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Metal Intensity in Comparative Historical Perspective: China, North Asia, the United States & the Kuznets Curve

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Abstract

The aim of this paper is to investigate the likely future path of China's metal intensity by referencing the experience of relevant peers through initial engagement with a technology-led strategy and beyond. This question cuts to the very roots of Chinese long run economic strategy and performance. The broad conclusion is that there is no 'silver bullet' quantitative model that captures the dynamics of metal intensity through the entirety of the industrialisation process. Even the identification of a robust non-linear long run relationship between steel intensity and income per capita in the United States, styled here as the "metal intensity Kuznets curve", does not overturn this position. Each national industrialisation process, its entry into the global strategic transition and its relationship to metal intensity, appears to be *sui generis* and should be dealt with accordingly. China will not continue to follow a metal intensity path similar to Korea's for more than another decade. After that point, similarities with the Japanese and United States' experiences will increase, but a distinct Chinese character will develop. The peak in Chinese steel usage per capita should occur within a handful of years from 2020.

Keywords: metal intensity, Asian industrialisation, China, strategic transition, Kuznets curve

JEL Codes: 011, 013, 014, 053, N1

1. Introduction

The aim of this paper is to shed light on China's future path of steel and base metal intensity by referencing the experience of relevant peers through their point of entry into the global strategic transition and beyond. Foreknowledge of China's future metal demand is of direct relevance to the core constituencies of the world economy. Besides the Chinese themselves, such information is of immense strategic value to resource exporting nations and the global corporations that bestride them. China's competitors for access to these resources – predominantly the world's current and projected mega-states – are equally in need of such input to their own strategic decision making. It is an immensely practical task.

Will China follow a path like Korea, who has stayed in the metal intensive sweet spot for a sustained period of time; or will it only briefly touch on the middle income sweet spot of metal intensity *en route* to the current resting place of the European economies and their offshoots? Will it eventually sit just on the more metal intensive side of the high income cohort, in a similar place to where Japan resides? These questions cut to the very roots of Chinese long run economic strategy and performance. The immense scale of China's mega-state means that its strategic choices will generate substantial externalities that will require assertive responses from others. A better understanding of the path of metal intensity through time in a broader range of countries would be a great help to those tackling the immense task of meeting and responding to China's long run metal demands.

A broad conclusion of this paper is that China is unlikely to follow the Korean path once it moves deeper into middle income status. The superficially attractive correlation between the Korean and Chinese paths, based on limited time series, is perceived sceptically from the medium term point of view. The final path is likely to borrow from certain aspects of the experience of the United States and Japan, but the Chinese path will be distinctive. The United States is an apposite comparison as an economy built on a continental scale with a low population agglomeration ratio, while Japan is relevant due to the explosive but finite gains in world export share it enjoyed as its technological strategy unfolded, and the constraints that high population densities place on urban lifestyles. Together, these economies define some reasonable parameters for considering the Chinese case.

While the United States and Japan are clearly relevant to a medium term assessment, evidence on metal intensity from these jurisdictions are not deterministic for our purposes. The sketch of Chinese metal intensity assembled here assumes a strong increase until the period of 2015 to 2020, a flattish peak emerging from 2020 to 2025, before an orderly decline develops in the second half of the 2020s. These dates are informed by Sino-specific analysis with pragmatic, selective input from historical case studies.

The investigation presented below, that leads to the projection, argues that there is no "silver bullet" summary model that captures the dynamics of metal intensity through the entirety of the industrialisation process. The apparent non-linear association between development level and metal intensity, styled as the "metal intensity Kuznets curve" in this paper, may prove to be a siren's song of cross sectional sample bias, like its progenitor. The true model of metal intensity must simultaneously capture

flow, stock, cyclical and structural influences. That is a challenging task irrespective of data availability. In the presence of data constraints the task engenders pessimism.

The national relationships between metal intensity and standard macroeconomic variables are complex and idiosyncratic. The firm implication from them is that each nation's industrialisation process, which is triggered by its entry into the contemporary global strategic transition of technological change (Snooks 1999), and its relationship to metal intensity, is *sui generis* and should be treated as such. Any attempt to generalise across this field should proceed with extreme caution. Furthermore, data availability, particularly the absence of a definitive set of lengthy metal consumption time series suitable for comparative analysis inhibits a truly effective investigation of the issue. The most notable frustration here is the lack of information on the experience of major nations transitioning between emerging strategic status and membership of the strategic core. Future labour on this issue would be profitably directed towards constructing these basic time series for a representative sample of nations. While the investigation of intra-national (provincial) data on metal intensity has much to recommend it, as this stage the results derived should be regarded as tentative rather than conclusive.

< figure 1 here >

2. Global strategic transition, industrialisation & metal intensity

This paper began by claiming that questions surrounding China's future metal intensity "cut to the very roots of Chinese long run economic strategy and performance". The meaning of this phase needs more formal clarification. This analysis is underpinned by a general dynamic theory that makes systematic sense of China's rise in the broadest context. The framework adopted springs directly from the expansive canon of Graeme Snooks (1993, 1996, 1997, 1998a, 1998b, 1999). The general Snooksian model of global strategic transition (1999), a corollary of dynamic strategy theory (1996, 1997, 1998) are the core concepts applicable to this particular study.

This section formally introduces the strategy function.

$$O = f(N, K, R, T, E, S_O, S_L, S_I) \quad (1)$$

The strategic outcome, O, is proxied by gross domestic product (GDP). O is a function of strategic instruments: N is labour, K is the capital stock, R is natural resource endowment, T is the stock of available technology, tacit and realisable, E is economies of scale, and S is 'strategic', with subscripts O, L and I representing organizations, leadership¹ and ideas respectively (Snooks 1999: 219).

Function (1) can be simplified to

$$O = f(P, T, E, \pi) \quad (2)$$

¹ Strategic leadership can come from any agents able to provide or control the signaling mechanisms in the economy that impact upon strategic confidence. The strategic administration (the bureaucracy and the executive) is the most important element of strategic leadership, but the role is not necessarily a state monopoly. In practice, any agent with an encompassing interest is a candidate.

P represents the stock of physical inputs: labour, resources and capital. T and E are unchanged from their definitions in (1). The π signifies a vector comprised of the strategic variables S_O , S_L and S_I . Expanding further, π is an increasing function of strategic confidence (subscript C) and the price signal, strategic inflation (subscript P).

$$\pi = f(S_C, S_P) \quad (3)$$

So, the strategic outcome O relies upon physical factors, technological factors and strategic factors. The feedback mechanisms between these factors, which are determined by the strategic pursuits of materialist man (Snooks 1996), endow the model with dynamic characteristics. The underlying concept that allows the induction of the strategy function is that of strategic demand (Snooks 1998: 141-165). Strategic demand is the effective realizable desire of decision makers regarding the gamut of inputs relevant to their survival and prosperity. This driving force manifests itself in the pursuit of dynamic strategies and sub-strategies.

The natures of the strategic factors that enter the function are time and context variant. They depend upon the technological underpinnings of the prevailing dynamic strategy and the sub-strategies that are pursued under its rubric. The nature of π under a conquest strategy will be very different to π in the context of a family multiplication strategy (Snooks 1996). The nature of π will depend on the creativity and risk appetite of the strategic decision makers involved, the problems they face and the mix of physical and technical factors available. The physical element of the equation is at the heart of this project. From this point forward, all discussion of π will be in the context of the contemporary global dynamic strategy of technological change.

It is the spread of the dynamic strategy of technological change from the strategic core that drives the contemporary global strategic transition (Snooks 1999). The global strategic transition (hereafter GST) is the process whereby non- and anti-strategic countries are drawn into the “vortex” of technologically driven economic growth in the strategic core. The agents (in this case nation-states) in the strategic core are the leading exponents of the paradigm. They are easily recognised by their high levels of productivity per worker due to both depth and quality of capital stock and a consequently high standard of material well being. The advance of the GST, which lifts the absolute material conditions of new entrants and expands the markets available to incumbent technological strategists, brings global output closer to its potential level.

The relevance of this framework to Chinese experience is obvious. China made a discretionary decision to engage with the GST in the late 1970s. The contours of this engagement have been detailed at length elsewhere (McKay 2008). The influx of technology from the leading strategic countries unleashed powerful forces of productivity enhancement within the economy. Output has been expanding ever since at a rate that implies a quadrupling in scale every twenty years. Per capita output has also expanded at extraordinarily impressive compound rates: faster even than the

brilliant ascents of Japan, South Korea, Singapore and Greater China's strategically-inclined prodigals (Hong Kong under Britain and Taiwan under the Nationalists).²

Prior to engagement with the GST, Maoist China was an anti-strategic society. Nations in this category are unable or unwilling to unlock the synergy between the factors in the strategy function. Further, the non- or anti-strategic society is constrained by rent-seeking (redistributive) behaviour. Conversely the strategic society is propelled forward by profit-seeking (surplus producing) activity. Potential output in non- and anti-strategic societies is limited by their call on physical resources, the size of the internal market and a static and low-lying indigenous technological attainment. Potential output in strategic societies has a higher ceiling supported by economies of scale from specialization and servicing a global market, a greater call on resources through the ability to trade and a productivity premium conditioned by π . In the language of growth accounting, strategic countries will achieve a higher rate of TFP.

From the perspective of the task at hand, we are most interested in the dynamic feedback between China's choices and the physical elements of its strategy function, specifically metals. We have some knowledge of this historical interaction in peer economies, the analysis of which forms a large portion of the remainder of the paper. Yet China's future strategic choices will be time and context variant. The industrial technological paradigm is clearly closer to exhaustion now than when the United States, Japan or even Korea were all making similar decisions. The relative price of raw materials vis-à-vis manufactures in the early 21st century tells us as much. China's choices will suit their own demands and the environment in which they are made. Views from the outside, even direct experience on the precisely relevant theme is thereby rendered interesting rather than vital.

3. Metal intensity in the United States: the case for the MIKC

While cross sectional metal intensity data of recent vintage is available for a wide variety of countries at various levels of development (figure 1), we lack a comprehensive set of long time series of a representative sample of nations. What is available for comparative analysis is presented in figure 2. The longest national time series available is for steel use per capita in the United States. Here we analyse the US experience in the context of the Kuznets formulation.

A Kuznets relationship is represented by a second order polynomial, with income per capita and its square term on the right hand side of the equation and the relevant development metric on the left. To test for this relationship in the metal field, we regress the Hodrick-Prescott filter of annual steel intensity per capita in the United States from 1929 to 2002 against the natural logs of the aforementioned right hand

² It is worth noting that East Asia has been the most able adaptor of the benefits bestowed by GST entry since Western Europe and the United States adopted the technological strategy from Britain. The sequentially accelerating growth rates achieved by Asian countries as they enter the GST, exemplified by China, offers tentative support for the Snooks-Panov algorithm (Nazaretyan 2005). The Snooks-Panov algorithm summarises the observed geometric acceleration of the time between the origin and exhaustion of technical paradigms in both human society and macro-life. That is a discussion for another day.

side variables. For the relationship to be robust the estimated coefficients need to be opposite in sign and statistically significant.

The empirical evidence in favour of a Kuznets relationship in the field of long run steel intensity in the United States is strong. Not only are the coefficients correctly signed and significant at the 1% level, the adjusted fit of the model is surprisingly high. We conduct the same test with the raw data and get broadly similar results.

The results for all tests are presented in appendix table 1 and figures 3a and 3b. For the twentieth century United States at least, a MIKC seems to exist.

< figures 2 & 3a & 3b here >

4. A cautionary tale from the archives

The finding that steel intensity in the United States during the twentieth century has followed an upside down U shape indicates that the Kuznets framework may be applicable to the entire metal intensity field. Unfortunately, the United States offers the only sufficiently lengthy time series enabling this proposition to be tested. The cross sectional data offers corroborating, if tentative evidence (figures 1 and 4). It is very tempting to use these apparent relationships to define a generalised path of metal intensity through the industrialisation process.

< figure 4 here >

Tempting yes, but the validity of such a methodology is highly debatable. Kuznets' original observation of the upside down U in income per capita and income distribution space (Kuznets 1955), which became known as the Kuznets curve, is actually an egregious example of cross sectional bias. In similar fashion to our data on metal intensity, Kuznets had a patchy time series of US income distribution (plus the United Kingdom and Germany/Prussia/Saxony) and a cross section of information from a few countries at a spread of lower income levels.³ These economies provided the hump in his hypothesized curve, "corroborating" the patchy time series evidence.

Subsequent experience of East Asian trajectories following their entry into the GST in the quarter century following the second World War, where inequality was reduced between the low and middle income stages of development, has shown that the Latin American and South Asian paths observed by Kuznets are idiosyncratic rather than general. Indeed, the Latin trajectory was an outgrowth of poor planning decisions that ignored comparative advantage in favour of import substitution – an anti-strategic position (Lin 2008). The dual impediments of caste and colonial overlordship, which are redistributive strategies rather than surplus enhancing ones, seem sufficient to comprehend the South Asian case. These two models encouraged the super-normal growth of an anti-strategic rent seeking elite, with predictable outcomes for income distribution. Therefore, the original Kuznets curve is a cautionary tale for scholars of development looking to cross sectional data for predictive relationships.

³ Kuznets used data from India (1949/50), Ceylon (now Sri Lanka, 1950) and Puerto Rico (1948).

The hump in our steel intensity curve is provided by two medium sized North Asian economies – Korea and Taiwan province (figure 1). They are both relatively new entrants to the GST, with their engagement occurring within the last half century. Are these economies typical or atypical? This judgement could validate or invalidate the cross section as representative, as we do not have readily available alternatives to substitute into the middle income space. Most development economists would choose the latter taxonomy if they were judging the case globally and the former if assessing the case regionally. This is a vexed issue that we will return to later in section 5.

