

## **Productivity, Tradability, and The Great Divergence\***

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### **Abstract**

For the first-generation models of *very* long-run growth, empirical success has been mixed. As growth theory now moves beyond one-sector, one-country models, the “industrial revolution” is typically mapped onto a modern-traditional goods dichotomy with differential productivity in rich and poor countries. We argue for the usefulness of an alternative framework, where goods are differentiated by tradability and productivity. The two characteristics can interact, and can help explain an important, but little noticed stylized fact: that, over time, the Balassa-Samuelson effect is getting stronger and stronger. Previous studies have missed this fact. Theorists have not employed it as a check on the model. Being unnoticed, it has gone unexplained. We employ a Ricardian continuum-of-goods model to explain this fact and find that endogenous tradability allows for theory and history to be consistent under a wide range of underlying productivity shocks. Moreover, this theory could illuminate studies of economic growth both past and present.

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*To repeat, no one scenario can alone explain such a fact. Many different, and mutually exclusive, sufficiency conditions could lead to it. The Penn [Balassa-Samuelson] effect is an important phenomenon of actual history but not an inevitable fact of life. It can quantitatively vary and, in different times and places, trace to quite different process, as we shall see. (Samuelson 1994, 206)<sup>1</sup>*

## **Introduction**

Where does economic growth take root? In which sectors does it most rapidly advance? How does this vary across countries? And how could we identify such tendencies from aggregate data over the very long run?

These are durable and intriguing questions for scholars in several fields. A frenzy of research activity in recent years has brought macroeconomics and economic history together and yielded several new theories of “modern economic growth” or “an industrial revolution.” In various strands of this literature models of both endogenous and exogenous form have adapted to multiple growth regimes, including Malthusian preconditions, and refined the ways in which human capital accumulation can kickstart development.<sup>2</sup> Even attempts to apply these models to *The Industrial Revolution* have followed.

Such advances were welcome because the older, simpler growth models sidestepped some crucial historical puzzles. First, for the fairly typical one-sector model, an explanation of *The Industrial Revolution* is impossible: this would require at least two sectors, one industrial and one not, and some way to connect growth and industrialization. Second, though the applicability of a typical one-country model could be justified as a theory of the entire world’s growth path over two hundred years, such simplifications elide one of the most striking features of our epoch: the so-called Great Divergence, where some countries have participated in modern economic growth and others have not, leaving regional income per capita gaps today of perhaps 20:1 compared to the 2:1 or 3:1 seen in the nineteenth century (Maddison 2001). Third, these first two features are presumptively connected by the mechanisms of trade, and the stylized fact here concerns the evolution of the international economic order whereby rich and poor countries coexist and specialize in producing different goods; obviously, confronted with this last challenge, a one-sector, one-country model has little to say.

In the new generation of models, an increasingly common way to add multiple goods and countries to a long-run growth model is to arbitrarily designate two types of goods, say, “agriculture” (*A*) and “manufacturing” (*M*). By construction, modelers can

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<sup>1</sup> A self-effacing Samuelson (1994) actually refers to the “Penn effect” in the original. This honors the laborious empirical work by the ICP/PWT team to collect the vast quantities of data that supplied the all-important evidence, and also the robustness of the empirical finding as compared to the fragile theoretical underpinnings he exposes. With apologies to the author, we adopt the more common usage here.

<sup>2</sup> This literature is growing rapidly. Notable contributions include Lucas (1988, 2002), Matsuyama (1992), Jones (1999), Galor and Weil (2000), Hansen and Prescott (2002), and Galor and Mountford (2003).

designate, *ex ante*, that the two goods have different properties. The *M* good can simply have faster rates of exogenous technological progress or, for a slightly less transparent mechanism, may exhibit stronger human capital externalities too (the latter is useful if a demographic feedback mechanism is sought or if one wishes to make predictions about education and the industrial revolution). If this type of model economy is opened then divergence effects can be strengthened by factor chasing. If two such economies start off in this position with one slightly ahead, endogenous feedback and/or globalization can drive them even further apart.

