic Growth. *The Review of Income and Wealth*, Vol. 55(3), September.

Gollin, Douglas, 2002. “Getting Income Shares Right,” *Journal of Political Economy*, 110(2), 458-574

Hall, Robert E., "The Relation Between Price and Marginal Cost in U.S. Industry," *Journal of Political Economy*, 96, 1988, 921-947.

Hsieh, Chang-Tai, 1999. “Productivity Growth and Factor Prices in East Asia,” *American Economic Review*, 89, 2, June, 133-138.

Hsieh, Chang-Tai, 2002. “What Explains the Industrial Revolution in East Asia? Evidence from the Factor Markets, *American Economic Review*, 92, 3, June, 502-526.

Hsieh, Chang-Tai and Peter J. Klenow, 2007. “Relative Prices and Relative Prosperity,” *American Economic Review*, 97, 3, June, 562-585.

Hsieh, Chang-Tai and Peter J. Klenow, 2009. “Misallocation and Manufacturing TFP in China and India,” *Quarterly Journal of Economics*, CXXIV, 4, November, 1403-1448.

Hu, Jintao, 2010. Speech at the Second Meeting of the Communique of the Fifth Plenum of the 17th Central Committee of the Communist Party of China. October 18, 2010.

Hulten, Charles R., 2010. “Growth Accounting,” *Handbook of the Economics of Innovation*, Chapter 23, Bronwyn H. Hall and Nathan Rosenberg (eds.), Elsevier-North Holland, 987-1031.

Hulten, Charles R., 2010. *Decoding Microsoft: Intangible Capital as a Source of Company Growth*, NBER Working Paper 15799, National Bureau of Economic Research, March.

Hulten, Charles R., 2012. *Intangible Capital, Product Innovation, and the Theory of the Firm Growth*. Unpublished.

Hulten, Charles and Xiaohui Hao, 2008. *What is a company really worth? Intangible capital and the "market to book value" puzzle*. NBER Working Paper 14548, National Bureau of Economic Research, December.

Hulten, Charles, Xiaohui Hao and Kirsten Jaeger, 2010. *Macro versus Micro Comparisons of Intangible Capital: The Case of Germany and the U.S.*, Research Paper of CoInvest Project, available at http://www.coinvest.org.uk/bin/view/CoInvest/COINVESTHulteninterim

Hulten, Charles and Anders Isaksson, 2007. *Why Development Levels Differ: The Sources of Differential Economic Growth in a Panel of High and Low Income Countries*, NBER Working Paper 13469, National Bureau of Economic Research, March. October.

Jorgenson, Dale W., 1963. "Capital Theory and Investment Behavior," *American Economic Review*, 53, 2, May, 247-259.

Jorgenson, Dale W. and Zvi Griliches, 1967. "The Explanation of Productivity Change," *Review of Economic Studies*, 34, July, 349 83.

Koopman, Robert, William Powers, Zhi Wang, and Shang-Jin Wei, *Give Credit Where Credit is Due: Tracing Value Added in Global Production Chains*, National Bureau of Economic Research, Working Paper 16426, September 2010.

Krugman, Paul, 1994. "The Myth of Asia's Miracle," *Foreign Affairs*, 73, 6, November/December, 62-77.

Lev, Baruch, 2001. *Intangibles: Management, Measurement, and Reporting*, Brookings Institution Press, Washington D.C..

Linden, Greg , Jason Dedrick, and Kenneth L. Kraemer, 2009. *Innovation and Job Creation in a Global Economy: The Case of Apple's iPod*, Working Paper, Personal Computing Industry Center, UC Irvine, January.

Lucas, Robert E. Jr, 1978. "On the Size Distribution of Business Firms," *The Bell Journal of Economics*, 9, 2 Autumn, 508-523.

Mandel, Michael, 2006. "Why the Economy is a Lot Stronger Than You Think," *Business Week*, February 13, 62-70.

Mankiw, N. Gregory, David Romer, and David N. Weil, 1992. "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, 107, 2, May, 407-437.