To be fair to Kuznets, who was the consummate empirical economist of his generation, he was “acutely conscious of the meagreness of the reliable information presented. The paper is perhaps 5 per cent empirical information and 95% speculation, some of it possible tainted by wishful thinking. The excuse for building an elaborate structure on such a shaky foundation is a deep interest in the subject and a wish to share it. The formal and no less genuine excuse is that the subject is central to much of economic analysis and thinking; that our knowledge of it is inadequate; that a more cogent view of the whole field may help channel our interests and work in intellectually profitable directions; that speculation is an effective way of presenting a broad view of the field; and that as long as it is recognized as a collection of hunches calling for further investigation rather than a set of fully tested conclusions, little harm and much good may result” (Kuznets 1955: 26).

It is easy to agree and to empathise with some of the sentiments expressed in this disclaimer. Indeed, Kuznets might have been putting the case for a wider research agenda on metal intensity in the current day such is the overlap between his case and ours. However, the final assertion is somewhat problematic when the task at hand is a practical forecasting project that might guide real-world decision making. The absence of a general dynamic theory underpinning Kuznets’ hypothesizing is clearly limiting.

The degree of harm from hypothesizing in the presence of severe data constraints might be stylized as a negative function of the maturity of the applied analysis that the original speculative ‘breakthrough’ attracts. The dynamic process of strategic imitation (Snooks 1996, 1997, 1998) predicts that a sophisticated and nuanced intellectual innovation will be quickly picked up by less able thinkers, and the nuance will often be lost. The application of a theory can even become misleading. A mixed example is the innovative extension of the Kuznetsian hypothesis into the environmental field (Grossman & Kruger 1995). This has been a lucrative and knowledge enhancing application. This branch includes a burgeoning literature on the applicability of the “environmental Kuznets curve” to China (Cai and Yang 2008, Bao, Chen and Song 2008, Bao and Peng 2006). Yet the debate has also highlighted the limitations of the framework as a generalisable forecasting system, with national deviations from the central model common, and only certain measures of pollution behaving in accordance with theory. That has not stopped some scholars from adopting the framework as a crude argument in favour of a passive approach to negative environmental externalities.

It is extremely important the *caveats* presented here are recognized and understood from a forecasting perspective. The following section of the paper underscores this point.

5. An aside on automobile penetration: why time series matter

While cross sectional metal intensity data of recent vintage is available for a wide variety of countries at various states of engagement with the strategic transition, using this data alone has the potential to be highly misleading. A focus on comparative time series data is crucial to define the path from A (GST entry) to B (peak metal intensity) to C (membership of the strategic core). Cross sections can help with this task, but they can easily mislead rather than guide. The difficulty is that while a cross section may be able to define states of nature at A and C, the path between these two states may be hidden, and B identified erroneously, if the sample is imperfect.

An instructive example of the potential problems associated with cross sectional data comes from the field of automobile penetration. Contemporary data on the number of passenger cars per 1000 persons for a wide variety of countries is readily available. In addition, there are time series for the United States (from 1929) and Japan (from 1960). Ignoring the two time series for a moment, the cross sectional data implies that a simple linear association exists between income per capita and automobile penetration, with a clustering of observations in the lower left and upper right corners of the chart space (figure 5a).

The time series tell a far richer story (figure 5b). They indicate that the path between low and high automobile penetration may be concave (as in Japan) or convex (as in the US). Once again, we find that a reliance on relationships inferred solely from a cross section would lead to damaging forecasting errors. Recall the variables in the strategy function for a moment, and the difference between the Japan and American paths is clearly explicable. Japan is highly urbanised, densely populated and without a domestic oil resource. The United States is moderately urbanised, reasonably sparsely populated and it controls a great deal of oil. Japanese strategists were quite rational to follow the path they did and the Americans likewise.

Here again, we are struck by the diversity of national experiences, rather than their similarity. The ability to ascribe any economy as “typical” seems very limited. Once again, we find little guidance on the transition between stages, with scant evidence from middle income locales. Forecasters operating in the automobile penetration field have realised this, and are projecting a non-linear, concave path for China. Two such forecasting projects (International Monetary Fund 2005, Westpac Economic Research 2007) that generate similar results are re-produced in stylised form in figure 5c, alongside schematics of the Japanese and American experiences.

There is a very practical reason why we should be interested in the time series on automobile penetration besides the aforementioned analogical and methodological considerations. In the interests of parsimony, we did not supplement the regression tests reported in section 2 with additional explanatory variables. The evidence for a Kuznetsian relationship in the historical steel intensity of the United States is comfortably sufficient when couched in the simplest of forms. However, when data on automobile penetration are included in the test (in original form and as a squared term) as additional information on the stage of development, *the model improves on all metrics by a non-trivial margin*. Most simply the adjusted R^2 (the “fit”) rises from 0.63 to 0.71 and the standard error declines. (For estimation output, refer to table 1 in

the appendix). Thus we can conclude that automobile penetration is an important measure for assessing both the general stage of economic development *and the likely metal intensity of the economy*. The augmented model of the MIKC for the United States is illustrated in figure 6.

These conclusions add to the complexity of the original task. The presence of a Kuznets relationship in the long run steel intensity of the United States offered some hope that a generalisable relationship between metal demand and development level could be defined. The lack of long time series makes it difficult to test this hypothesis directly. There are two long time series in the field of automobile penetration: the United States and Japan. The presence of a relationship between metal intensity and automobile penetration raises hopes of an indirect test of the homogeneity of national paths. But as these two major countries followed such strikingly disparate paths regarding automobile penetration, we cannot infer or back-cast Japan's metal intensity path using the United States example.

6. Observations on the North Asian peer group

The backbone of the comparative analysis of metal intensity within North Asia is table 1. China, Japan and Korea are its subject. Per capita consumption of steel, aluminium and copper (sourced from the IMF, units are kilograms) during their respective GST entry phases are benchmarked against macroeconomic variables that *a priori* are expected to have a relationship with metal intensity.

< insert table 1 here >

The macroeconomic variables chosen for the table are GDP per capita (under both PPP and market exchange rate weights); Industrial value added (IVA), % of GDP; Urban population as a share of total population; Exports of goods and services as a % of GDP; and Trade (exports plus imports) as a % of GDP; Merchandise exports, % of world exports; Gross fixed capital formation (GFCF) as a % of GDP; and Gross savings as a % of GDP.

Keeping all of the *caveats* from the preceding sections of the chapter in mind, the following points have emerged from an investigation of the data that is available. They are all relevant to constructing an educated, if tentative guess about China's future trajectory.

Industrial value-added (IVA) tends to peak as a share of GDP between income levels of \$US10k and 15k per capita in PPP terms, and then decline. That accords with the observed peak in catch-up growth rates (deepening GST engagement) of approximately \$US13k in late-coming East Asian countries (Garnaut et al 2008, Perkins and Rawski 2007). That said, China is an outlier in the sample with a high IVA share prior to GST entry, a relic of the self sufficient ethic that under-pinned the pre-1978 anti-strategic economy, and the price distortions that went along with the industrial bias of the command system.

< insert figure 7 here >

In contrast to the historical record on IVA, urbanisation tends to keep increasing well past middle income levels. It also tends to plateau rather than decline. That is almost certainly due to the fact that IVA loses ground to services activity, which thrives on agglomeration, rather than land intensive endeavours, which do not. In short, while a nation can develop to a post-industrial state, under the technological paradigm it does not develop to a post-urban state. Rather, it concentrates its population further. Evidence that the optimal city size increases with the institutional complexity that lags the strategic demands generated by technological change is littered through history (Snooks 1997).

< insert figures 8 and 9 here >

Degree of outward orientation and metal intensity are positively related. The most metal intensive economy in the sample, Korea, is a middle income export oriented manufacturer. It is also highly urbanised and has extremely high population density. Neither a plateau in its urbanisation rate and IVA share, nor a decline in its investment and savings rates, has handicapped its ability to raise metal intensity beyond the usual turning point between \$10k and \$15k per head. Its ability to continue gaining global market share beyond these points has enabled metal intensity to continue rising. Brazil, a low income economy with a weak outward orientation, is the counterpoint.

< insert figures 10 and 11 here >

China's metal intensity was relatively insensitive to the very early stages of GST entry and gains in export share. In the current decade though, metal intensity has become substantially more sensitive to development, catching and surpassing the comparable Japanese and then Korean rates. The low sensitivity seen in the early years is consistent with the conventional light to heavy industrial path pursued by many new GST entrants. In Japan and Korea metal intensity grew extremely rapidly in the 5 to 15 years from GST entry, while the Chinese experience was less dramatic. China's surge comes in the 15 to 25 year era. This different may be partially attributable to the inadequacy of our time series, which prevents the use of true GST entry points for Japan and Korea.⁴

Copper and aluminium use have been more sensitive to the Asian industrialisation process than has steel use. This is perhaps due to the rapidly increasing degree of openness that has been a feature of Asian industrialisation; and the relative demands of the traded and non-traded sectors vis-à-vis ferrous and non-ferrous metals. Ferrous metals have a lower value to weight ratio than the non-ferrous complex and are therefore less likely to be traded. Further, as an economy ascends the value chain, high value-added durable goods will displace heavy industrial products in the output mix, raising the demand for non-ferrous vis-à-vis ferrous metals. While rural-urban migration underpins demand for housing, infrastructure and steel, the demands of

⁴ While an entry point for Korea in the early to middle 1960s is uncontroversial, Japan is a different case. Japan's economic exploits prior to the Second World War are often discounted by non-specialists, but its industrial complex was strong enough to furnish a military force capable of defeating a European power (Russia) in a land and naval war in 1904/5. A late 1800s entry point, two generation after the first tier of European industrialisers, at 37% of Western European GDP/capita levels (Maddison 2003), would be quite reasonable. This is a debate for another day, but it underscores once again that the available data falls well short of the worthy task at hand.

outward oriented manufacturing appear to be the stronger force at higher levels of income.

Bringing these observations together, we can say that an economy engaged with the GST, with strong strategic leadership sponsoring industrial and technological progress, approaching the GDP per capita level consistent with a peak in industry share, in the midst of an urbanising trend, moving up the manufacturing value chain, making global market share gains and tapping external economies of scale, saving enough to rapidly build the capital stock without a binding external financing constraint, reaching an age of fixed and rotating capital stock where depreciation costs are non-trivial, with a willingness to increase population density and provide the requisite infrastructure to do so, and is moving to extend access to the key pillars of social and economic infrastructure to all its citizens might be fairly said to be in a metal intensity ‘sweet spot’.

7. Foreign direct investment and long run constraints global on market share

China’s high degree of openness to foreign direct investment (FDI) contrasts with Japan but gels with Korea. China’s rapid gains in world export market share have been primarily a function of the activities of foreign funded firms, particularly in the post-WTO accession era (figure 12). Trade fragmentation, with China serving the role of ‘assembler of first resort’, has amplified both the trend of foreign participation and the growth of export market share (Athukorala and Yamashita 2008). These observations open up another difficult forecasting problem. Korea has continued to expand its export market share almost uninterrupted and has achieved extremely high rates of metal intensity.

China’s path of metal intensity to date is closest to the Korean experience. However, if inward FDI flows were to stabilise or decline (or another region assumed ‘assembler of first resort’ status)⁵ export market share could presumably do likewise, at least until an alternative strategy could be adopted (McKay 2008). That would prevent China from following the Korean path. Indigenous Korean firms have established themselves as globally competitive innovators in a number of sectors such as electronics and shipbuilding. Indigenous Chinese firms have yet to do so, and are probably at least a decade away from establishing strong brand awareness among non-Chinese consumers. This perspective on the Chinese development path cautions against excessive reliance on the Korean example.

China’s ability to continue expanding its world export share will surely be constrained by its enormous absolute scale and the resistance of its large trading partners. The strong penetration of Chinese-made imports is already a major political issue in the United States. The bilateral trade position is a rallying point for both sides of US

⁵ India, with its formidable labour supply profile, is the most commonly cited candidate for this role. A more likely outcome is that a group of competing low income, labour surplus economies will eventually displace China. In addition to India, long run Asian candidates include Pakistan, Bangladesh, Indonesia, Vietnam and possibly emerging strategic states in North Korea and Myanmar. In 2050, the combined population of these countries excluding India is expected to be 1.1 billion (United Nations 2007).

politics and the exchange rate is a lightning rod.⁶ The historical example of the angst created by the bilateral balance between the US and Japan, and the USD/JPY exchange rate, is the obvious precedent. Over the coming decade, the expected appreciation of China's nominal exchange rate, and a rise in the relative price level as administrative distortions are progressively removed and productivity catch-up continues, should appreciate the real exchange rate and reduce the current level of cost competitiveness enjoyed by the export sector.⁷ At some point, China will be unable to seriously expect to expand its exports at a faster pace than aggregate world demand. Korea's small size offers it the luxury of continuing to follow a strategy led by export manufacturing at income levels far higher than a larger economy – let alone a mega-state like China (Snooks 1997) – would find obstacles placed in its path.

China will clearly be constrained in its choices to some extent by the strategic activities of its competitors. The attitudes of governments to Chinese purchases of mineral resources in their domains will eventually become as important as access for Chinese exports is in the current phase. This area has already become contentious, with a Chinese principal prevented from purchasing an energy asset in the United States, and the presence of great angst within Australia regarding direct inroads into the resource sector by Chinese investors (Drysdale and Findlay 2008).

8. Does intra-national convergence hold the key?

A provincial approach to the Chinese data on metal intensity has the potential to eventually remedy the shortcomings of the national datasets.⁸ The provincial data also tentatively support a Kuznets style metal intensity path. It is eminently reasonable to assume that there is a high level of relevant information content in the paths already traced by China's wealthier provinces that are most actively engaged with the technological strategy.

This field of endeavour is particularly promising, but it does rely to a degree on the arguable assumption that China's wealthiest provinces have already defined a structural peak in metal intensities from which they are declining. In other words, they are beyond the "turning point"⁹ of an implicit Chinese MIKC. It may be that observed reductions in the metal intensity of the Beijing and Shanghai economies are the beginning of a transition to a more cyclically informed usage, and therefore may represent local rather than absolute maxima. After all, income levels in Beijing and Shanghai are still only a quarter of present US levels, implying that they are hardly at a level of productivity consistent with membership of the strategic core. The US experience of metal intensity makes this point about local versus global maxima in a number of historic contexts. High amplitude cyclicity was the norm throughout the twentieth century (chart 3b).

