Appendix: Liberty Street Economics: Can China Catch Up with Greece?

Hunter L. Clark and Matthew Higgins

Growth Scenarios for China

This appendix describes three scenarios for GDP and per capita income growth in China through 2035, building on similar scenarios developed in Higgins (2020) while taking in new and revised data and, to a lesser extent, revised assumptions. We term these scenarios Golden, Hum Drum, and Sour.

In the Golden Scenario, everything goes right for China, with productivity growth remaining near the top of the global charts and the share of investment spending in GDP declining only gradually from its current elevated level. The Hum Drum Scenario relies on less optimistic and, arguably, more reasonable assumptions, featuring moderate productivity growth and a faster but still gradual decline in the investment share. The Sour Scenario relies on more pessimistic but by no means implausible assumptions, featuring below-average productivity growth and more rapid normalization of China's capital spending share. We analyze the implications of these assumptions for GDP and income growth via the lens of the neoclassical growth model.

A.1. The Neoclassical Growth Model

The neoclassical growth model has provided the standard framework for studying long-term economic growth since it was introduced by Robert Solow (1956, 1957) more than six decades ago. Under the model, economic growth comes from two basic sources: increases in capital and labor inputs, and improvements in technology. The basic growth accounting equation is given by:

(1) $$\hat{Y}_t = \hat{A} + \alpha\hat{K}_t + (1-\alpha)\hat{L}_t$$

In equation (1), Y represents real GDP, A the economy's technology level, *K* the quantity of capital inputs, and L the quantity of labor inputs. The ^ symbol denotes a proportional rate of change or percentage increase. The terms α and $1-\alpha$ represent the elasticity of output relative to, respectively, capital and labor inputs. (Thus, a 1 percent increase in capital inputs would raise GDP by the factor $\alpha < 1$ percent). The fact that these terms sum to 1 expresses constant returns to scale, so that a 1 percent increase in both inputs results in a 1 percent increase in GDP. In a competitive economy, with factors of production paid their marginal product, these terms also represent the shares of national income accruing to capital and labor. The term A captures the efficiency with which capital and labor inputs are used, or total factor productivity (TFP). A higher value for A means that greater output can be produced from given factor inputs. Given measures for these terms, equation (1) can be used to decompose observed growth into contributions from factor accumulation and technological change.

The evolution of the capital stock is determined by the economy's saving rate and the rate of depreciation:

(2) $$K_{t+1} = (1 - \delta)K_t + s_t Y_t,$$

where δ is the rate of depreciation and s_t is the economy's investment rate. Equations (1) and (2), taken together, have a surprisingly powerful implication: An economy's long-run growth rate is independent of its investment rate. To be sure, a high-investment economy will follow a higher income trajectory and will grow faster than its long-term rate if it begins below that trajectory. But high investment is a self-limiting path to growth. Over the long run, the economy settles at an equilibrium with a constant capital-to-output ratio, with GDP growth determined solely by the pace of TFP and labor input growth. This equilibrium takes hold more quickly the faster the existing capital stock depreciates.[1]

Our projections rely on capital input data from the Penn World Table, based on disaggregated investment outlays in nine categories. The composition of investment matters for the aggregate capital stock because some capital assets depreciate more rapidly than others: consider structures compared with software. Recent editions of the Penn Table also report estimates of the flow of services provided by the capital stock.[2] This is the preferred measure of capital inputs from a theoretical perspective. In equilibrium, rapidly depreciating assets must yield a higher service flow to equalize investment returns across asset types. Historical growth accounting exercises in both our blog note and appendix rely on these capital services data. (Our results would be basically the same using the capital stock series.) Projection results assume that future growth in the flow of capital services is equal to growth in the capital stock.

Data on employment and average hours worked are also taken from the Penn Table. In addition, the Penn Table contains data on labor quality, derived from underlying data on average years of schooling and estimates of the economic returns to education (Barro and Lee 2013). Labor inputs here are measured by a composite variable taking in all three of these elements:

(3) $$L_t = hc_t avh_t N_t,$$

where hc_t represents the average level of human capital, avh_t average hours worked, and N_t total employment. This is in line with the emphasis on human capital in the recent growth literature and follows many studies in using the "extended Solow model" introduced by Mankiw, Romer, and Weil (1992). The extended Solow model implies that long-term GDP growth depends on the pace of human capital development as well as on TFP and raw labor input growth. A further interesting implication concerns the drivers of per capita income growth (assuming that long-run growth involves constant values for labor force participation and average hours worked). Per capita income growth now depends only on the pace of human capital upgrading and TFP growth.[3]

What about TFP growth? The neoclassical growth model treats this term as a residual—that is, as the part of GDP growth not accounted for by capital and labor accumulation (including human capital accumulation in the extended Solow model).[4] While this is an important limitation of the neoclassical model, growth accounting studies based on the model have yielded important insights. A key finding is that capital and labor accumulation play a diminishing role as growth drivers as economies ascend the global income ladder (Eichengreen et al., 2014; Higgins 2020). Economies that fall into the so-called "middle-income trap" fail to make the transition from growth based on factor accumulation to growth based on technology and education.