Still, the connection between the theorizing and the empirical reality remains tenuous, leading to serious doubts among economic historians. An interesting question is whether such an approach is simply too *post hoc*. It is relatively simple to match the gross features of the data over 200 hundred years. Making the modern good advance quickly and use education (whilst making demography subject to a quantity-quality tradeoff) will almost guarantee a fit at the level of the big picture. Yet a number of recent empirical criticisms of these theories note that, whilst their aggregative predictions ring true by construction, they often miss the mark in their detailed predictions for factor prices, accumulation, trade, and other variables. Voth (2003, 224) observes that “the Industrial Revolution in most growth models shares few similarities with the economic events unfolding in England in the 18th century” and Clark (2002, 4) opines that “[t]hese proliferating theories of the Industrial Revolution operate, however, on a very thin empirical substrate that makes confrontation between most of the theories and their empirical implications impossible.”<sup>3</sup>

Unfortunately, the news may be no more encouraging for the multi-good second-generation models. These models seek to map the Industrial Revolution into a theoretical world where total factor productivity (TFP) surges ahead in *M* goods and lags behind in *A* goods. Here the evidence may be as unfavorable as it is thin, where we focus on the canonical British case. Crafts (1985, 87) noted that even as early as 1840 there was no apparent gap between industrial and agricultural productivity levels. Moreover, according to Crafts and Harley (1993), and in contrast to the seminal work of McCloskey (1981), agricultural TFP growth exceeded that in all manufacturing sectors save for a select few leading sectors—Cotton, Worsteds, Woolens, Irons, Canals and railroads, and Shipping. This created the “paradox” noted by Williamson (1987) and Temin (1997) that, under the Crafts-Harley view of the Industrial Revolution, Britain had a comparative *disadvantage* in most of the manufacturing sector. This debate is hardly settled (Harley and Crafts

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<sup>3</sup> Voth notes that growth-scale linkages seem hard to find except on geological timescales; human capital accumulation via formal education was insignificant during the Industrial Revolution, skill premia appear to have been small; demographic variables exploded in a quite contrary fashion in the medium-run; and models that seek to fit a sharp discontinuity are increasingly divorced from an empirical literature that has been repeatedly revising downwards the estimates of the “trend break” in British economic growth ever since the seminal work of Crafts (1985). As if theory needs further cleaning up, Clark present a much longer laundry list, including many of the above points and adding that: few models can produce a sharp enough discontinuity; there is little evidence of a dramatic shift in institutions and property rights at the time of the industrial revolution; most of the gain from innovation were not captured by the innovators themselves; and there was a wide gap between children born and children surviving to adulthood.

2000; Temin 2000); we return to it in the concluding section of this paper where the link to our own analysis is drawn out. Moving to a much longer historical span, if our interest is “modern economic growth” and not just “the industrial revolution,” the evidence that manufacturing productivity carved out a big lead is also scant. Clark (2002) finds that from 1750 to 1970 TFP in British agriculture rose by a factor of 4.2, and for the economy as a whole by a factor of 4.8, only slightly faster, a difference in growth rates over 220 years of 0.0006 percent per annum. Delicate skills would be needed to build a convincing model of the industrial revolution that hinged on such miniscule sectoral differences in TFP growth.

Whilst such arcane historical debates rage on, one might instead turn to the easily accessible and presumably more robust evidence from the postwar period to justify the manufacturing-agricultural dichotomy in recent models. Here the evidence is not particularly helpful either. Jorgenson and Stiroh (2000) have computed TFP growth rates for a 37-sector disaggregation of the U.S. economy from 1958 to 1996. In their ranking, agriculture falls 4<sup>th</sup> overall (1.17 percent per annum), behind only Textile Mill Products (1.23), Industrial Machinery and Equipment (1.46), and, in first place, Electronic and Electric Equipment (1.98). All four ranked far above the economywide TFP growth rate (0.45 percent)—again offering little a priori support for a model that labels its two sectors *M* and *A*.<sup>4</sup>

These types of regularities are not only confined to today’s developed countries. For example, consider Argentina, one of the saddest example of the divergence today. From 1913 to the 1980s, Argentine real per capita income less than doubled, but in the United States (and in most of the OECD) real incomes tripled (Maddison 2001). Remarkably, the same kind of widening gap was observed in agriculture: “Comparing averages for periods 1913–1930 and 1975–1984, U.S agricultural yields tripled, whereas Argentinean yields did not even double” (Mundlak and Regúnaga 2003).