⁶ For multiple perspectives on China's exchange arrangements, see McKay (2007), Gang (2006), Goldstein (2004), Eichengreen (2004), Frankel (2004), Prasad et al (2005) and McKinnon (2006).

⁷ See Golley and Tyers (2007) for an examination of the dynamics of the real exchange rate. They argue that the depreciating impact of high domestic savings has more than offset a vector of appreciating factors, leading to the somewhat surprising depreciation of the real rate over the last decade.

⁸ A provincial approach to environmental problems, utilising a non-linear framework, is also bearing fruit (Cai and Du 2008, Bao, Chen and Song 2008, Bao and Peng 2006).

⁹ This is not to be confused with a Lewisian turning point (Garnaut and Song 2006a, 2006b).

It might also be argued that Shanghai and Beijing are atypical observations. If these top tier cities are treated as outliers, then it creates problems for cross sectional analysis, because without them the Kuznets relation is far from clear. If these cities are excluded, then it would be prudent to wait for a broader selection of provinces to mature in their steel usage before attempting to define a definitive turning point for an economy as diverse as China.

The proclivity of high income countries to maintain an elevated if somewhat reduced metal consumption pattern well beyond the peak in industrialisation implies that stock effects become a progressively more significant determinant of metal demand. The analysis presented here could therefore be augmented by data on relative capital stock, or levels of flow investment which take account of the ongoing costs of depreciating and replacing fixed and rotating capital. Further, the metal intensity of fixed investment may rise as higher levels of technology are attained and households demand more sophisticated products. House sizes increase with income (raising ferrous input), they become more 'wired' (raising non-ferrous input) and structurally sound (again raising ferrous input). Deepening the social infrastructure stock brings initial demand for wiring and piping and then on-going maintenance requirements. It therefore seems obvious that models of metal intensity that focus solely on "flow" variables will be incomplete. Each of these arguments is relevant to the provincial analysis of Chinese metal intensity, as well as the study of metal intensity across countries.

9. Whither China?

It remains to make an assessment of what the Chinese path of metal intensity will look like. The reasoning in sections 6 and 7 indicates that while China may look like Korea now, it is unlikely to do so at higher income levels. The main constraint in this regard will be China's inability to follow an export-led strategy in the same way that Korea has done.

China's continental land mass represents a major contrast with the compact nature of the Japanese archipelago and the Korean peninsula. The United States is a far better comparison in this regard. The United States' effort to build an internal mega-market with a continental transport system linking a multitude of metropolitan nodes tallies well with China's existing plans to expand inter-provincial commerce via the construction of an ambitious national road and rail network.

The density of population in China is far higher than in the United States at any point in its history. Therefore, while China will have a national inter-city transport network similar to that of the United States, intra-city transit systems will presumably develop very differently. China is therefore less likely to develop cities characterised by suburban sprawl that rely upon automobiles. Rather, it will borrow from Japanese and European models of mass public transit. One study (McKinsey Global Institute 2008) estimates that China will construct 170 mass transit systems by 2025, servicing the majority of a projected 221 urban agglomerations with populations in excess of one million people. This projected style of urbanisation reinforces the assessment that China's future path of automobile penetration will not resemble that of the United States.

China's on-going urbanisation drive is proceeding on a scale that does not have a precedent. The westward expansion of the population of the United States (a family multiplication strategy rather than a technological theme focussing on a rural-urban shift [Snooks 1997: chapter 12]), or the mass Siberian migration of European Russians (ibid: 442-6) are tempting but not terribly productive analogies. These two historical examples were based around physical resource acquisition and exploitation. In China's case, labour is moving to expedite the diffusion of the technological strategy, not to exploit untapped physical resources. The combination of immense scale and a distinct strategic underpinning argue that this particular factor must be considered on its own merit without the benefit of firm historical guidance.

The aforementioned factors – external saturation, internal integration, mass urbanisation, urban style (alongside an anticipated path for income per capita) - must guide our medium term judgement. The United States is a reasonable comparison in some, Japan in others. At times though China's uniqueness shines like a beacon.

Some milestones and relevant trajectories can be defined to give some idea of the timing of the peak in Chinese metal intensity. China should reach the \$13k per capita income level around 2015, if it continues to expand at the rates projected by growth accountants, and the demographers at the UN have done their sums correctly (Perkins and Rawski 2007, Wang 2007, Garnaut et al 2008, He et al 2007, United Nations 2007). Given its distance from the strategic leadership will still be substantial at this point (around 20% of US GDP per capita), a relative level well below that at which other East Asian countries began to experience decelerating growth (Garnaut et al 2008), we might reasonably consider 2015 as the earliest possible time that per capita growth would begin to decline. And indeed, we note that the 'turning point' in the general MIKC represented by the cross sectional data in figure 4, for what it is worth, is around \$24k per capita. In the MIKC estimated for the United States, the turning point was around \$17k per capita. China cannot be reasonably expected to reach either point any sooner than 2023 or 2019 respectively.

Further to those points, the five year period 2015 to 2020 is the turning point for China's demographic profile as projected by the United Nations population division (United Nations 2007).¹⁰ The momentum of urbanisation will also have calmed by this time, with 72 million rural to urban migrants anticipated in the five years to 2020, down 10% from the estimated peak rate of the 2005 to 2010 period. By the five years to 2030, the rate of urbanisation will have declined by 38% from peak rates, with the urban share of the population surpassing 60%, equivalent to the global average.

The saturation point for the global economy regarding China's exports is another core factor to consider. This was done in section 7 with specific reference to differentiating China and Korea. Here we consider the Japanese example. Japan's export share grew in trend terms through most of the Bretton Woods era, paused during the mid 1970s as energy exporters reigned, and then continued its ascent all the way up to the Plaza Accord of 1985. At this point Japanese GDP per capita had reached three quarters of the United States' level (it would peak around 85% in 1991); it had been the world's second largest economy for sixteen years; and the real exchange rate had more than

¹⁰ For an analysis of the demographic profile, and an application to the long run growth trajectory, see Golley and Tyers 2006.

doubled in value since the yen was de-pegged from the US dollar. Further nominal and real yen appreciation beyond 1985 resulted in a loss of competitiveness and precipitated a trend decline in Japan's export share in the second half of the 1980s. Japan also had nowhere else to go from a sectoral perspective. By this stage Japanese firms defined the technological frontier in many sectors. It became clear that Japan could no longer seriously expect to sustain export growth faster than the rate of growth in aggregate world trade. As its cost competitiveness eroded, increasingly it was unable to do even that. Japan's externally focused development strategy had exhausted (McKay 2008).

If these broad economic (as opposed to political) themes and relativities need to be replicated in the Chinese instance before we reach the saturation point for world export market share, then we are some way from reaching such a peak. China will be only reach two fifths of US GDP per capita levels by 2030, a level not far removed from the Japanese position in the mid 1960s. Japan was expanded its export share for two decades beyond this landmark. Further, China's real exchange rate has only just embarked upon an appreciating trajectory. The economy has only recently exited a protracted disinflationary period. Modest flexibility was introduced into the nominal exchange rate regime as recently as July 2005 (Golley and Tyers 2007, McKay 2007). It seems unlikely that the level of the real exchange rate will present a major hurdle for Chinese export market share gains for a significant period of time.

China's world export market share is approaching the levels at which Japan's share peaked. But as China is still increasing its share of world output extremely rapidly, that growth accommodates a higher natural share of global export trade. China is likely to be the largest, if not the richest economy in the world. It will become far larger in relative terms than Japan was when it achieved a 9% share of world exports. As we argued in section 7, the growth in China's export share will submit to gravity at a GDP per capita level well below that currently prevailing in Korea, but it will not face the economic hurdles that constrained Japan any time soon. If we recognise that the politics of the situation are relevant, then it may be that China finds that rapid global market share gains cease well ahead of the schedule facing a 'normal' economy. Even a very pessimistic reading of the situation would put that point deep into the next decade, or possibly early in the 2020s.

The United States increased its share of world merchandise exports from around 3% in 1800 to 9.8% in 1860, 13.2% by 1900 and 16% in 1960¹¹ (Lipsey 2000: table 15.1 p. 688). Clearly, gains in world export share can continue for a very long time before the global economy becomes saturated with the output of a large and expanding strategic state.

As discussed in section 5, Chinese auto penetration is anticipated to follow a path that is moderate by either Japanese or American standards. The International Monetary Fund's projections for auto ownership per 1000 persons incorporate a 250% expansion between 2010 and 2020, and a 180% rise between 2020 and 2030 (International Monetary Fund 2005: 182). A non-linear interpolation of these points results in the path presented in figure 5c. At 267 cars per 1000 people, China would

¹¹ The figure for 1960 is the author's calculation from World Bank data accessed via subscription to the World Development Indicators database. All other data on historical United States exports are taken from the in text reference.

be less than half of the way to the saturation point observed elsewhere. That implies that further automobile penetration beyond that point would contribute to keeping Chinese metal intensity at a relatively high level beyond the turning point.

The preceding discussion sketches a very broad range within which various factors relevant to China's intensity of steel use might peak: as early as 2015 and as late as 2030. It seems fairly safe to trim this distribution at the near end. The idea of resource intensive high growth decelerating as soon as 2015, at such low levels of relative income, relative capital stock, in the midst of the urbanisation drive and prior to the peak in export market share does not seem plausible. However, we might reasonably see the 2015 to 2020 period as the likely moment when China conclusively veers off the Korean trajectory and begins to define a more distinctive individual path with a flatter gradient of increase.

If we allow China to follow Korea up to 2015, when we assume Chinese income per capita has reached \$13k, then that would imply steel consumption of 700kg per capita, or 910 million metric tons. That is equivalent to 80% of global steel output in 2005. A demand profile like that will obviously put extreme pressure on global supply potential. It may encourage substitution decisions, and it may crowd out smaller consumers. In sum, if China was to follow this path, other countries may have to review their own strategies to cope, whether they are net importers or net exporters of resources.

The supply response to the strategic demands of the Chinese development process will be critical to the final outcome. A strategic price signal, in the form of the spectacular commodity price rises observed since 2003, is starkly evident, so the incentive to invest is currently very large. The dominant players in supplying the market, the major global diversified resources companies, are trumpeting their ability to meet huge projected Chinese demands (Albanese 2008, Kloppers 2008). Taking that claim on board, while simultaneously recognising the unpredictable nature of the exploration and discovery process and the oligopolistic nature of the industry, and there is no reason to presume that excess supply of raw materials will emerge in a sustainable fashion in ferrous metals markets. That will keep prices elevated relative to historical norms and continue to drive the strategic demand for future investment. That indicates that presuming the resource endowment exists, it will be progressively utilised by strategists over the period. Thus we assume that China's choices will not be curtailed by finite supply.

The 2015 to 2020 period represents a transition phase in the projection, with the structural drivers becoming more erratic and beginning to blend more frequently with cyclical factors to determine metal demand. The precise peak in Chinese steel usage per capita would thus occur somewhere within a few years of 2020, with the distribution of likely outcomes skewed towards the later dates in this range.

Importantly, it must be acknowledged that demand would become significantly more volatile around the turning point. The experience of the United States highlights that once cyclical factors become a material determinant of per capita steel usage, the path of annual observations describes a violent saw tooth pattern. The gradient of the underlying trend is likely to flatten appreciably once China moves assertively away from the Korean course. It may even flatten absolutely. This seems more likely than a

trend of swift erosion in the intensity of steel usage on the far side of the turning point. Given that the broad range initially defined stretched all the way out to 2030, and the huge uncertainties at play, a hedging forecast allows for a flat trend for a time following the tentatively defined peak.

That leaves a profile of Chinese steel usage per capita that looks something like the schematic diagram presented as figure 13 below. The discontinuities of the curve are defined as follows:

a) 700kgs per capita in 2015 b) 750kgs per capita in 2019 c) 750kgs per capita in 2023 d) 550kgs per capita in 2030.

< figure 13 here >

10. Summary & conclusions

Attempting to sketch China's future path of metal intensity is not possible without first assessing its overall strategic attitudes towards a multitude of issues, both domestic and international. The study began by stating that there is no "silver bullet" model of metal intensity. Even the presence of a robust Kuznetsian relationship in the United States between steel intensity and income per capita, which was documented in section 2 as the MIKC, does not overturn this statement. The corroboration of the MIKC in cross sectional data does not necessary buttress the case. The two findings are both useful, but together they do not provide us with a general model that may be confidently applied to forecasting problems. Kuznets himself warned against speculating beyond one's data. Over reaching is an ever present risk when the data itself is frustratingly sparse.

The example of comparative long run automobile penetration in the United States and Japan, a metric that was shown to be statistically relevant to explaining steel use in the former, highlights the idiosyncratic rather than common elements of national strategies. The contrasting paths to high automobile penetration observed in the United States and Japan indicates that we must be extremely cautious about back-casting existing time series with a relationship based on either a) a time series from a single country, or b) a cross section of multiple countries where the "hump" in the MIKC may be generated by atypical observations. Or worse, we could be relying on a cross section of strategic and anti-strategic nations, where the experiences of the latter are not relevant for the former.

In conclusion, the data presented in this paper offer a broad range of perspectives on the change in metal intensity at various distances from GST entry. Some tentative generalisations have emerged as have some important findings for individual countries. However, there are shortcomings in using either the general-to-specific or the specific-to-general approaches in a forecasting framework.

As for China's future path of metal intensity, it seems unlikely that it will continue to resemble Korea beyond 2015 or so. The post 2015 trajectory will feature certain aspects that are reminiscent of the paths taken by the United States and Japan, but the final outcome will not fully resemble either. As a tentative and preliminary judgement, and assuming that resource limits are not reached, the peak in Chinese

steel usage per capita is likely to occur at a point not too distant from 2020: possibly sooner, but more likely to be later. The peak level of steel intensity induced from the analysis is 750kgs per capita. That is well below Korean levels of consumption, but close enough to Japan's peak rate. It is suggested that this peak will be sustained through the early and middle 2020s, before declining towards the end of the decade.