Further details concerning the data underlying our projections are described in Section A.4.

A.2. Projection Specification

The Golden Scenario sets TFP growth through 2035 equal to the 90th percentile of subsequent 13-year performance for countries at China's income level, at just below 1.9 percent. (See the third chart in our blog.) This is close to the rate implied by China's official growth data for 2009–2022. The Hum Drum Scenario sets TFP growth through 2035 at the median value for countries at China's income level, at just below 1.2 percent. Finally, the Sour Scenario sets TFP growth at the 25th percentile for countries reaching China's income level, at just 0.2 percent.

Notably, the TFP growth rate under the Sour Scenario is above the rate consistent with the Penn World Table's alternative GDP series for recent years. Indeed, as shown in the table below, these data imply that TFP growth in China has already fallen below zero. While the Sour Scenario is indeed sour, it is by no means implausible.

The Sources of Growth in China

	2015-2022	2008-2015	2001-2008
1) Labor quantity	-0.2	0.4	0.5
2) Labor quality	0.6	0.6	0.3
3) Capital	3.5	5.2	5.1
4) TFP: official data	1.8	2.1	4.6
5) TFP: PWT data	-0.4	0.5	2.7
GDP: official data	5.6	8.2	10.5
GDP: PWT data	3.4	6.6	8.6

Sources: Penn World Table version 10.01, Total Economy Database, national sources, author's calculations. (The Penn World Table ends in 2019; the Total Economy Database is used to fill in values for through 2022.) Offical GDP growth equals the sum of rows 1 through 4. PWT GDP growth equals the sum of rows 1 through 3 plus row 5. (These sums may be off by a tenth given rounding.) Figures refer to growth *from* 2015 to 2022, or equivalently, *during* 2016 through 2022, and similarly for earlier periods.

We considered but rejected setting the growth contribution from capital accumulation in the same manner. But matching the 90th percentile of the contribution in our sample would require keeping the share of capital spending in GDP at 55 percent, a figure with no historical precedent. (Capital expenditure spending in Japan and the Asian Tigers leads our sample, averaging 32 percent of GDP in the 13-years after reaching China's income level.) Even matching the 75th percentile would require capital spending at 40 percent of GDP, close to its current level.

These high investment shares reflect the diminishing returns to capital accumulation: Given China's already capital-intensive production structure, it derives a smaller growth benefit from a given investment share than other countries near its income level. Keeping the capital spending near or above its current share of GDP would be inconsistent with the Chinese government's stated goal of rebalancing the economy away from investment and toward consumption. More important, the credit expansion needed to support such a trajectory would multiply the risk of a financial crisis, a development that would materially set back China's growth prospects.

Instead, the Golden Scenario assumes that capital spending as a share of GDP declines gradually, reaching 30 percent by 2035—still above the 90th percentile of the current distribution for the 32 countries or territories the IMF classifies as "Advanced Economies." The Hum Drum Scenario assumes a somewhat faster decline, leaving China's capital spending share at 25 percent in 2035, about the 55th percentile of the current Advanced Economy distribution. Finally, the Sour Scenario has capital spending falling to 20 percent of GDP by 2035, toward the lower end of the Advanced Economy distribution. The average GDP growth contributions corresponding to these investment trajectories are 1.9 ppt, 1.5 ppt and 1.1 ppt, respectively.

The Golden Scenario assumes that human capital upgrading in China continues at its recent rapid pace, with the index of educational attainment rising at a 0.94 percent annual rate. This corresponds to roughly the 75th percentile of subsequent 13-year growth for countries reaching China's income level. This assumption is quite optimistic: China's labor force is relatively well educated for country at its income level, and there is no meaningful prospect that the pace of educational upgrading might accelerate. The Humdrum Scenario sets the pace of human capital upgrading at the median among countries reaching China's income level, 0.74 percent per annum. The Sour Scenario sets this pace at 0.63 percent per annum. These parameter choices have only a minor impact on growth outcomes given their narrow range—a range further diminished when multiplied by labor's share in output.

All three scenarios assume that aggregate hours worked evolves in line with China's working-age population over the projection horizon, something essentially predetermined given the country's current age structure. This implicitly sets age-specific labor-force participation rates and average hours per worker at current levels. While it is possible to imagine favorable shifts in these variables, any changes are more likely to be a source of additional downside. Hours per worker and labor-force participation in China are quite high for a country at its income level, and most countries in our sample saw declines in these variables over the subsequent period.