To sum up, although the extant growth models have built a useful foundation, they have not resolved all of the puzzles, nor are they the only way to understand the processes of growth over the last century or two. The field is still open. To lay down yet another empirical challenge that an ideal growth model needs to address, we expose another puzzle: an important new stylized fact that demands explanation concerning not the division between goods partitioned by characteristics such as “modern” and “traditional” but by their degree of tradability.

Our concerns are twofold in this paper. We aim to develop a new framework that could be useful for thinking about the three key issues—sectoral heterogeneity, cross-country divergence, and trade patterns—and we seek to do so in a way that has a very direct empirical foundation. In doing so we argue for a relatively neglected intellectual connection. We think that the study of economic growth can profitably gain from the study of real exchange rates and vice versa, allowing a synergy between international trade, open economy macroeconomics, and economic history.

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<sup>4</sup> Not every model does this and there could be merit in an agnostic approach—for example, Lucas (1988), whose two-sector model has goods with the innocuous labels “1” and “2.”

## Conventional Wisdom and Stylized Facts

In theories of the real exchange rate built around tradable and nontradable goods the central stylized fact to be “explained” is the effect noted by many scholars over the years, but highlighted by Bela Balassa and Paul Samuelson in their seminal papers from the year 1964: the tendency for poorer countries to have lower overall price levels than rich countries.<sup>5</sup> Today, a typical textbook illustration of this effect usually draws on the Penn World Table (PWT 6) data, and generically resembles Figure 1a, which shows a scatter plot of log relative price levels versus log relative income per capita for a cross section of 142 countries the year 1995. We also performed an OLS regression

$$(1) \quad \ln(P_i/P_{US}) = \alpha + \beta \ln(y_i/y_{US}) + \varepsilon_i.$$

and the fitted values are shown as a straight line in the figure.<sup>6</sup> We follow standard terminology and use the term “Balassa-Samuelson (BS) effect” as shorthand for a positive (and statistically significant) slope estimate  $\beta$ .<sup>7</sup> In our example, the slope is 0.41 with a standard error of 0.04.

The theory that Balassa and Samuelson constructed to explain this phenomenon is also now textbook material, and the simplest version runs as follows.<sup>8</sup> Consider two countries, home and foreign, where foreign variables are denoted with an asterisk (\*). Let there be two goods, traded ( $T$ ) and nontraded ( $N$ ), produced competitively in each country using only homogeneous labor as an input, with wages  $W$  and  $W^*$  in each country. Let the labor productivity in each sector be  $A_T$  and  $A_N$  at home, and  $A^*_T$  and  $A^*_N$  in the foreign country. Trade is costless for the traded goods, so their prices are equalized in the two countries and this pins down the relative wage levels in the two countries, since  $W/A_T = P_T = P^*_T = W^*/A^*_T$ . The wage levels, in turn, pin down the nontraded goods prices with  $W/A_N = P_N$  and  $W^*/A^*_N = P^*_N$ . With an arbitrary choice of numéraire, say  $P^*_T = 1$ , one can easily solve the six equations in the six unknowns for four prices and two wage levels. Now construct a simple price index, say, Cobb-Douglas, where the share of

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<sup>5</sup> In Samuelson’s (1994) paper it is so central as to be labeled the “BASIC FACT” (uppercase in the original). In that paper it is also explained, as we shall see, why “explained” might belong in quotes.

<sup>6</sup> Note that in our diagrams the abscissa is measured in *PPP-adjusted* international dollars and so too is the independent variable in the econometrics that follow. The BS effect could, equivalently, be measured by the slope of a plot of relative prices on the ordinate versus nominal incomes converted at exchange rates on the abscissa (e.g., Balassa 1964, Figure 1). In this case, the slope would be slightly different (lower) and equal to  $\beta/(1+\beta)$ . This nonlinear transformation of the coefficient, naturally, should make no material difference to the analysis, but in small samples, or with noisy PPP estimates, the effect might be to blur a borderline slope, which might explain the conflicting results of Clague and Tanzi (1972) using actual versus PPP exchange rates. Officer (1982, 216) considers PPP-adjusted exchange rates the correct choice.