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Figure 1: Steel consumption & level of development

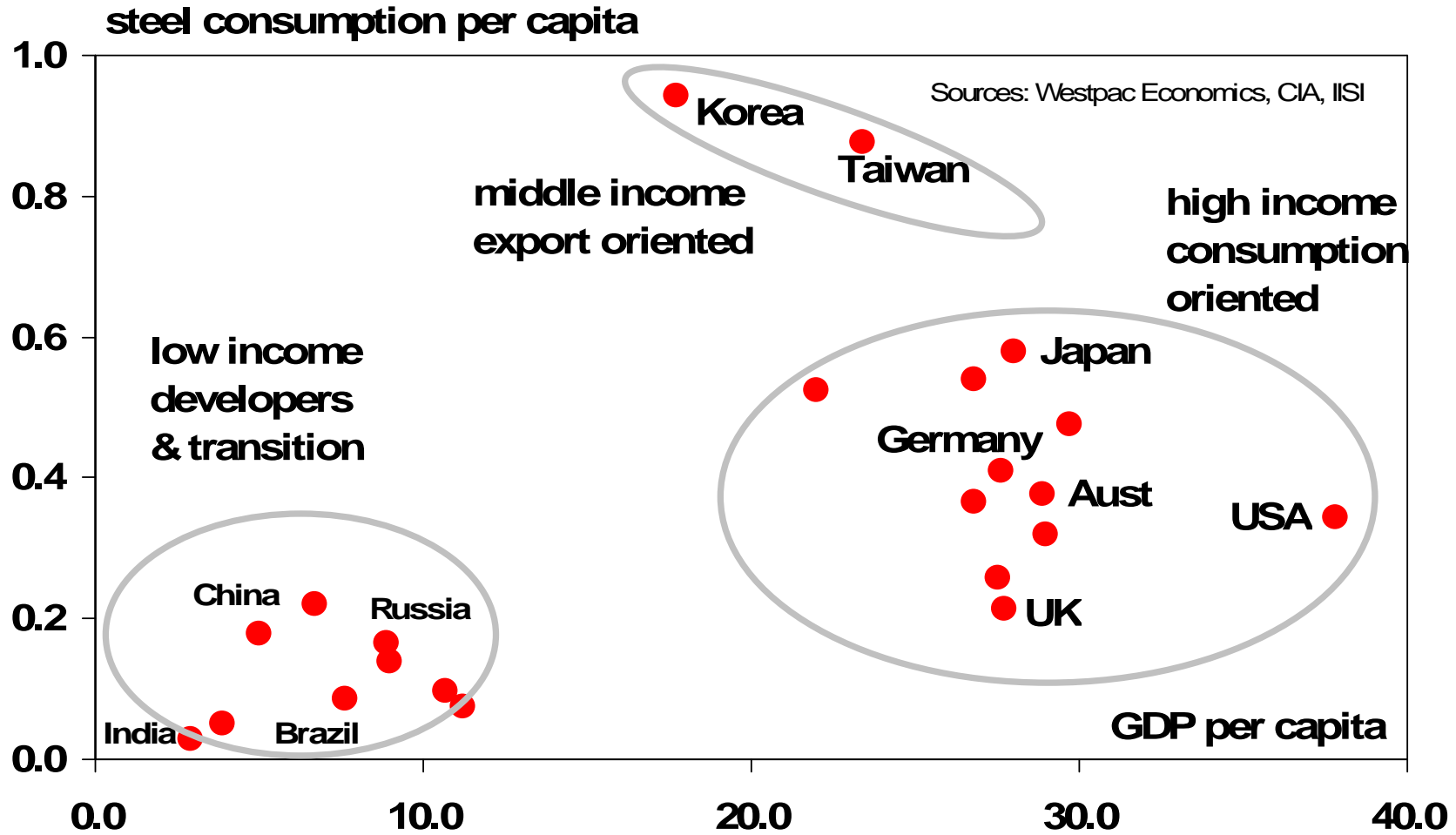


Figure 2: Steel use & income per capita: 1974 ~

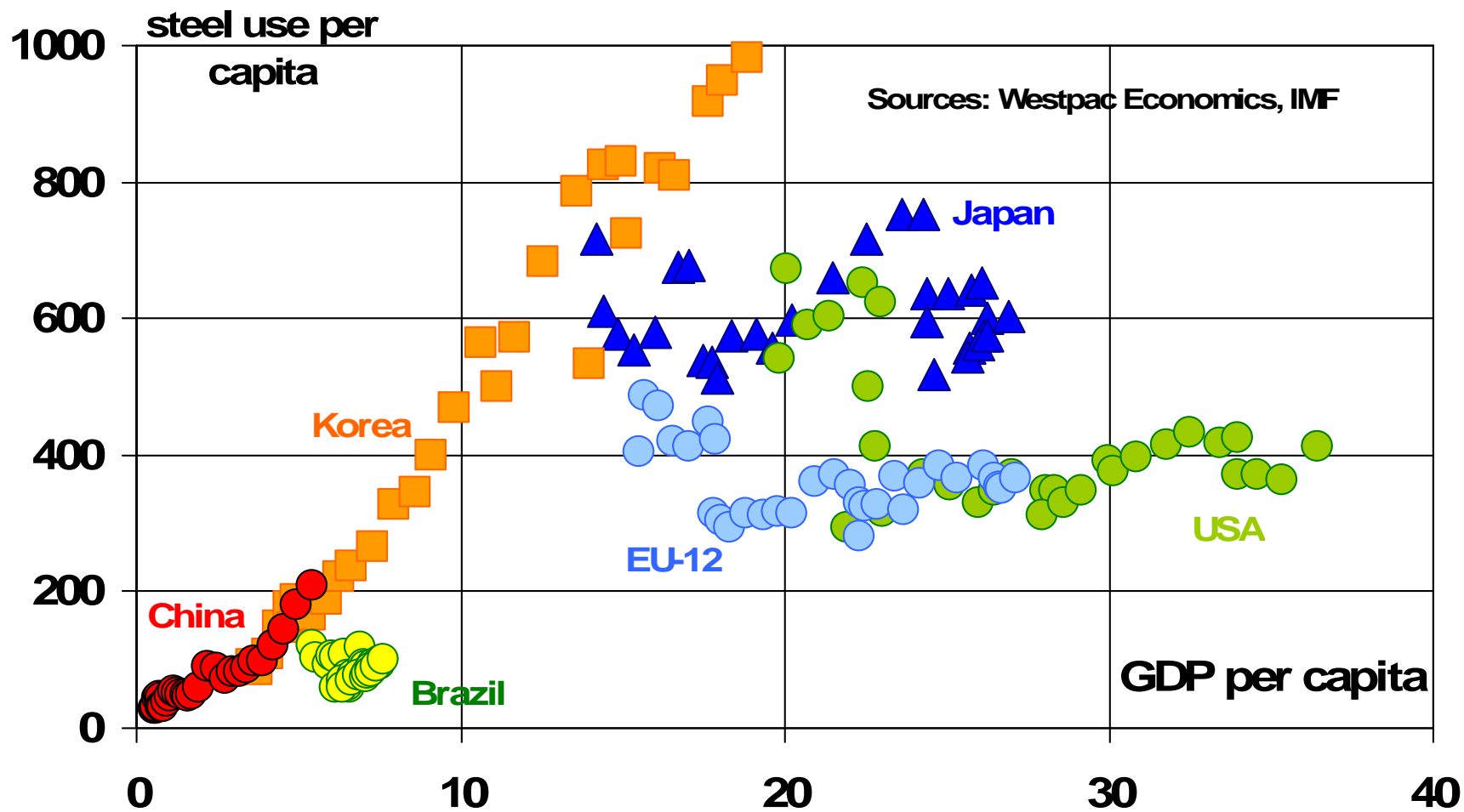
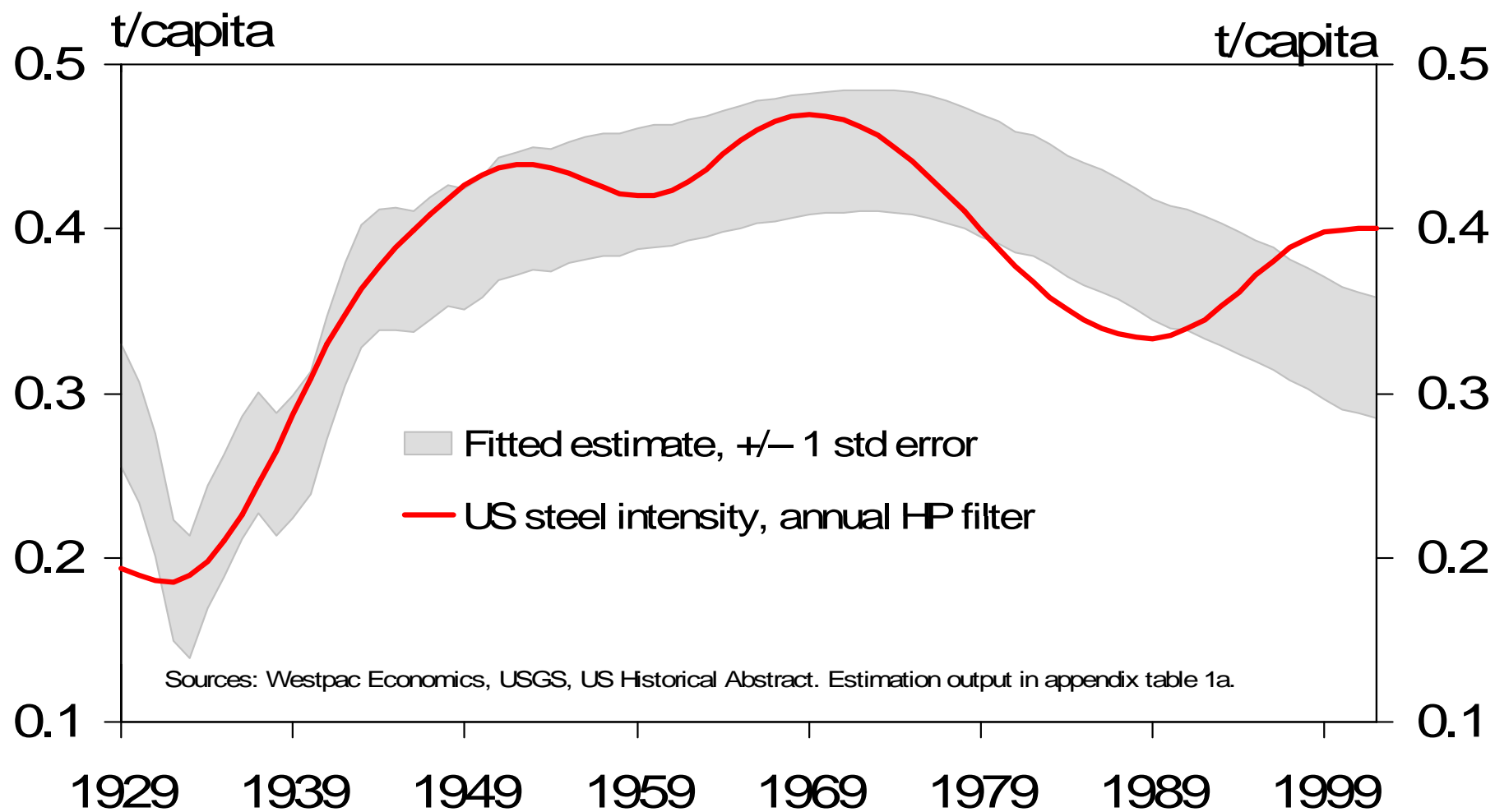


Figure 3a: A Kuznets curve of US steel intensity



Sources: Westpac Economics, USGS, US Historical Abstract. Estimation output in appendix table 1a.

Figure 3b: A Kuznets curve of US steel intensity

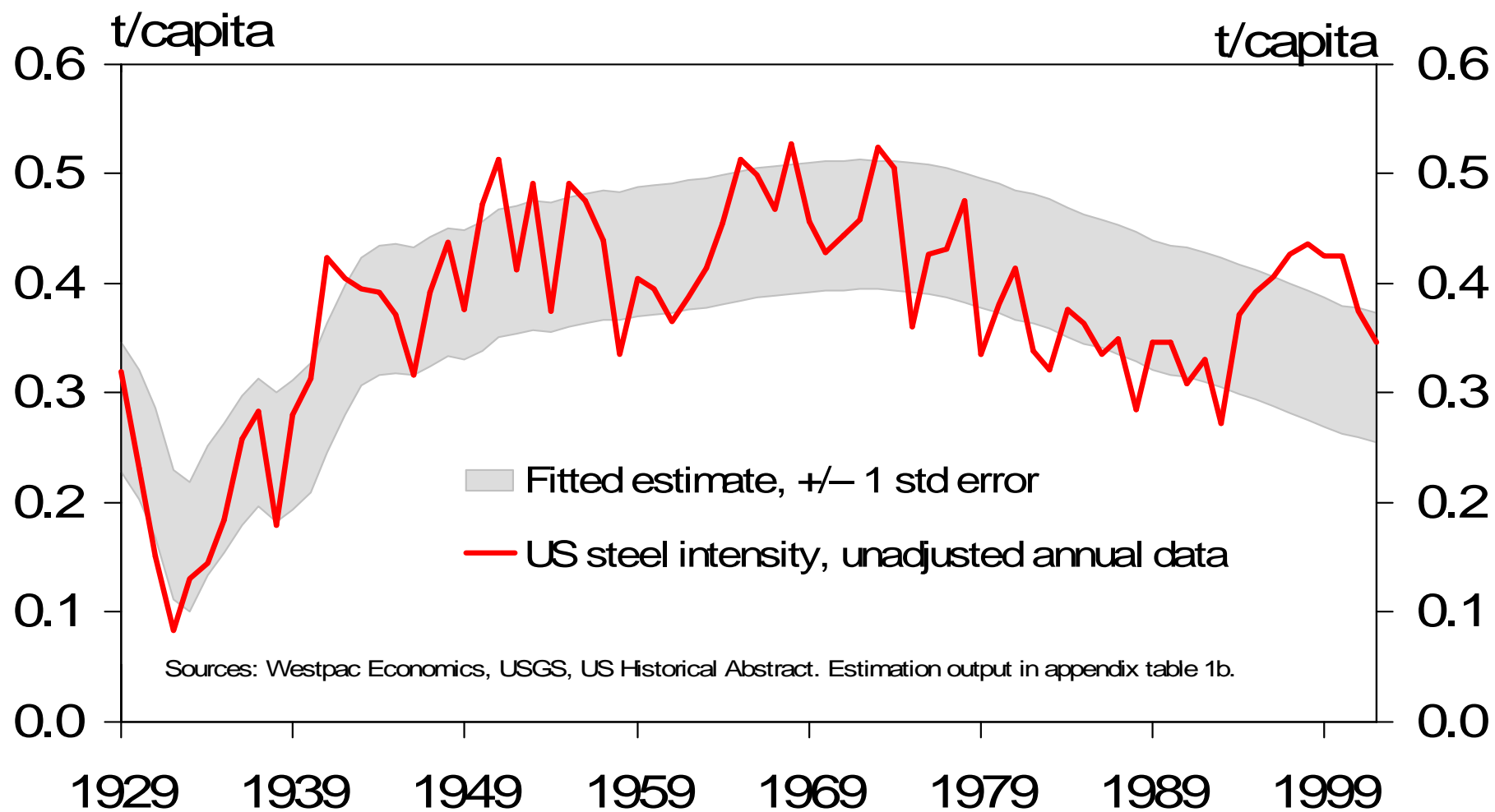


Figure 4: A general Kuznets curve of steel intensity?