Demographic change stands to be an appreciable weight on per capita income growth in China over the projection horizon. China's working age population is projected to fall by 6.1 percent by 2035. The country's total population is projected to fall only 1.9 percent—an unfavorable differential of 4.2 ppt. Given the Solow model specification, this translates into a drag on per capita income growth averaging 0.3 ppt per annum. While this demographic drag might not seem large, the typical country reaching China's income level has enjoyed a demographic *boost* of 0.3 ppt. China's relative demographic handicap through 2035 amounts to more than 8 ppt. in lost per capita income.

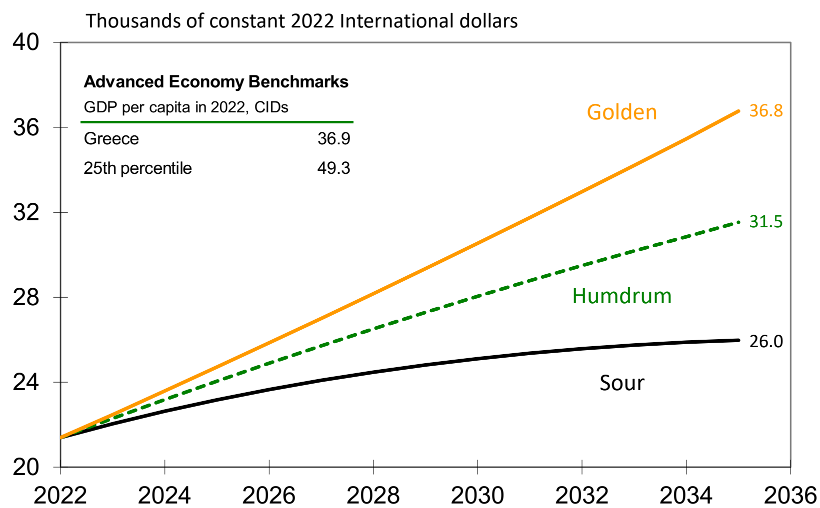
A.3 Projection Results

In the Golden Scenario, GDP growth averages 4.1 percent over the next 13 years (2022-35). Of note, growth slows continuously over the projection horizon, largely reflecting diminishing returns to capital accumulation, beginning the period at 4.9 percent but ending it at 3.3 percent. Given the small projected decline in China's total population, per capita income growth through 2035 averages just under 4.3 percent. This performance leaves Chinese per capita income essentially equal to the current level in Greece, but at only three-fourths of the Advanced Economy 25th percentile (chart below). Given the range of favorable assumptions entertained under the Golden Scenario, we regard this outcome as unlikely.

In the Humdrum Scenario, GDP growth averages 2.9 percent through 2035, beginning the projection horizon at 4.1 percent but ending at 1.9 percent. Per capita income growth averages 3.1 percent, about the 45th percentile among the 42 countries reaching current income level in the past. This performance would leave Chinese per capita income about 15 percent below the current level in Greece, and still farther below the Advanced Economy 25th percentile. (An extended projection shows that it would take until 2043 to catch Greece.) We see the Humdrum Scenario results as relatively solid given China's unfavorable demographics and already capital-heavy production structure. We regard them as representing our benchmark.

Under the Sour Scenario, GDP growth averages 1.4 percent through 2035, beginning the projection horizon at 3.0 percent and ending it measurably below 1 percent. Income growth averages 1.5 percent, placing incomes in 2035 a little more than 20 percent higher than at present. Per capita income would then be about 30 percent below the current level in Greece. While these results are indeed sour, we see them as lying well inside the range of plausible outcomes.

Real Per Capita Income Projections for China



Sources: Penn World Table, version 10.01; Total Economy Database; IMF World Economic Outlook database, April 2023 edition; authors' calculations. See appendix text for projection details. 25th percentile based on the 32 countries with populations above 1 million classified by the IMF as Advanced Economies.

A.4 Data and Projection Details

Our projections are benchmarked to the latest vintage of the Penn World Table (Version 10.1, 2023). Feenstra, Inklaar, and Timmer (2015) provide a comprehensive treatment of the conceptual and measurement issues involved in constructing the data set. This source provides data or estimates over 1950-2019 for 183 countries on the following key variables: real GDP, real capital stock, employment, average hours worked (most countries), labor quality (most countries), the labor income share, the depreciation rate of the capital stock, and total factor productivity. Our empirical analysis, however, excludes countries that derive the bulk of their export revenues from fuels or that had populations below 1 million as of 2010. This leaves our country sample at 127.

The data in the Penn Table go only through 2019. To fill in data for China through 2022, we rely on Chinese official sources, and for some variables, the Conference Board's Total Economy Database.