<sup>7</sup> Occasionally, more verbose terminology is invoked, viz. “(Ricardo-)Harrod-) Balassa-Samuelson effect.” We keep it short, but to clarify genealogy the reader is referred to the brief literature review appearing below.

<sup>8</sup> A two-factor variant with internationally mobile capital is presented by Froot and Rogoff (1995). The results are similar.

nontraded goods in consumption is  $\theta$ . Then the relationship between the price levels of the two countries is given by

$$(2) \quad \frac{P}{P^*} = \frac{P_N^\theta P_T^{1-\theta}}{P_N^{*\theta} P_T^{*1-\theta}} = \left( \frac{P_N}{P_N^*} \right)^\theta = \left( \frac{A_T / A_N}{A_T^* / A_N^*} \right)^\theta.$$

As is well known, neither Balassa nor Samuelson can take full credit for the discovery of this idea, though their expositions unfolded the argument at new levels of clarity and rigor. Officer (1982, 127) traces the lineage through Ricardo, Taussig, Ohlin, Viner, Harrod, and Rothschild. Since, 1964, however, there has been little development of the idea, perhaps owing to the perceived empirical weaknesses to be discussed shortly.<sup>9</sup> A notable exception was Bhagwati (1984), who used a multi-factor setting to show that countries that were “similar” (in terms of factor abundance) might not exhibit the BS effect.<sup>10</sup> This was one of the first papers to suggest why the BS effect might operate at certain times, or in certain samples of countries, but be absent on other occasions.<sup>11</sup>

The relevance of equation (2) for explaining the typical pattern in regression (1) depends on the assumed sources of economic growth. Though rarely tested directly, the conventional auxiliary assumption asserts that differential modern economic growth has been achieved as a result of the rapid productivity advance (in rich countries) of traded goods sectors (think: textiles, manufacturing, hi-tech). In the meantime, the nontraded goods sectors are assumed to have been relatively quiescent, and their productivities to have changed relatively little (the well worn example is the haircut). For notational convenience, let  $A_T = ab$ ,  $A_N = a$ ,  $A_T^* = a^*b^*$ ,  $A_N^* = a^*$ . The  $a$  and  $a^*$  terms capture balanced productivity growth and the  $b$  and  $b^*$  terms capture biased (or BS) growth that only affects traded goods. Equation (2) can then be rewritten

$$(3) \quad \frac{P}{P^*} = \left( \frac{b}{b^*} \right)^\theta.$$

This expression is independent of  $a$  and  $a^*$  because balanced productivity growth, which affects both sectors, does not affect any relative prices. We can also find a simple expression for real national income, which is given by real wage income, hence

$$(4) \quad \frac{W/P}{W^*/P^*} = \left( \frac{A_T P_T}{A_T^* P_T^*} \right) / \left( \frac{P_N}{P_N^*} \right)^\theta = \left( \frac{a}{a^*} \right) \left( \frac{b}{b^*} \right)^{1-\theta}.$$

<sup>9</sup> For a survey of the limited terrain see Asea and Corden (1994).

<sup>10</sup> However, the multi-factor construct comes at a “high price in loss of generality” (Samuelson 1994, 209). Samuelson devised other examples to show the fragility of the result, as noted below.

<sup>11</sup> A recent contribution is Fitzgerald (2003). We discuss this paper below, since some of aspects of her model have parallels with our own approach.

Thus, *assuming* fixed  $a$  and  $a^*$  but varying  $b$  and  $b^*$ , the BS effect is present and the elasticity of the price level with respect to real income would be  $\theta/(1-\theta)$ . This elasticity will be zero when the range of nontraded goods vanishes, but is otherwise positive and can be arbitrarily large when the nontraded share approaches unity.