McGrattan, Ellen R., and Edward C. Prescott, 2010."Technology Capital and the US Current Account," *American Economic Review,* 100, September, 1493-1522.

Nakamura, Leonard, 1999. “Intangibles: What Put the *New* in the New Economy?” Federal Reserve Bank of Philadelphia *Business Review*, July/August 1999, 3-16.

Nerlove, Marc, and Kenneth J. Arrow, "Optimal Advertising Policy Under Dynamic Conditions,” *Economica*, New Series, vol. 29, 114, May 1962, 129-142.

Nishimizu , Mieko, and Charles R. Hulten, 1978. "The Sources of Japanese Economic Growth, 1955-71," *Review of Economics and Statistics*, Vol. 60, No. 3, August, pp. 351-361.

OECD, 1998. *Measuring intangible investment: national efforts to measure intangible investment*. Available at http://www.oecd.org/dataoecd/45/41/1943317.pdf

Organization for Economic Co-Operation and Development (OECD), 2007. *CHINA Synthesis Report*, OECD Reviews of Innovation Policy, OECD.

Prescott, Edward C., and Michael Visscher, 1980. “Organizational Capital,” *Journal of Political Economy*, 88, 3, 446-461.

Qian, Yingyi, 2000. The process of China’s market transition (1978-1998): the evolutionary, historical and comparative perspectives. *Journal of Institutional and Theoretical Economics*, 156 (1), 151-171.

Qian, Yingyi, 2003. How reform worked in China. In D. Rodik (Ed.) *Search of prosperity: Analytic narratives on economic growth*. Princeton, NJ: Princeton University Press, 297-333.

Romer, Paul M., "Endogenous Technical Change," *Journal of Political Economy*, 98, No. 5, October, S71-S102.

Schaaper, Martin, 2009. *Measuring China’s innovation system: national specificities and international comparisons.* OECD STI working paper 2009/1, Statistics Analysis of Science, Technology and Industry.

Solow, Robert M., 1956. "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70, February, 65-94.

Solow, Robert M., 1957. "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39, August, pp. 312-320.

*Summary of Five Year Plans*, various years. http://www.gov.cn/2011lh/content_1825838_2.htm.

Timmer, Marcel, Abdul Azeez Erumban, Bart Los, Gaaitzen de Vries, and Robert Stehrer, *Slicing Up Global Value Chains: The Role of China*, paper presented at the CRIW/Productivity Workshop at the 2011 NBER Summer Institute, July 19, 2011.

van Ark, Bart, Janet Hao, Carol Corrado and Charles Hulten, 2009. “Measuring Intangible Capital and its Contribution to Economic Growth in Europe,” *EIB Papers*, European Investment Bank, volume 14 (1), December 2009, 62-93.

Woo, Wing Thye, 1998. Chinese economic growth: sources and prospects, in M. Fouquin and F. Lemoine (eds.) The Chinese Economy, *Economica*, London.

World Bank, *The World Development Report 2011: Conflict, Security, and Development*, Washington DC, 2011.

World Bank and the Development Research Center of the State Council, the People's Republic of China, *China 2030: Building a Modern, Harmonious, and Creative High-Income Society*, Conference Edition, The World Bank, 2012.

Wu, Harry, 2011. *Accounting for China's growth in 1952-2008-China's growth performance debate revisited with a newly constructed data set*, Institute for Economic Research, Hitosubashi University, February.

Xing, Yuqing, and Neal Detert, 2010. *How the iPhone Widens the United States Trade Deficit with the People's Republic of China*, ADBI Working Paper Series No. 257, Asian Development Bank Institute December.

Young, Alwyn, 1995. "Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," *Quarterly Journal of Economics*, August, 641-680.

Young, Alwyn, 2003. From gold to base metals: productivity growth in the People's Republic of China during the reform era, *Journal of Political Economy*, 1120-1161.