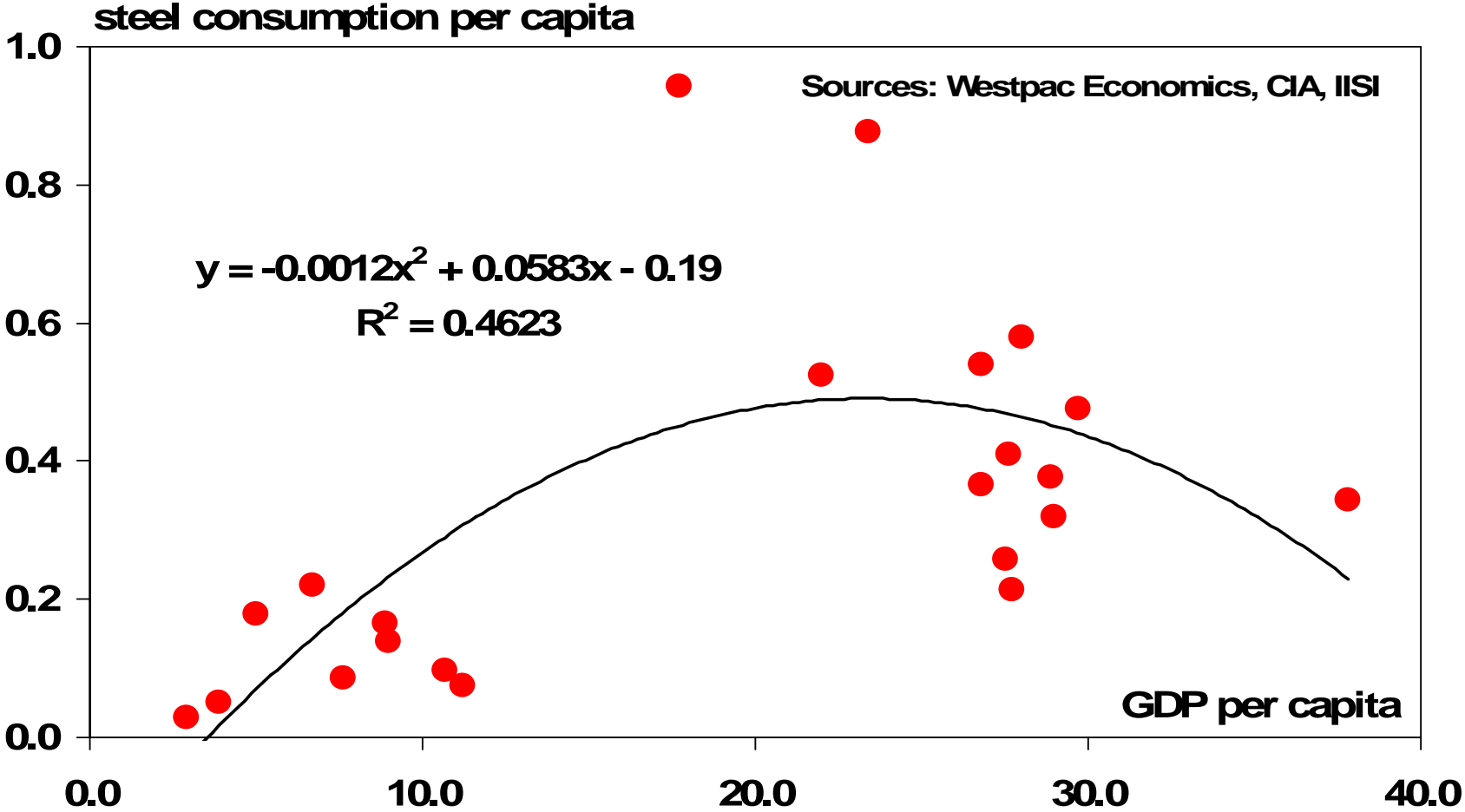


Figure 5a: Auto penetration & income. A linear relationship?

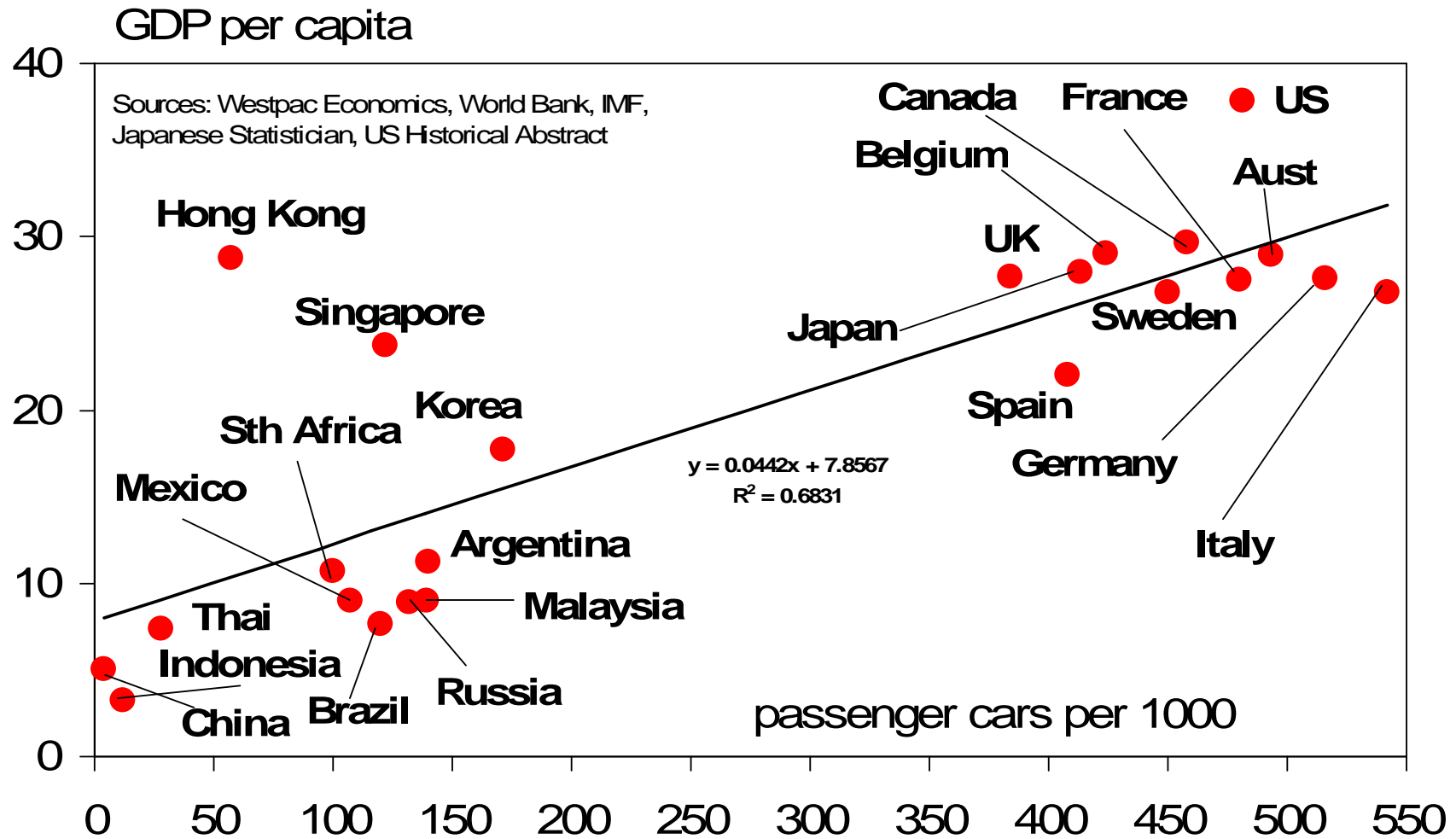


Figure 5b: Auto penetration & income. A linear relationship?