However, it is also clear from the above that the BS effect is not guaranteed to exist. The BS effect will be zero if the sources of growth are spread across the two sectors evenly, as when  $a/a^*$  changes but  $b/b^*$  does not. And, since  $\theta > 0$ , it is only biased technological change favoring the traded sector that can generate the BS effect, and the expression is increasing in  $b/b^*$ . And there is even the possibility of an anti-BS effect: if technological change were biased toward nontraded goods (here equivalent to a rise in  $b$  and a fall in  $a$  such that  $ab$  remains constant) then the price level could *fall* as a country got richer. It is this rich range of possibilities that invites empirical investigation, as the range of possible results has very different implications for how we should think of the sources of economic growth over the very long run.

### **The Emergence of Divergence**

Returning to the long-run data, it is just as well that such a variety of outcomes can be accommodated. Figure 1b shows that in the 1950 PWT data for 53 countries the BS effect was much weaker, with a slope of only 0.08 and a standard error of 0.07. Table 1, panel (a) confirms that, in a sequence of PWT cross sections every 5 years from 1950 to 1995, the BS effect has gradually strengthened, with the slope estimate roughly quadrupling in size over half a century. In their 1964 contribution, Balassa and Samuelson were certainly very timely, if not quite ahead of their time, since the 1960 cross section supports their hypothesis, but from a statistical standpoint there was not much evidence when they wrote, and the overwhelming support in large samples has accumulated ever since.

Our evidence hints at a new stylized fact: perhaps the BS effect has *not* been a universal feature of modern economic development, and instead has just appeared rather suddenly in the postwar period? Is this conclusion justified, and what could explain it? Were Ricardo, Taussig, and other pioneers concerning themselves more with a theoretical possibility than a proven empirical feature of their bygone eras?

To further explore the question, Table 1(b) examines longer run historical data prior to the postwar PWT sample, and as far back as 1870.<sup>12</sup> The obvious drawback is that such data, whilst longer in span, are narrower in terms of cross section coverage. One set of estimates of regression (1) is based on the real exchange rate data compiled by Taylor (2002) linked to PWT postwar price levels and compared to the real income per capita of Maddison (1995). These results also support the notion that the BS effect has only emerged and strengthened over recent decades. Before 1920 there are no significant slope coefficients at the 5% level and occasional negative slopes. The 1920 and 1930 regressions exhibit the BS effect, but the 1950 regression does not. Again, only after 1960 are the effects consistently positive.

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<sup>12</sup> Historical time-series studies of the BS effect are rare. One of the few is Lothian and Taylor (2003).

Are these longer run results robust? Aside from the small sample size, an obvious source of worry is the use of long-span deflator series. As has been noted in other contexts (De Long 1988), back-projections in Maddison data can introduce serious errors-in-variables problems. Suppose today's data were accurate, but the historical price deflators were flawed (for this example assume that all the nominal output data were correct). Then, by back projection, errors in the price level in the past would be negatively correlated with real output levels in the past, introducing an anti-BS bias into regression (1) on historical cross sections. The problem would get more severe as the errors accumulated in (backwards) time, and the illusion of a BS effect disappearing in the past would be created.

We can envisage three responses to this concern. One is that even in the postwar PWT data where data quality is thought to be better and the time separation of any cross section from a benchmark is small before 1970—and where several benchmarks exist after 1970—the strengthening of the BS effect is still confirmed. A second response is to go back and use true benchmark data in the distant past to avoid back-projection pitfalls. Unfortunately, the construction of historical PPP benchmarks is in its infancy and only a limited set of countries have been studied. Ward and Devereux (2003) construct true PPP benchmarks for 12 countries at 5 dates from 1872 to 1950, and correct the Maddison real income estimates accordingly. They find, puzzlingly, that the dispersion of price levels in this group of converging economies did not change much over the last 100+ years; but Table 1(b) shows that, despite this, the correlation of price levels with per capita output levels *did* strengthen markedly over time in this sample. Thus, the finding of a generally weak BS effect prior to 1950 is unchanged whether one uses these benchmark data (B) or the Maddison constructs (M). Apparently, by this reckoning, the much-maligned Maddison method does not impart excessive bias to the long-span deflators.<sup>13</sup> A third possible response to the errors in variables critique would be to admit that such problems could be present but are not yet verifiable. The existing Ward-Devereux benchmark data are a welcome contribution and an important advance, but we need data for a much larger number of countries. Resolving this conundrum might be a goal of future research by macroeconomic historians.