## DATA REFERENCES

China Input-output Tables, various years. National Bureau of Statistics of China, available at http://www.stats.gov.cn/tjsj/ndsj/China Statistical Yearbook, various years. National Bureau of Statistics of China, available at http://www.stats.gov.cn/tjsj/ndsj/

Communique on Land and Resources of China, various years. The Ministry of Land and Resources of the People's Republic of China, available at http://www.mlr.gov.cn/zwgk/tjxx/

Hu, Hongli, Zhangxi Lin and William Foster, 2002. China's software industry-current status and development strategies. Available at http://zlin.ba.ttu.edu/papers/Outgoing/GITM-ITC-3.pdf

National Annual Report of Firms of Engineering Inspection and Design, various years. The Ministry of Housing and Urban-Rural Development of the People's Republic of China.

National Report of Press and Publishing Industry, various years. Provided by the Newspaper of the China News and Publishing Industry, available at http://www.chuban.cc/syzx/dlcbygk/ndzk/

OECD, 2010. Main Science And Technology Indicators: 2010/2 edition. http://www.oecd.org/document/33/0,3343,en_2649_34451_1901082_1_1_1_37417,00.html

Statistical Report of the National Software Industry issued by the Ministry of Industry and Information Technology for the years from 2006 to 2009, available at http://www.miit.gov.cn/n11293472/n11293832/n11294132/n12858477/index.html

Total Economy Database, 2011. The Conference Board, available at http://www.conference-board.org/data/economydatabase/ .

**Table 1**
**Intangible Investment in the whole economy of and in the market sector of China (percent of GDP)**

| | China-all **1990** | China-all AAGR **1990-06** | China-all **2006** | China-market **2006** |
|---|---|---|---|---|
| **1. Computerized information** | **0.01** | **0.17** | **1.87** | **1.88** |
| **2. Innovative property** | **2.48** | **2.44** | **3.79** | **3.38** |
| a) R&D, including social sciences and humanities | 0.68 | 0.61 | 1.34 | 1.02 |
| b) Mineral exploration and evaluation | 0.20 | 0.20 | 0.21 | 0.21 |
| c) Copyright and license costs | 0.27 | 0.23 | 0.12 | 0.08 |
| d) Development costs in financial industry | 0.64 | 0.56 | 0.46 | 0.47 |
| e) New architectural and engineering designs | 0.68 | 0.86 | 1.66 | 1.62 |
| **3. Economic competencies** | **1.29** | **1.55** | **1.81** | **1.80** |
| a) Brand equity | 0.08 | 0.18 | 0.40 | 0.38 |
| Advertising expenditure | 0.08 | 0.18 | 0.40 | 0.38 |
| Market research | | | | |
| b) Firm-specific human capital | 0.33 | 0.35 | 0.28 | 0.29 |
| Continuing vocational training | 0.33 | 0.35 | 0.28 | 0.29 |
| Apprentice training | | | | |
| c) Organizational structure | 0.89 | 1.01 | 1.13 | 1.13 |
| Purchased | | | | |
| Own account | 0.89 | 1.01 | 1.13 | 1.13 |
| **Total Investment** | **3.79** | **4.17** | **7.47** | **7.06** |

Note: GDP in this table is the sum of conventional GDP and new intangibles. When expressed as a fraction of conventional GDP, the 1990 and 2006 estimates are 3.93 and 7.90 percent (7.43 for the market economy). Sources: Most data are from the China Statistical Yearbooks provided by the National Bureau of Statistics of China and from Annual Reports of various ministries. The data sources for each type of intangible investment are described in an appendix available from the authors.

**Table 2**
**Intangible Investment in the market sector of China and in the market sectors of other countries (percent of GDP)**