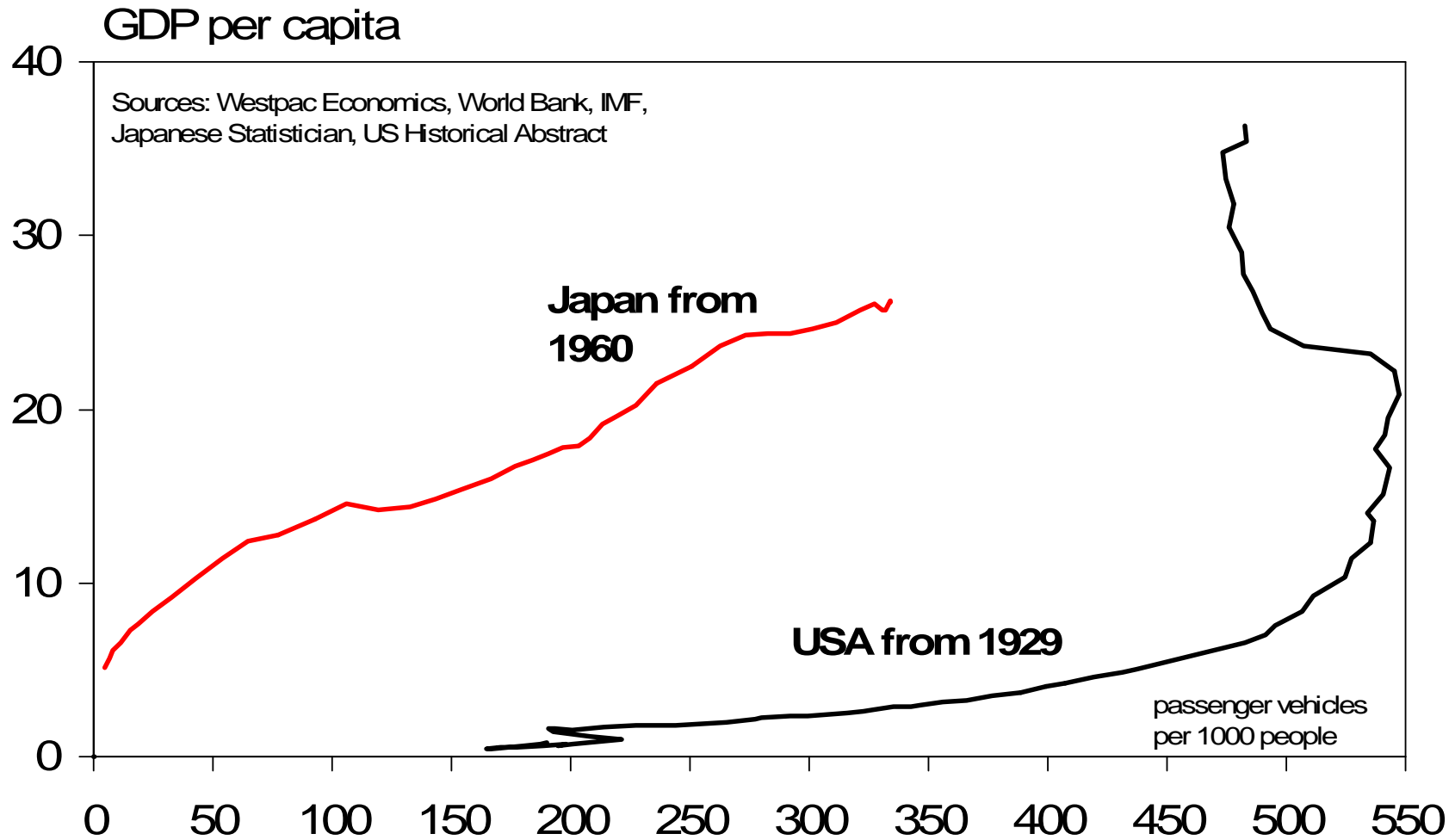


Figure 5c: Schematic actual and projected auto penetration

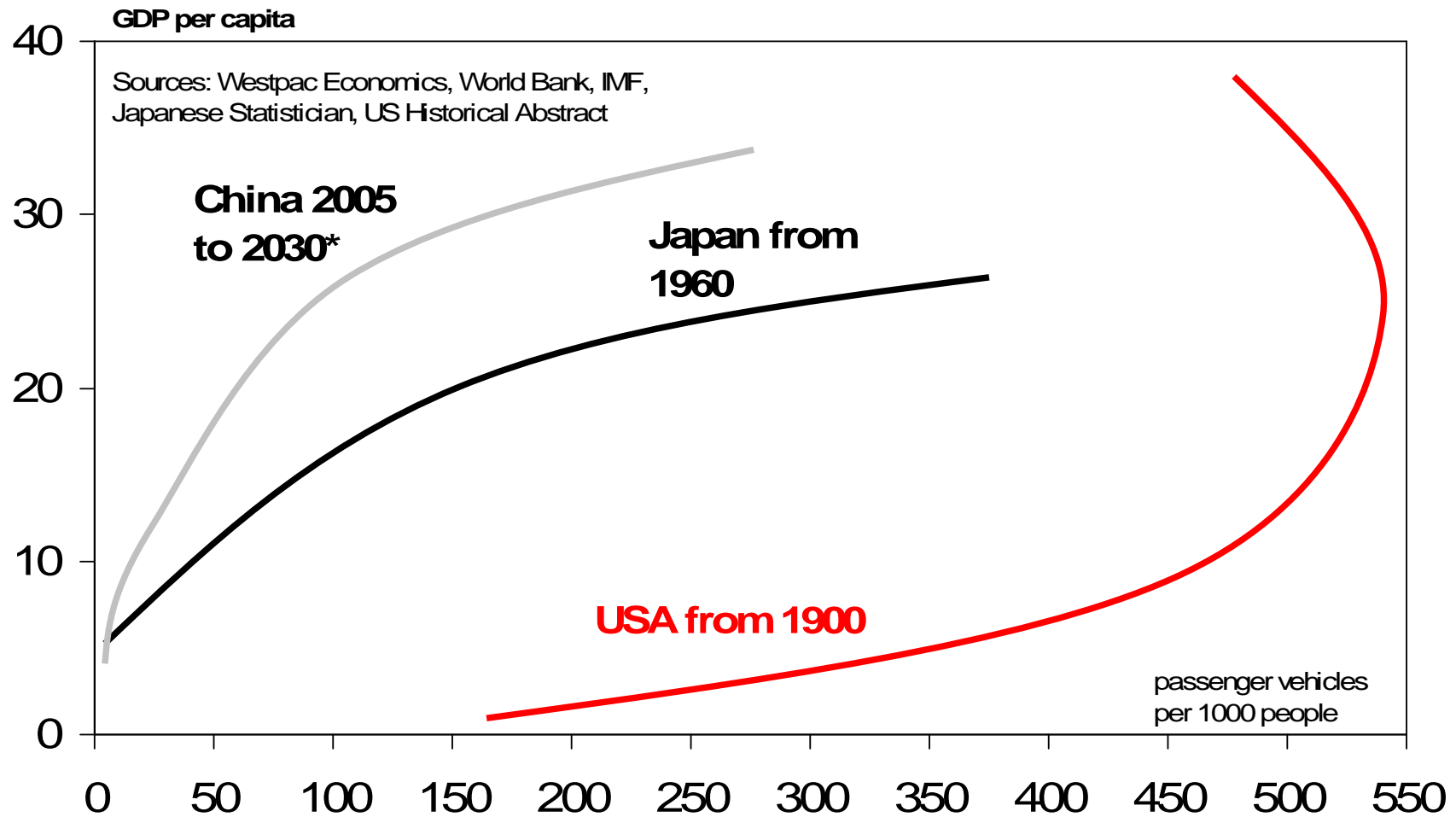


Figure 6: The augmented Kuznets curve of US steel intensity

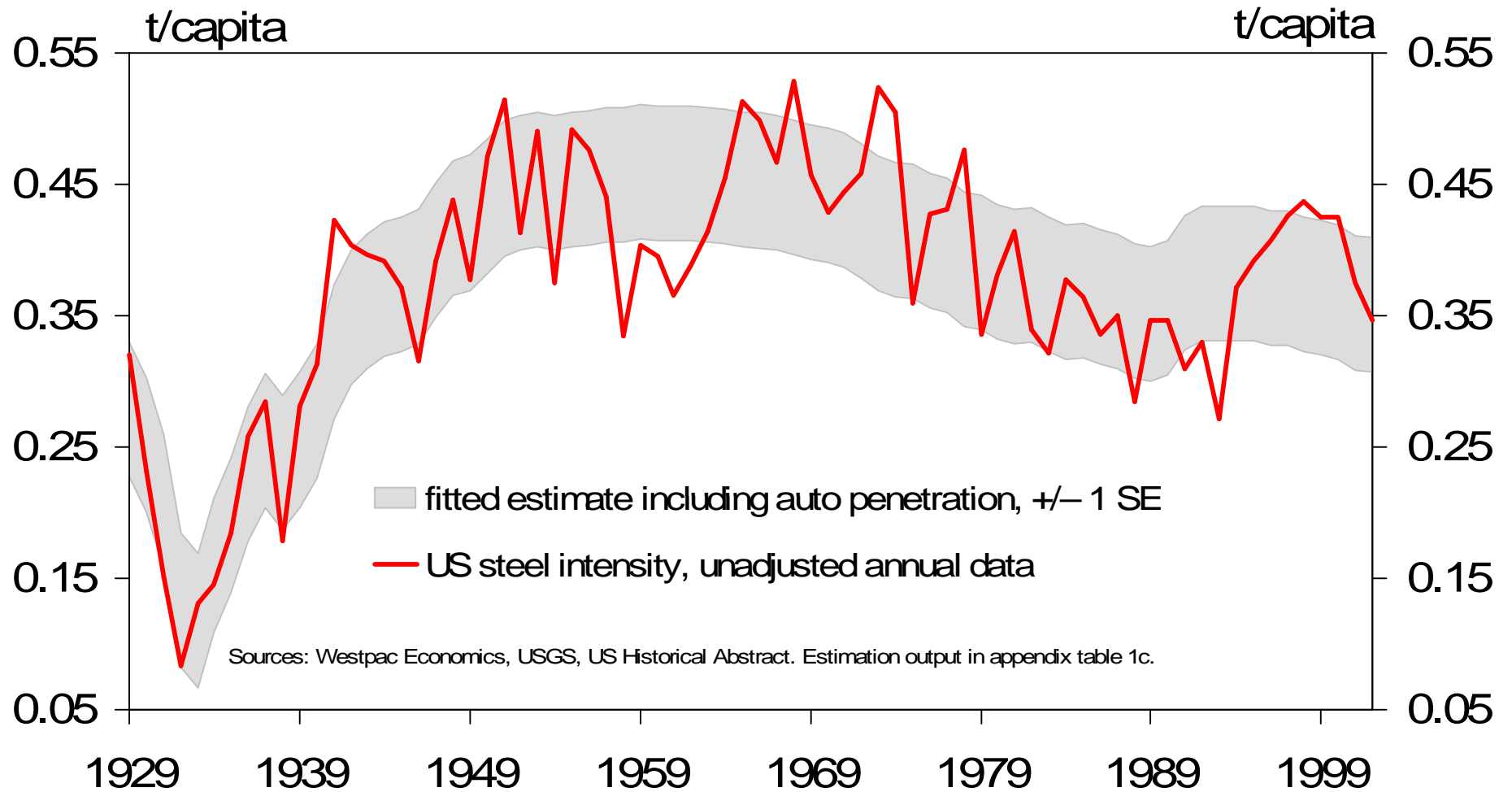


Figure 7: Industry share of output & income per capita

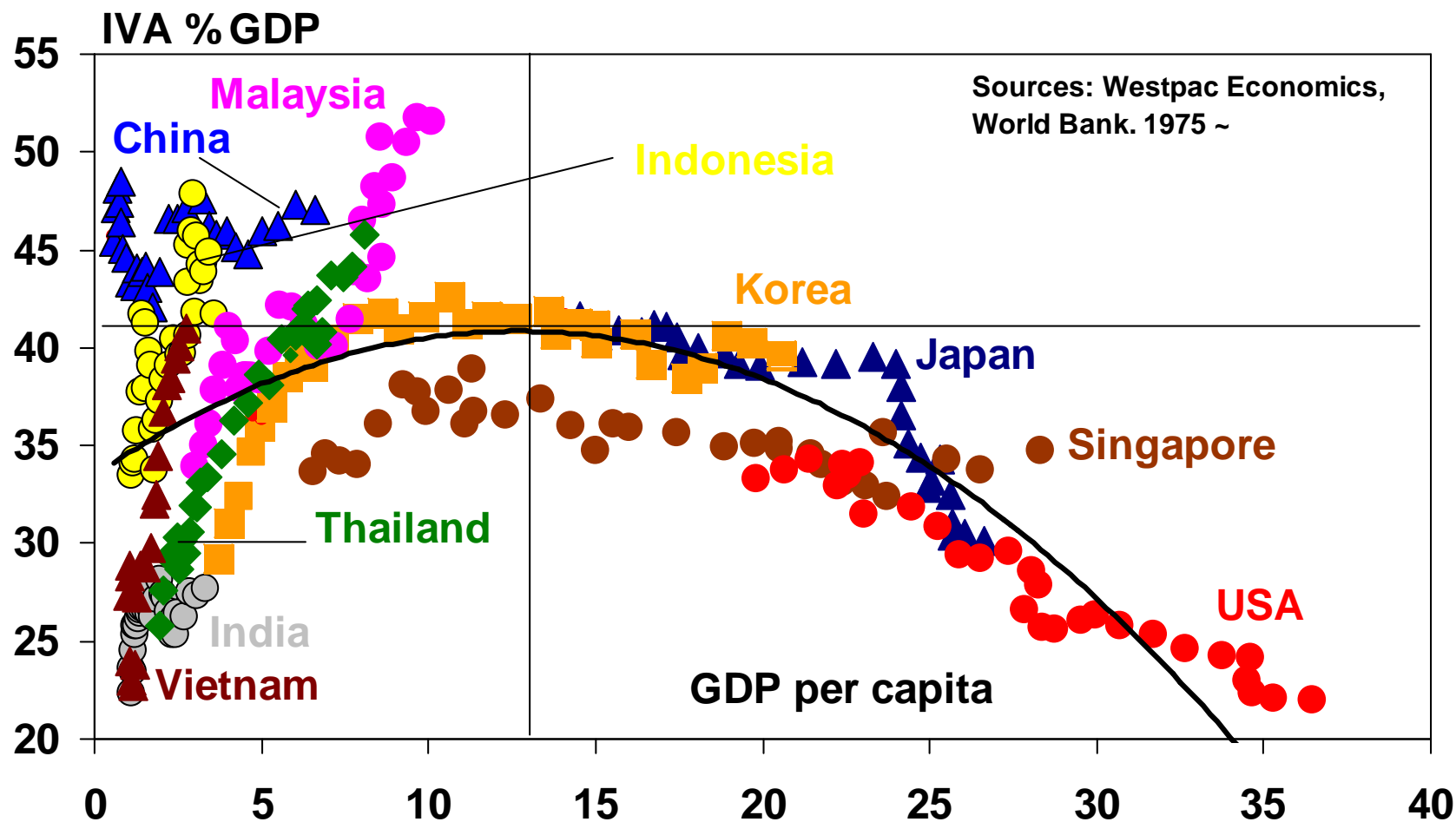
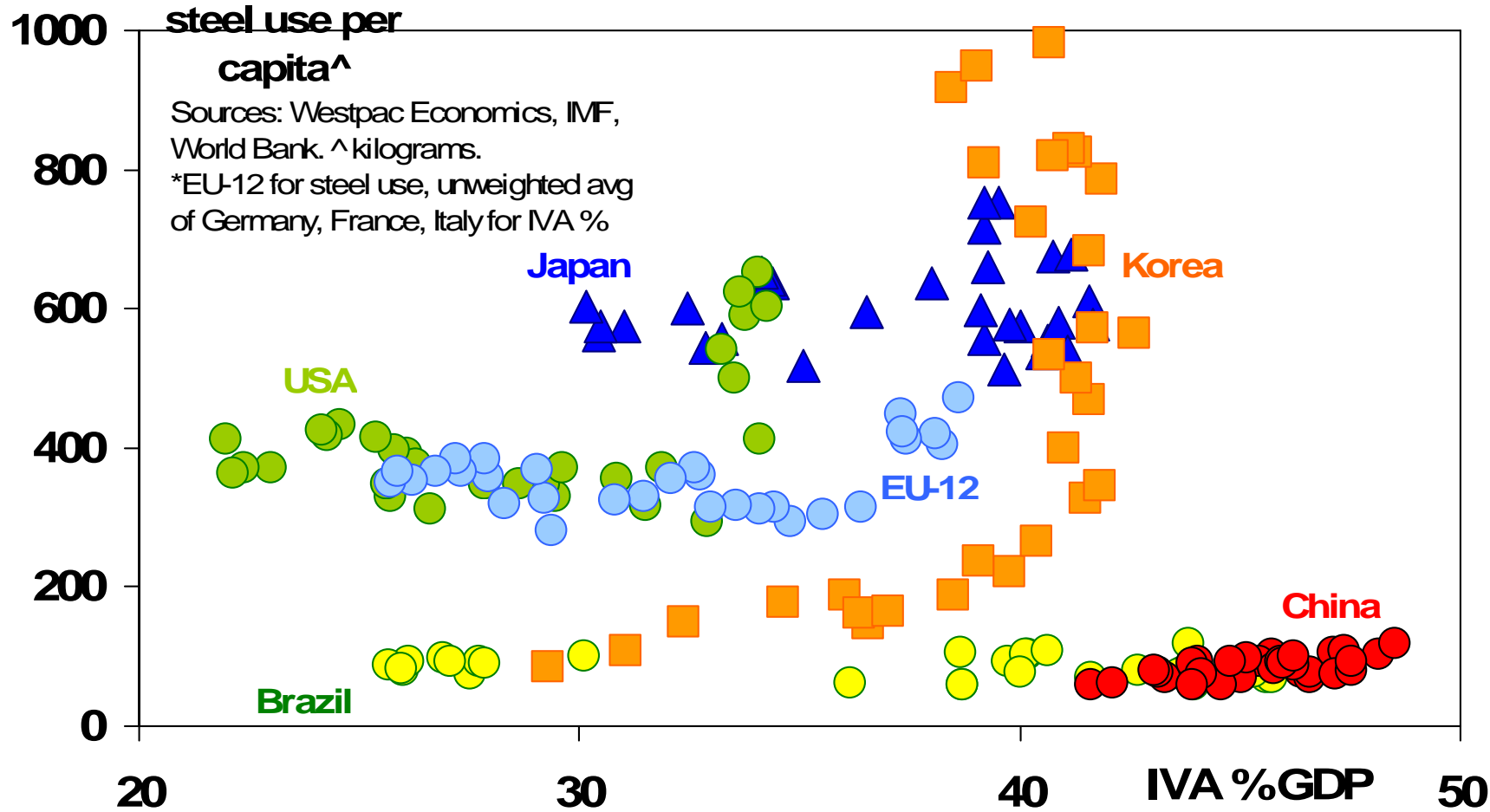