Feeling somewhat reassured by the close alignment of the Ward-Devereux and Maddison estimates we searched for a largish historical cross section, and we finally refer the reader to the row marked 1913 where we compare Maddison's real GDP figures with nominal income figures from standard sources, to arrive at a set of  $N=24$  countries with Maddison (implicit) price levels and real income per capita data. For this cross section also the BS effect is found to be statistically insignificant and even of the wrong sign. Figure 1c displays the raw data and the result is clear to the naked eye.

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<sup>13</sup> Another important set of historical GDP estimates has been constructed but it is unsuitable for use in this paper. Prados de la Escosura (2000) corrects the Maddison data by assuming a uniform BS effect over time, back projecting the postwar relationship to provide a set of alternative deflators in the late nineteenth and early twentieth century. If employed here, such estimates would impart circularity in our argument, since they assume that the BS effect has remained consistent over time.

Can these long-run data be trusted? Economic historians are still locked in debate about the precise way to extend real income estimates backwards from the PWT data to the nineteenth century, and Maddison's figures, though ubiquitous, are by no means unchallenged. Prados (2000) offers a revised version of the Maddison figures using more refined country-level data spliced to the ICP project's postwar database. Table 1(c) presents slope estimates based on these data for benchmarks as far back as 1820. The same general result holds here, with the BS effect strengthening markedly in the postwar data. Although the point estimates are much more unstable over time, it is rare before 1950 to see a significant positive BS effect.

Whilst the 19<sup>th</sup> century data might be fuzzy enough for most people, we next attempt, perhaps rashly, to test for the Balassa-Samuelson effect in data stretching back from 1850 as far as 1500. Broadberry and Gupta (2003) have assembled a database for various European cities, India, and China for this period, comprising silver wages, grain wages, and (for Europe only) cross-country consumption price levels (based on the work of Robert Allen and others). Since real income per capita data do not exist for this period, we regress their CPI level on the real wage level for 14 European cities over seven nonoverlapping 50-year periods from 1500–49 to 1800–49. Table 1(d) shows that in this period there was little evidence of a BS effect, and that in most periods the slope estimate was of the wrong sign, albeit with some hint of a pro-BS trend over time. Again, we view this as *prima facie* evidence that the textbook BS effect that we take for granted today has not necessarily been a “universal constant” of history. This is, we propose, a significant and original finding.

We have examined the data in other ways to check the robustness of our finding. Panel estimation is feasible given that two of our data sets contain annual data: PWT after 1950 and Taylor/PWT/Maddison since 1870. Running a cross section regression on these data in every year produced the slope estimates (and 95% confidence intervals) shown in Figures 2a and 2c. (Figure 2b shows that the PWT result is not an artifact of changing sample size, since the effect is just as large when we restrict attention to a balanced panel of 53 countries from 1950 to 1998). Thus, even outside the benchmark dates in Table 1, our basic story is reinforced. The PWT data show an almost monotonic upward trend in the slope estimate, and the long span data show that this up trend is essentially a postwar phenomenon.

Table 2 reports the results of panel estimation by decade on these datasets. We think some care is need once we leave the realm of pure cross-section empirics. For one thing, identifying the BS effect from a time series correlation could be misleading, since high-frequency business-cycle correlations of the real exchange rate with output fluctuations (arising from quite different mechanisms) might cloud the picture. Panel estimation allows us to keep the cross-section features of the data intact, but only with the right choice of technique. Since the presence of the BS effect after 1950 is generally accepted, and since we wish to argue for the more novel finding that the BS effect was absent previously, it is important to adopt a panel econometric specification that does not bias against finding a BS effect. Since the BS hypothesis is, fundamentally, a statement about cross-sections, and since we have what purport to be price level data (not just

indices), we are in a position to study absolute, not relative PPP dynamics. Hence, we chose to omit country effects (fixed or random) in the intercept, since that would be tantamount to restricting the model to time-series identification. If we failed to find a BS effect in that setting, a skeptic could fairly claim that the fixed effects were absorbing all of the interesting parts of the BS story. Hence we estimate (1) using panel data, a common intercept, and with corrections for an error term with a common AR(1) term in all countries. The estimate of the AR(1) parameter  $\rho$  can then be read as a half-life of deviations from equilibrium real exchange rates. The estimation also allows for an error with contemporaneous cross-sectional correlation across countries (O'Connell 1997).