| Type of Investment | Germany 2006 | France 2006 | Italy 2006 | Spain 2006 | UK 2006 | US 2006 | Japan 2000-05 | China-market 2006 |
|---|---|---|---|---|---|---|---|---|
| **1. Computerized information** | **0.69** | **1.33** | **0.61** | **0.75** | **1.42** | **1.24** | **2.02** | **1.88** |
| **2. Innovative property** | **3.37** | **2.99** | **2.12** | **2.66** | **2.90** | **4.07** | **5.51** | **3.38** |
| a) R&D, including social sciences and humanities | 1.62 | 1.22 | 0.56 | 0.60 | 0.98 | 1.69 | 2.57 | 1.02 |
| b) Mineral exploration and evaluation | 0.01 | 0.04 | 0.09 | 0.04 | 0.04 | 0.78 | 0.00 | 0.21 |
| c) Copyright and license costs | 0.20 | 0.29 | 0.10 | 0.17 | 0.20 | 0.55 | 1.01 | 0.08 |
| d) Development costs in financial industry | 0.70 | 0.56 | 0.56 | 0.50 | 0.06 | 0.55 | 1.84 | 0.47 |
| e) New architectural and engineering designs | 0.85 | 0.87 | 0.82 | 1.35 | 1.60 | 0.50 | 0.00 | 1.62 |
| **3. Economic competencies** | **2.67** | **3.10** | **2.10** | **1.82** | **5.36** | **5.04** | **2.66** | **1.80** |
| a) Brand equity | 0.53 | 0.93 | 0.68 | 0.40 | 1.06 | 1.35 | 1.10 | 0.38 |
| Advertising expenditure | 0.39 | 0.69 | 0.45 | 0.18 | 0.84 | 1.24 | 0.00 | 0.38 |
| Market research | 0.14 | 0.24 | 0.23 | 0.22 | 0.22 | 0.11 | 0.00 | 0.00 |
| b) Firm-specific human capital | 1.21 | 1.42 | 0.98 | 0.77 | 2.33 | 1.05 | 0.46 | 0.29 |
| Continuing vocational training | 0.61 | 1.17 | 0.68 | 0.68 | 0.00 | 0.00 | 0.00 | 0.29 |
| Apprentice training | 0.60 | 0.24 | 0.31 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| c) Organizational structure | 0.94 | 0.76 | 0.43 | 0.65 | 1.96 | 2.64 | 1.10 | 1.13 |
| Purchased | 0.51 | 0.30 | 0.14 | 0.26 | 0.47 | 0.00 | 0.00 | 0.00 |
| Own account | 0.43 | 0.46 | 0.29 | 0.39 | 1.50 | 0.00 | 0.00 | 1.13 |
| **Total Investment** | **6.73** | **7.42** | **4.83** | **5.23** | **9.67** | **10.35** | **10.19** | **7.06** |
| **Investment excl. computerized info. and designs** | **5.20** | **5.21** | **3.39** | **3.13** | **6.65** | **8.61** | **6.78** | **3.56** |

Notes: (1) US 2006 uses a more aggregate US estimates (Corrado and Hulten, 2010) and the shares of detailed intangibles (1998-2000) from CHS 2005. (2) Japan R&D excludes social science, and social science R&D is in the 2.0 percent of the residual term of innovative property.
Sources: The data sources of the US are CHS (2005) and Corrado and Hulten (2010). The data source for Japan is Fukao et. al. (2009). The data source for the UK, Germany, France, Italy and Spain is van Ark et. al. (2009). (3) GDP in this table is the sum of conventional GDP and new intangibles, while GDP in the corresponding table of Fukao et. al. (2009) and van Ark et. al. (2009) is conventional GDP. We convert the percentages of conventional GDP to percentages of GDP with new intangibles.

## Table 3

**China Growth Accounting**
**(average annual growth rates)**

| | with intangibles | | without intangibles | |
|---|---|---|---|---|
| Time period | 2000-08 | 2000-08 | 2000-08 | 2000-08 |
| Type of input shares | EIB shares | China shares | EIB shares | China shares |
| Labor’s 2008 income share | 61% | 41% | 70% | 43% |
| Tangible capital 2008 share | 26% | 46% | 30% | 57% |
| Intangible capital 2008 share | 12% | 14% | 0% | 0% |
| Output per person (AAGRs) | 9.72% | 9.72% | 9.65% | 9.65% |
| Contributions | | | | |
| Tangible capital per worker | 3.12% | 5.23% | 3.54% | 6.26% |
| Intangible capital per worker | 1.58% | 1.47% | | |
| TFP | 5.03% | 3.02% | 6.11% | 3.39% |

Note: EIB shares use the average input shares of the US, UK, Germany, France, Italy, Spain, Austria and Denmark.
Source: Data on GDP, employment, and gross capital formation are from the China Statistical Yearbooks. Data on initial capital stock (1980) are from Chow (2002). We use a perpetual inventory method and a 5 percent depreciation rate to estimate the capital stock of years from 1981 to 2008. Sources of EIB shares are unpublished data from van Ark et. al. (2009) and Corrado and Hulten (2010). The income share of labor is 0.44 on average from 2000 to 2008, that of tangible capital 0.44, and that of intangible capital 0.12.