Figure 8: Steel use & IVA share of output



steel use per capita^
Sources: Westpac Economics, IMF, World Bank. ^ kilograms.
*EU-12 for steel use, unweighted avg of Germany, France, Italy for IVA %

Figure 9: Steel intensity & urbanisation rates

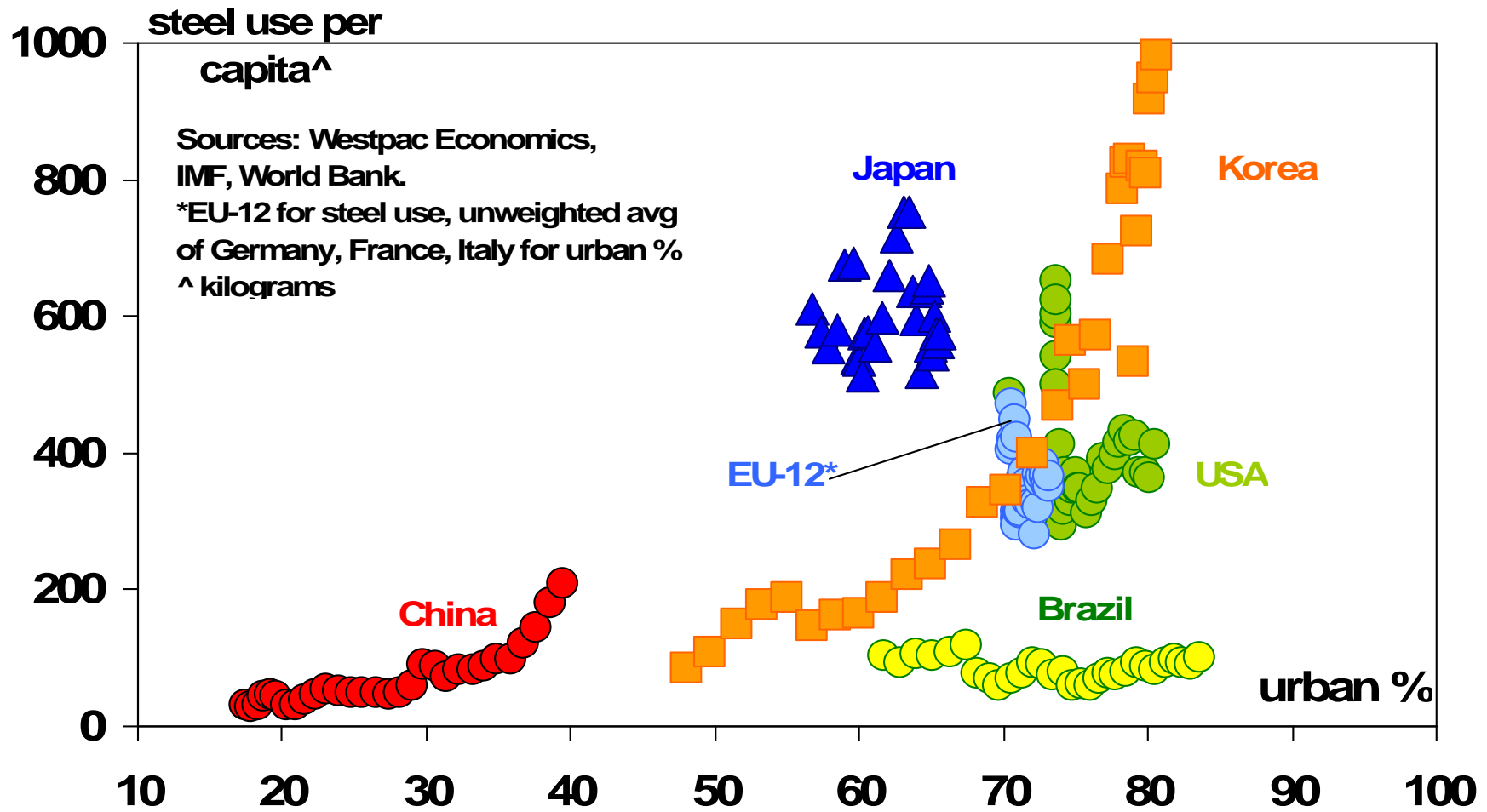


Figure 10: Steel intensity & world export share

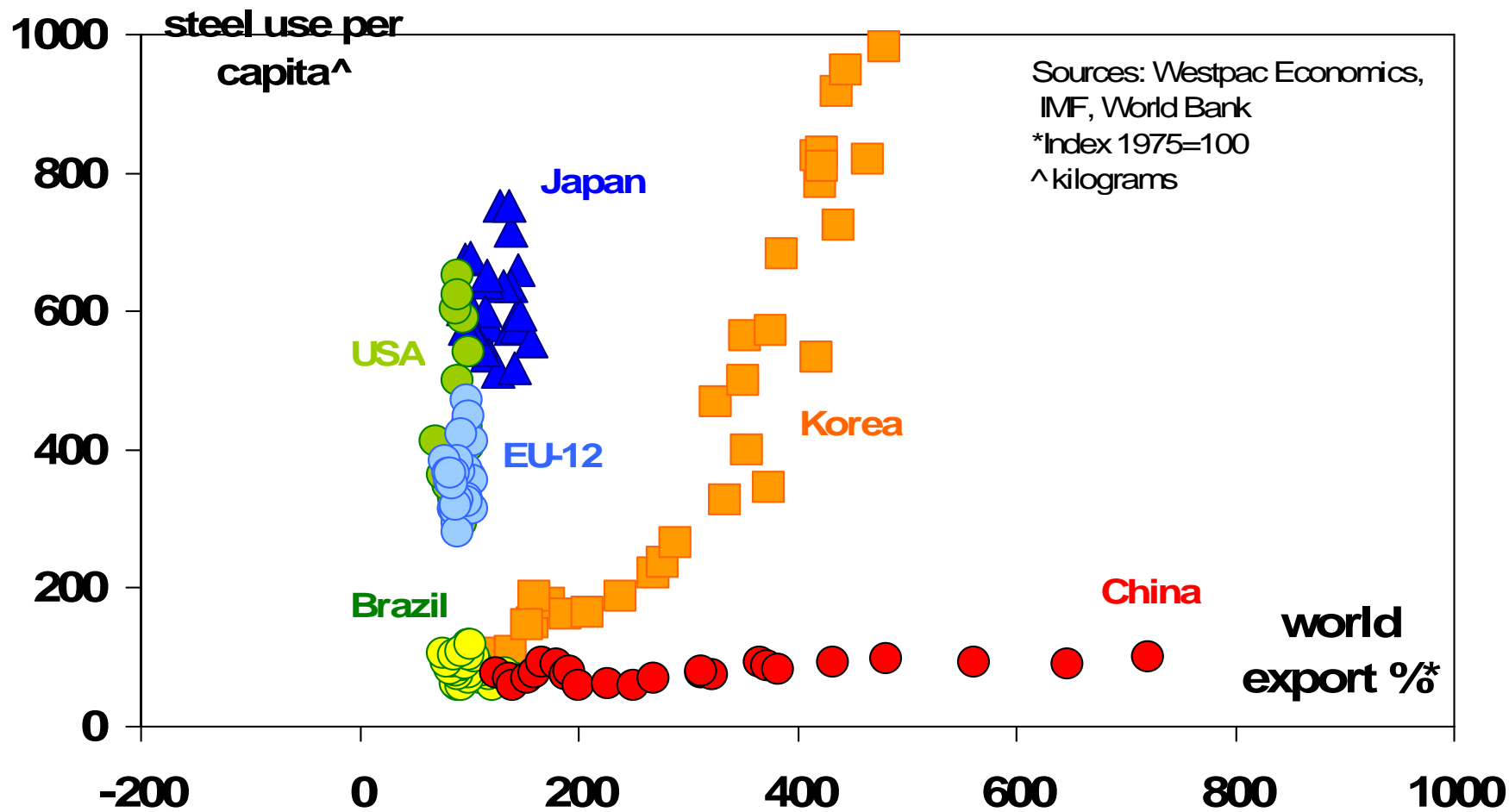
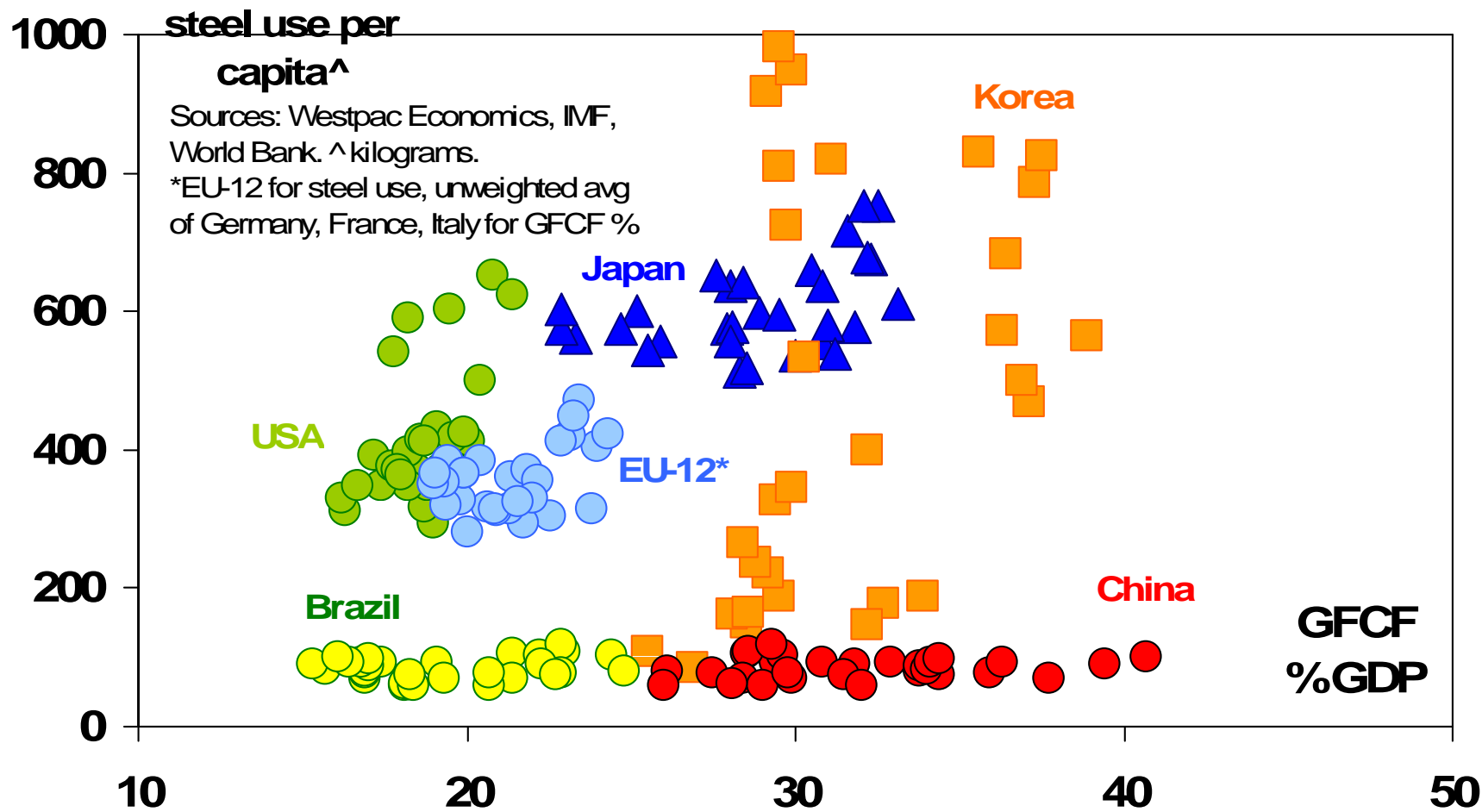


Figure 11. Steel intensity & GFCF share of output



steel use per capita^
Sources: Westpac Economics, IMF, World Bank. ^ kilograms.
*EU-12 for steel use, unweighted avg of Germany, France, Italy for GFCF %