Table 2 shows that the results are essentially the same in a dynamic panel setting. In Panel (a) the PWT data exhibit a steadily increasing slope that increase by a factor of 3 from 0.12 in the 1950s to 0.32 in the 1990s. Panel (b) shows that for the long span data, the BS effect is weak before 1920, of mixed import from 1920 to 1960, and strong from 1960 to the present.

If indeed the BS effect has strengthened markedly in the last 50 years, this would reconcile the mixed findings in a wider literature that has from time to time examined the BS effect and its theoretical underpinnings in postwar data. Older studies that focused on the 1950s and 1960s tended to find weak evidence, such as Officer (1982).<sup>14</sup> More recent studies have sometimes found stronger results, but, according to a recent survey, “[o]verall, the empirical evidence on the Harrod-Balassa-Samuelson effect is quite mixed” (Sarno and Taylor 2002, 82).<sup>15</sup> Even so, puzzles remain. In many macro studies, as well as in some micro studies, when a statistically significant slope coefficient has been found, it is not at all clear that it coincides with the model parameters according to BS logic. For example, in a study of 24 developed and developing countries in 1979, the price of a haircut was found to vary systematically with per capita income and by a factor of about 5 to 1 from poor to rich; but per capita incomes varied by a factor of about 25 to 1; with stagnant TFP in haircuts, the BS logic would imply that incomes (wages) and nontraded prices should move equiproportionately.<sup>16</sup> Many such deviations from the simple theory have arisen.

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<sup>14</sup> Our slope coefficients can be directly compared with those of Officer (1982, Chapter 16, especially Table 2). He examined the OECD economies in successive annual cross-sections from 1950 to 1973 and found no BS effect in (1). The slope was often close to zero in the 1950s and 1960s, though rising to around 0.25 circa 1970. Our results are in broad agreement: we find that most of the BS action has arrived in the years since Officer's analysis ended, although even in the 1960s, a small effect *was* there, but was only detectable in a large sample that included more low income countries. Thus, Officer's weak results might be explained by a small sample problem ( $N=15$  at most). Alternatively, the focus on countries at very similar levels of development might rob the regression of variance or introduce countervailing theoretical effects (Bhagwati 1984; Fitzgerald 2003).

<sup>15</sup> See, *inter alia*, Hsieh (1982); Marston (1990); Micossi and Milesi-Ferreti (1994); De Gregorio, Giovannini, and Wolf (1994); De Gregorio and Wolf (1994); Chinn and Johnston (1996); Ito, Isard, and Symansky (1999); Chinn (2000). The newer studies and their estimates are not directly comparable to ours, since they address some of the internal workings of the BS hypothesis, e.g., using manufacturing and/or services employment to attempt to pin down the underlying sectoral productivity shocks.

<sup>16</sup> Clements and Semudram (1983), based on data on the price of a shampoo and set in various cities, and drawn from a travel brochure for women published by the airline QANTAS. This is akin to today's famous Big Mac index, though the nontraded content of a haircut may be rather higher than that of a burger.

### **Theory versus History: Disconnect?**

The data seem to be sending a strong and consistent message. The BS effect has not always been a fact of economic life, and appears to be a phenomenon of only the postwar period. This new stylized fact raises many interesting questions: Which models can most plausibly explain such an historical pattern in the data? And what do the theory and the empirics tell us about the mechanics of economic development?

The simple model can, of course, be rigged to produce the actual historical changes seen by assuming suitable changes in exogenous variables. The question is whether such forces seem historically plausible. And because the simple model is so simple, it is also easy to question. For example, it yields a linear mapping from technologies to price levels so there is no nonlinear part of the model to complicate the predictions (this will not be true of the new model we introduce next). There are just two ways for the BS result to emerge over time. Either the biasedness of productivity growth would have to increase (more growth via  $b$  than via  $a$ ); or else the nontraded share  $\theta$  would have to rise over time to steepen the slope for a given  $b$ . Doubts arise because neither of these mappings of theory into history seems entirely clean.