## Table 4

## Comparison of the Sources of Growth Accounting-Across Countries (% AAGR)

| | Germany 2000-06 | France 2000-06 | Japan 2000-05 | UK 2000-06 | US 2000-06 | China-EIB 2000-06 | China-Chn. 2000-06 |
|---|---|---|---|---|---|---|---|
| Output per person | 1.61 | 1.29 | 2.11 | 2.45 | 2.37 | 9.25 | 9.25 |
| Contributions: | | | | | | | |
| Tangible capital | 0.57 | 0.39 | 0.83 | 0.34 | 0.62 | 3.04 | 5.20 |
| Intangible capital | 0.39 | 0.37 | 0.33 | 0.64 | 0.72 | 1.55 | 1.48 |
| TFP | 0.65 | 0.52 | 0.95 | 1.47 | 1.03 | 4.66 | 2.57 |

Note: China-EIB uses the average input shares of US, UK, Germany, France, Italy, Spain, Austria and Denmark. We use official data on China for this table.
Sources: The data source of Japan is Fukao et. al. (2009). We use the unpublished data of van Ark et. al. (2009), Mauro et. al. (2009) and Corrado and Hulten (2010) to carry out growth accounting of Germany, France, the UK and the US.

**Table 5:**
**China Growth Accounting Versus Japan in Its High Growth Era (% AAGR)**

| | China 2000-2008 | | Japan 1955-1971 | |
|---|---|---|---|---|
| Type of input shares | EIB shares | China shares | Nishimizu-Hulten Capital I | Nishimizu-Hulten Capital II |
| Output per person | 9.65 | 9.65 | 8.07 | 8.07 |
| Contributions: | | | | |
| Tangible capital | 3.54 | 6.26 | 5.19 | 4.41 |
| TFP | 6.11 | 3.39 | 2.88 | 3.66 |

Note: All estimates are without intangibles.

Sources: Japan data is from Nishimizu and Hulten (2010). Chinese data on GDP, employment, and gross capital formation are from the China Statistical Yearbooks. Data on initial capital stock (1980) is from Chow (2002). We use a perpetual inventory method and a 5 percent depreciation rate to estimate the capital stock of years from 1981 to 2008. Sources of EIB shares are unpublished data from van Ark et. al. (2009) and Corrado and Hulten (2010).