Figure 12: China's adjusted world export share*

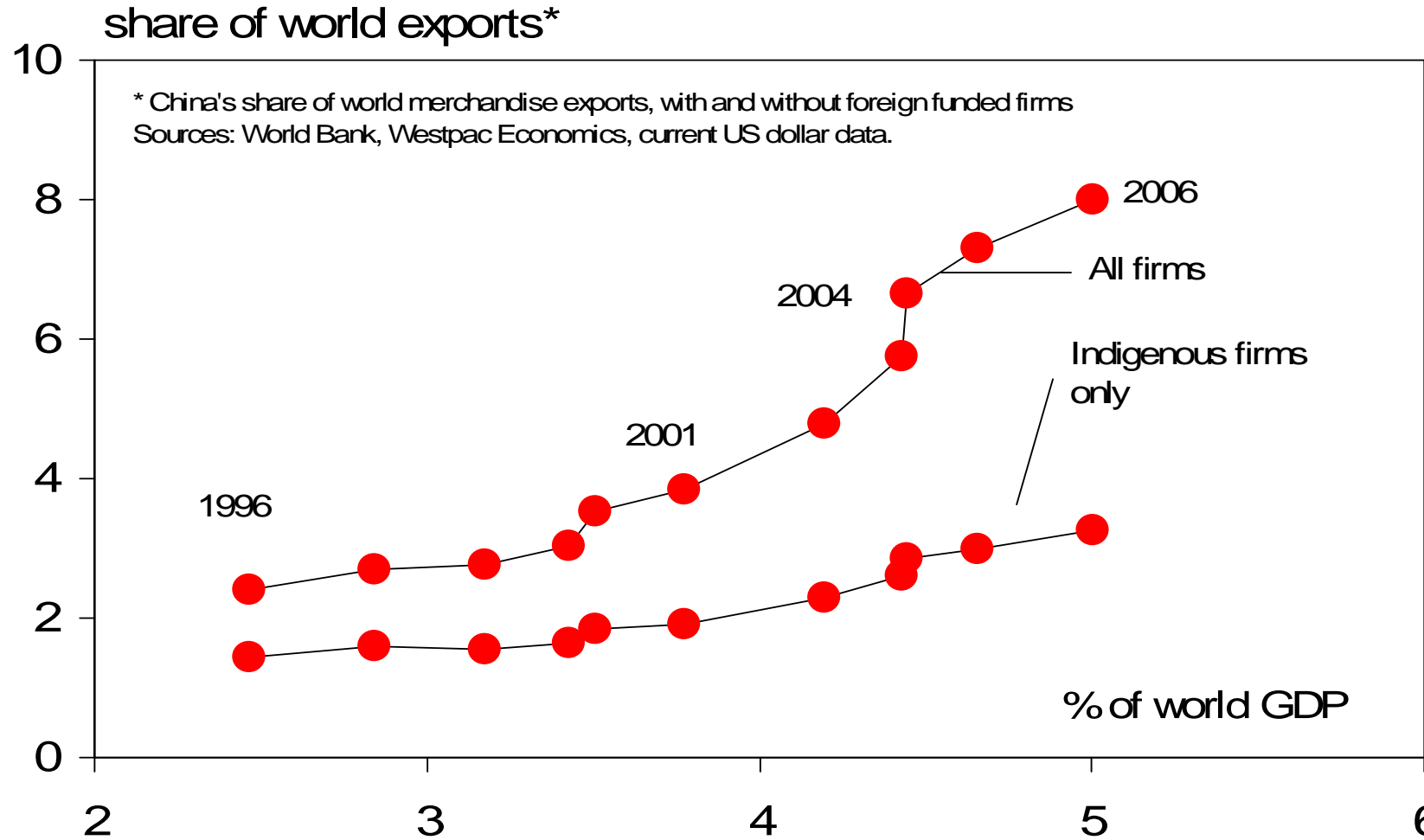
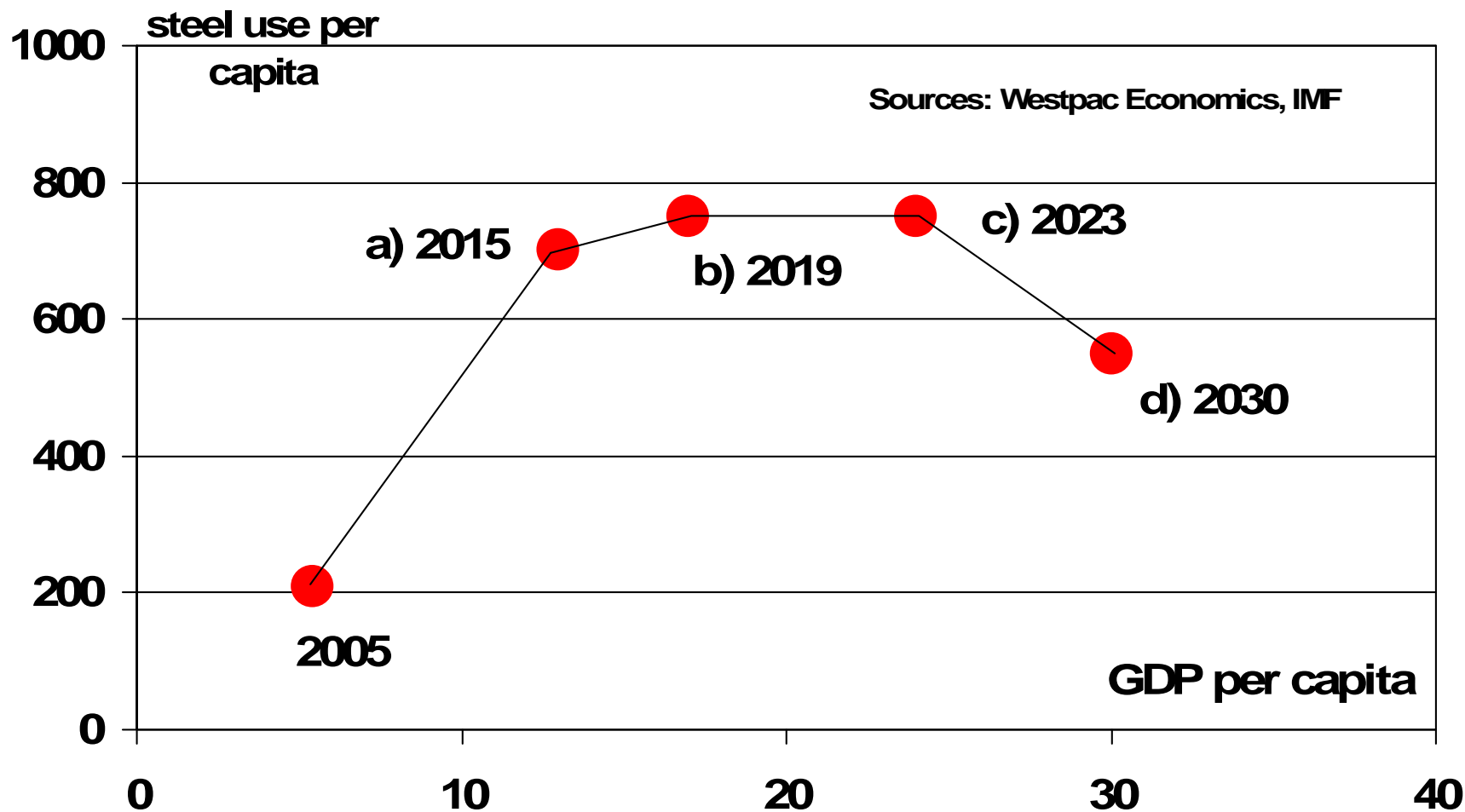


Figure 13: Chinese steel usage per capita: a forecast



	Years from GST entry	GDP ppp index	Steel use index	Copper use index	Alum. Use index	IVA index	Savings index	GFCF index	Exports index	Goods Trade index	World export share index	Urban pop index	Pop per km^2 index	Memo GDP mkt \$/cap index
China 1978	0	100	100	100	100	100	100	100	100	100	100	100	100	100
	5	135	89	100	99	93	94	98	164	134	101	116	107	138
	10	223	109	134	100	92	98	106	257	234	160	137	115	226
	15	322	202	225	191	97	113	127	351	310	200	159	123	325
	20	504	200	305	329	96	110	114	306	222	322	182	130	501
	25	729	408	647	679	95	116	133	445	362	432	206	135	733
China 1978	Years from GST entry	GDP ppp \$US/capita	Steel use kg/capita	Copper use kg/capita	Alum. Use kg/capita	IVA %GDP	Savings %GDP	GFCF %GDP	Exports %GDP	Goods Trade %GDP	World export share %	Urban pop %	Pop per km^2 persons	Memo GDP mkt \$/cap
	0	679	44	0.4	0.6	48	38	30	7	14	0.8	19	103	165
	5	919	39	0.4	0.6	45	35	29	11	19	0.8	22	110	228
	10	1516	48	0.5	0.6	44	37	31	17	33	1.7	26	118	373
	15	2187	90	0.8	1.1	47	42	38	23	44	2.4	30	126	536
	20	3423	89	1.1	1.9	46	41	34	20	32	3.3	34	133	827
25	4951	181	2.4	4.0	46	43	39	30	52	5.8	39	138	1209	
Japan 1960	Years from GST entry	GDP ppp index	Steel use index	Copper use index	Alum. Use index	IVA index	Savings index	GFCF index	Exports index	Goods Trade index	World export share index	Urban pop index	Pop per km^2 index	Memo GDP mkt \$/cap index
	0	100	na	100	100	na	100	100	100	100	100	100	100	100
	5	149	na	134	189	na	100	97	98	93	143	110	105	149
	10	243	na	243	545	na	120	119	101	97	195	123	110	244
	15	282	100	227	650	100	98	100	120	109	203	132	118	284
	20	333	99	304	869	99	93	98	128	123	204	138	124	337
	25	374	96	311	869	96	94	86	134	109	290	141	128	379
30	461	95	392	1211	95	100	99	98	83	258	146	131	469	
35	489	83	346	1153	83	87	85	86	71	268	150	133	498	
Japan 1960	Years from GST entry	GDP ppp \$US/capita	Steel use kg/capita	Copper use kg/capita	Alum. Use kg/capita	IVA %GDP	Savings %GDP	GFCF %GDP	Exports %GDP	Goods Trade %GDP	World export share %	Urban pop %	Pop per km^2 persons	Memo GDP mkt \$/cap
	0	5115	na	3.3	1.6	na	34	34	11	21	3.2	43	258	7099
	5	7614	na	4.4	3.0	na	34	33	11	20	4.6	47	270	10566
	10	12435	na	7.9	8.8	na	41	40	11	20	6.3	53	285	17298
	15	14424	42	7.4	10.5	42	33	33	13	23	6.5	57	305	20135
	20	17058	41	9.9	14.0	41	32	33	14	26	6.5	60	319	23917
	25	19129	40	10.2	14.0	40	32	29	14	23	9.3	61	331	26940
30	23599	40	12.8	19.6	40	34	33	10	17	8.3	63	339	33280	
35	25019	34	11.3	18.6	34	30	28	9	15	8.6	65	344	35322	
Korea 1974	Years from GST entry	GDP ppp index	Steel use index	Copper use index	Alum. Use index	IVA index	Savings index	GFCF index	Exports index	Goods Trade index	World export share index	Urban pop index	Pop per km^2 index	Memo GDP mkt \$/cap index
	0	100	100	100	100	100	100	100	100	100	100	100	100	100
	5	130	173	221	173	125	119	120	114	110	152	118	108	129
	10	179	283	511	349	134	152	107	119	112	276	135	116	176
	15	263	557	760	841	142	181	138	88	90	325	154	122	266
	20	365	937	1203	1464	143	181	139	93	88	421	163	128	368
25	435	975	1844	1710	139	169	116	126	114	464	166	133	437	
Korea 1974	Years from GST entry	GDP ppp \$US/capita	Steel use kg/capita	Copper use kg/capita	Alum. Use kg/capita	IVA %GDP	Savings %GDP	GFCF %GDP	Exports %GDP	Goods Trade %GDP	World export share %	Urban pop %	Pop per km^2 persons	Memo GDP mkt \$/cap
	0	3722	84	1.0	1.0	29	20	27	30	57	0.6	48	357	2489
	5	4848	146	2.2	1.8	37	24	32	34	62	0.9	57	386	3221
	10	6649	237	5.1	3.6	39	31	29	36	64	1.6	65	413	4386
	15	9792	468	7.6	8.6	42	36	37	26	51	1.9	74	434	6615
	20	13597	787	12.0	15.0	42	37	37	28	50	2.4	78	457	9159
25	16172	819	18.3	17.5	41	34	31	38	65	2.7	80	476	10884	

Notes: GST entry dates are China 1978, Japan 1960 and Korea 1974. The Korean results are very sensitive to the choice of starting point. Copper and aluminium consumption available from 1960, steel from 1974. PPP GDP and metal consumption data from the International Monetary Fund, prior to ICP 2008. All other data from the World Bank. * Industrial value added.

Table 1a: Estimation output related to the data presented in figure 3a.

Dependent variable: Hodrick-Prescott filter of US steel use per capita (t)
 Sample: 1929 to 2002
 Observations: 74
 Method: OLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Y	0.6938	0.0464	14.9452	0.0000
Y2	-0.0398	0.0028	-14.4674	0.0000
C	-2.5770	0.1922	-13.4103	0.0000
R-squared	0.787355	Mean dependent var	0.37473	
Adjusted R-squared	0.781365	S.D. dependent var	0.07908	
S.E. of regression	0.036976	Akaike info criterion	-3.717379	
Sum squared resid	0.097075	Schwarz criterion	-3.623971	
Log likelihood	140.5430	F-statistic	131.4448	
Durbin-Watson stat	0.0934	Prob(F-statistic)	0.0000	

Y is US GDP per capita; Y2 is its squared term; C is a constant.
 Y is entered as a natural log

Table 1b: Estimation output related to the data presented in figure 3b.

Dependent variable: Unadjusted data of US steel use per capita (t)
 Sample: 1929 to 2002
 Observations: 74
 Method: OLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Y	0.7551	0.0740	10.2053	0.0000
Y2	-0.0434	0.0044	-9.8894	0.0000
C	-2.8347	0.3063	-9.2545	0.0000
R-squared	0.6308	Mean dependent var	0.3747	
Adjusted R-squared	0.6204	S.D. dependent var	0.0957	
S.E. of regression	0.0589	Akaike info criterion	-2.7849	
Sum squared resid	0.2466	Schwarz criterion	-2.6915	
Log likelihood	106.0429	F-statistic	60.6629	
Durbin-Watson stat	0.9411	Prob(F-statistic)	0.0000	

Y is US GDP per capita; Y2 is its squared term; C is a constant.
 Y is entered as a natural log

Table 1c: Estimation output related to the data presented in figure 6.

Dependent variable: Unadjusted data of US steel use per capita (t)

Sample: 1929 to 2002

Observations: 74

Method: OLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Y	0.6458	0.1239	5.2126	0.0000
Y2	-0.0354	0.0067	-5.2648	0.0000
AU	3.3692	0.8586	3.9241	0.0002
AU2	-0.3001	0.0731	-4.1031	0.0001
C	-11.8872	2.1825	-5.4466	0.0000
R-squared	0.7287	Mean dependent var		0.3747
Adjusted R-squared	0.7130	S.D. dependent var		0.0957
S.E. of regression	0.0513	Akaike info criterion		-3.0389
Sum squared resid	0.1813	Schwarz criterion		-2.8832
Log likelihood	117.44	F-statistic		46.3339
Durbin-Watson stat	1.26	Prob(F-statistic)		0.0000

Y is US GDP per capita; Y2 is its squared term; C is a constant.

AU is automobiles per 1000 persons; AU2 is its squared term.

Y and AU are entered as natural logs.