To assess China's 2022 income level relative to other countries, we rely on estimates of GDP at current purchasing power parities from the IMF's World Economic Outlook database (April 2022 edition). These estimates are based on the results of the Income Comparisons Project (ICP), the same source that provides the raw material for the Penn World Table. The ICP is a World Bank initiative under the auspices of the United Nations and represents a multi-decade effort to place countries' national accounts on a comparable basis. The project involves periodic, highly detailed surveys of prices and expenditure patterns for a large number of countries. The World Bank statisticians then use this information to restate national GDP figures in purchasing power parity terms, that is, with reference to a standard consumption basket.

To assess when countries attained China's current income level, we project current income levels back in time given real GDP growth at constant national prices and data on past population levels. (The relevant variables in the Penn World Table are, respectively, RGDPN and POP.) Our analysis growth performance after reaching China's current income level is limited to countries that did so by 2006, to leave 13 years of subsequent history in the Penn World Table. (Some series relevant for growth accounting are found only in the Penn World Table and thus end in 2019.) Some 42 of our total sample of 127 countries satisfy this criterion.

Purchasing power parity estimates are subject to error. Countries differ widely in their consumption and production baskets at a *given* time, and consumption and production baskets change widely *over* time. Data construction inevitably involves imputations and, at times, judgmental adjustments. Comparisons of real income levels across countries—and especially, across countries and over time—should be regarded as approximate.

Our projections for China assume that future growth in capital services is equal to growth in the real capital stock, with the latter derived in the usual manner from the perpetual inventory method. Finally, it should be noted that our projections implicitly assume that relative prices and the composition of capital expenditure across types of goods remain at their current values. Large departures from these assumptions could have a meaningful impact on our results, though in a direction that would depend on their precise character.

References

Barro, R., and J.-W. Lee. 2013. "A New Dataset of Educational Attainment in the World, 1950-2010." *Journal of Development Economics* 104 (September).

Eichengreen, B., D. Park and K. Shin. 2014. "Growth Slowdowns Redux." *Japan and the World Economy* 32 (November).

Feenstra, R., R. Inklaar, and M. Timmer. 2015. "The Next Generation of the Penn World Table." *American Economic Review* 15, no. 10: 3150-82.

Higgins, M. 2020. "China's Growth Outlook: Is High-Income Status in Reach?" Federal Reserve Bank of New York *Economic Policy Review* 24, no. 4 (October).

Inklaar, R., P. Woltjer, and D. Gallardo Albarrán. 2019. "The Composition of Capital and Cross-Country Productivity Comparisons." Groningen Growth and Development Centre, University of Groningen, Netherlands.

Mankiw, N. G., D. Romer, and D. Weil. 1992. "A Contribution to the Empirics of Economic Growth." *Quarterly Journal of Economics* 107, no. 2 (May).

Penn World Table. 2023. Penn World Table version 10.01. Groningen Growth and Development Centre, University of Groningen, Netherlands.

Romer, P. 2015. "Mathiness in the Theory of Economic Growth." *American Economic Review* 105, no. 5: 89-93.

Solow, R. 1956. "A Contribution to the Theory of Economic Growth." *Quarterly Journal of Economics* 70, no. 1.

Solow, R. 1957. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics* 39, no. 3.

Wu, H. (2014). "China's Growth and Productivity Performance Debate Revisited: Accounting for the Sources of China's Growth with a New Data Set." Conference Board Economics Program, Working Paper no. EP14-10.

Notes

[1] With a constant savings rate s^*, a capital depreciation rate δ, and labor force growth at the rate $\widehat{N}^*$, the long-run capital-output ratio is given by: $k^* = s^* \left\{ \left(1 + \widehat{N}^*\right)\left(1 + \hat{A}\right)^{1/1-\alpha} - (1 - \delta) \right\}^{-1}$. The contribution of capital accumulation to growth in the steady state is given by: $\frac{\alpha}{1-\alpha}\hat{A} + \alpha\widehat{N}^*$.

[2] See Inklaar, Woltjer, and Gallardo Albarrán (2019) for details on the theoretical background and data construction.

[3] In particular, per capita income growth will be given by: $\hat{Y}^* - \widehat{N}^* = \hat{A}^*/(1 - \alpha) + \widehat{hc}^*$, where the * denotes long-run values. Of course, population growth and human capital upgrading—especially if the latter is based on average years of schooling—could settle at zero in the long run.

[4] This limitation spawned a large literature featuring endogenous technological change beginning in the mid-1980s under the banner of the "new growth theory." But this effort petered out by the late 1990s without reaching a clear consensus, and with little impact on subsequent growth accounting studies. See Romer (2015).