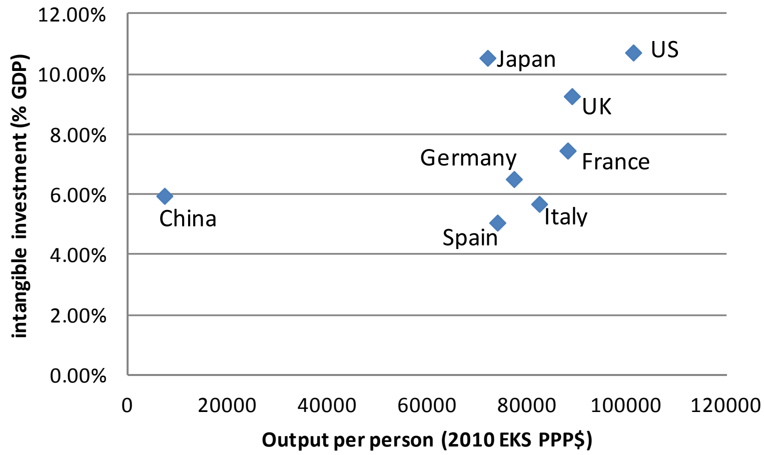
# Table 6

## Chinese Investment Rates for Different Types of Capital (% expanded GDP)

| | Total Tangible | ITC | Total Intangible | Total ex. Software & design | Education spending |
|---|---|---|---|---|---|
| 1995 | 31.74 | 0.79 | 4.17 | 3.01 | 2.85 |
| 1996 | 31.15 | 0.91 | 4.23 | 3.04 | 2.93 |
| 1997 | 30.54 | 0.97 | 4.30 | 3.13 | 2.98 |
| 1998 | 31.68 | 1.30 | 4.46 | 3.17 | 3.27 |
| 1999 | 32.10 | 1.50 | 4.69 | 3.33 | 3.52 |
| 2000 | 32.79 | 1.82 | 4.93 | 3.48 | 3.73 |
| 2001 | 33.11 | 1.96 | 5.11 | 3.53 | 4.07 |
| 2002 | 34.55 | 2.19 | 5.46 | 3.66 | 4.34 |
| 2003 | 37.28 | 2.38 | 6.06 | 3.71 | 4.33 |
| 2004 | 38.52 | 2.89 | 6.43 | 3.54 | 4.28 |
| 2005 | 37.59 | 3.17 | 6.93 | 3.63 | 4.26 |
| 2006 | 37.44 | 3.21 | 7.22 | 3.69 | 4.18 |
| 2007 | 36.94 | 3.16 | 7.38 | 3.80 | 4.32 |
| 2008 | 38.33 | 3.37 | 7.80 | 3.90 | 4.34 |
| Avg 95-00 | 31.67 | 1.21 | 4.46 | 3.19 | 3.21 |
| Avg 01-08 | 36.73 | 2.79 | 6.55 | 3.68 | 4.26 |
| Avg* 95-00 | 33.01 | 1.27 | 4.84 | 3.52 | 3.35 |
| Avg* 01-08 | 38.69 | 2.94 | 7.13 | 4.11 | 4.49 |

Note: intangible investment includes investment in software and mineral exploration. The averages with the asterisks shown in the last two rows report the shares of each type of investment in conventional GDP, rather than the expanded GDP of the prior two rows.
Sources: The source of education spending and tangible investment (Gross Fixed Capital Formation) is the China Statistical Yearbooks, provided by the National Bureau of Statistics.

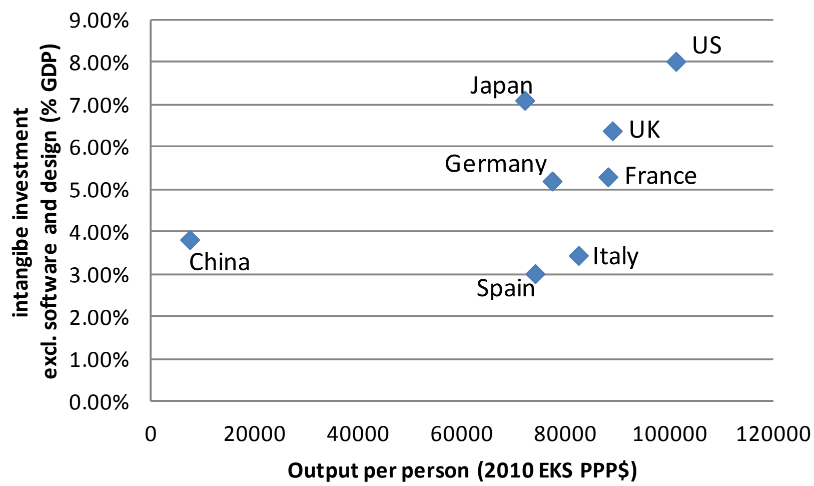
**Figure 1  Intangible Investment and Output per Person  (2001-04)**




Source: Output per person is from Total Economy Database (September 2011) of The Conference Board. For intangible investment, the data source is van Ark et al. (2009) for Germany, France, Italy, Spain, Fukao et. al. (2009) for Japan, Corrado and Hulten (2010) for the US and COINVEST (2011) for the UK. GDP is the sum of conventional GDP and new intangibles, while GDP in the corresponding table or figure of Fukao et. al. (2009) and van Ark et. al. (2009) is conventional GDP.  We convert the percentages of conventional GDP to percentages of GDP with new intangibles.

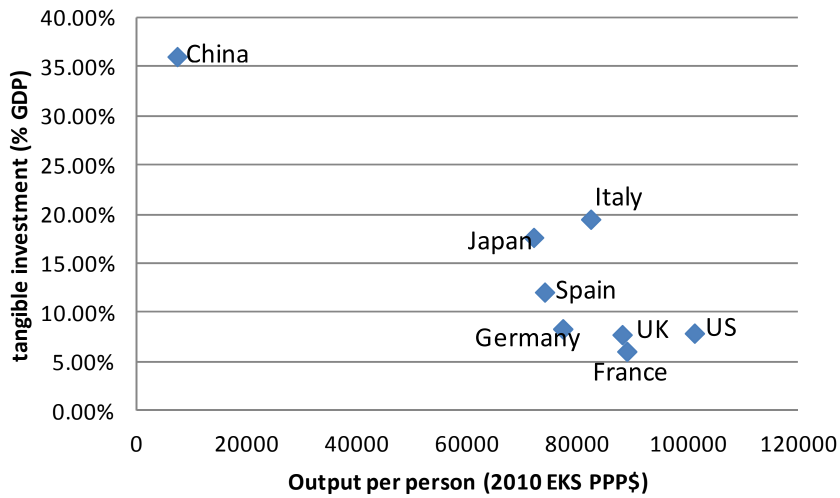
**Figure 2**

**Intangible Investment Rates ex Software and Architectural and Engineering Design compared to Labor Productivity in Various Countries**




Source: Output per person is the sum of the new intangibles per person estimated by us and the output per person from the Total Economy Database (September 2011) of The Conference Board.  For intangible investment, the data source is van Ark et al. (2009) for Germany, France, Italy, Spain, Fukao et. al. (2009) for Japan, Corrado and Hulten (2010) for the US and COINVEST (2011) for the UK.  GDP is the sum of conventional GDP and new intangibles.

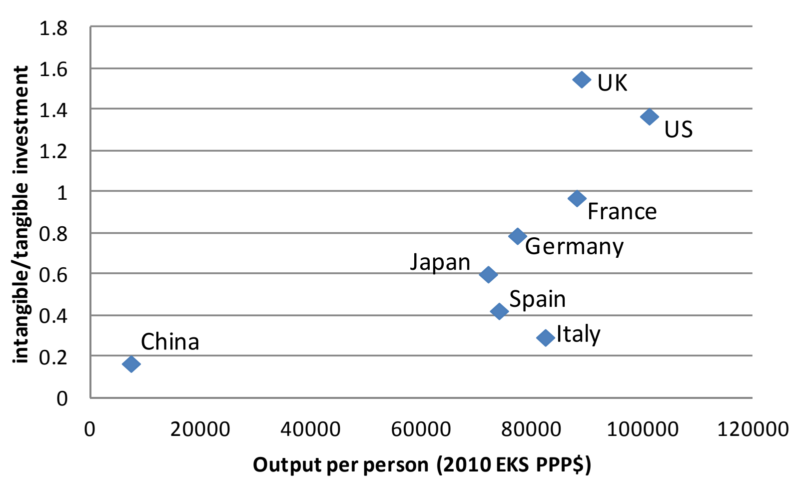
**Figure 3**
**Tangible Investment and Output per Person (2001-04)**




Source: Output per person is the sum of the new intangibles per person estimated by us and the output per person from the Total Economy Database (September 2011) of The Conference Board. Tangible investment is of the market sector. Data of the US is from Corrado and Hulten (2010), and that of Germany, France, Italy, Spain and the UK is from EU KLEMS. GDP is the sum of conventional GDP and new intangibles.

**Figure 4**

**Intangible/tangible Investment and Output per Person (2001-04)**




Sources: See notes to preceding figures.