Consider the biasedness of technological change toward traded goods. Is this any stronger in the recent postwar period than, say, in the 19<sup>th</sup> century or early 20<sup>th</sup> century? Earlier we cast some doubt on the distinction between agriculture and manufactures as the key division in the past, but the same historical statistics cannot necessarily support a weaker trade bias before 1950. Most historians seem to unanimously agree that all of the goods touched by the first Industrial Revolution were tradable—they just cannot agree on which ones. The new school stresses cotton textiles, iron, and a few other goods (Crafts 1985); the traditional school lists a broader range of goods, such as typical British products like umbrellas and beer (Temin 1997, 75).<sup>17</sup> The existing debate between the new and old schools centers on the quantity paradox mentioned earlier, but both schools are beset by a seeming price paradox: if TFP surged ahead in British tradables (and later in other countries that industrialized to differing degrees) it ought to have imparted a huge BS effect, but nothing of the sort is visible in the data circa 1870–1913.

Alternatively, if it is felt that the story might fit better in the recent postwar era when the BS effect has surfaced in the data, the rise of the service sector in modern, rich economies also militates against the BS logic. To the extent that modern deindustrialization in countries like the U.S. is supply and not demand driven (e.g., by changes in organization or information technology for nontraded services in rich countries, or by the transfer of traded-industrial good technologies to poor countries) the BS effect is weakened. And, to the extent that many such services are now becoming tradable, the model has even more problems in its basic assumptions.

One might also appeal to changes in the nontraded share  $\theta$ , but as a narrative tool this also appears blunt. Over the very long run, the only proxy we really have for  $\theta$  is the

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<sup>17</sup> Temin (1997, 67) notes out that in the Harley (1993) CGE model, the “other manufactures” were nontraded by assumption.

ratio of trade to GDP, both at the national and global level.<sup>18</sup> These data exhibit an increasing trend in the late nineteenth century, a collapse from roughly 1914 to 1945, and a recovery in the postwar period to even higher levels by the 1990s.<sup>19</sup> On the one hand, the well-known shift to autarky in the 1920s and 1930s does line up with a marked strengthening of the BS relationship in those decades (see Table 1). And perhaps the rise in trade shares from 1870 to 1914 weakened the BS effect in that epoch too. But from 1945 to the 1990s the conventional wisdom views the world as having become more integrated over time in goods markets. This would imply a fall in  $\theta$  in the simple model and a weakening of the BS effect, which is not what has happened at all, at first glance.

One possible way in which  $\theta$  has increased in recent decades, however, would be in the increased range of intermediate stages of wholesaling, retail, and distribution. It is now appreciated that these activities do comprise a large share of today's economy and have important effects on real exchange rates (Obstfeld 2001; Burstein, Neves, and Rebelo 2002). Our model does not incorporate these activities, nor does it incorporate intermediate stages of production that have increased some as a share of value added (GDP) but even more as a share of output and trade in a "fragmenting" world economy of vertical specialization (Feenstra 1998; Yi 2003). These forces may have expanded markedly over the last fifty to one hundred years to raise the nontraded share of total economic activity. Working in the converse direction, it is also striking that the "tradedness" so measured varies a great deal between different sectors of the economy, remaining on a fairly flat trend as a ratio to GDP as a whole, but increasing as a ratio to merchandise value added (Irwin 1996; Feenstra 1998). Getting a tighter grip on these issues remains a target for future research.

Although the simple model could be tinkered with further, we think the lack of harmony between the simple model and the empirical record should be viewed as grounds for further theoretical investigation.

### **A More General Model**

One unfortunate restriction of the simple model set out above is that there are only two goods. This means that the possible rankings of goods according to tradability and productivity are very limited. Either the traded good is more or less productive than the nontraded good; no other configuration is possible. This is a gross simplification of reality in two respects. First, many types of traded and nontraded goods exist; their productivity levels could advance at different rates and these rates need not be congruent with the degree of tradability. Second, goods are either traded or nontraded by assumption in the model but not in reality. As Meade (1951, 232; quoted by Obstfeld 2001) noted, "products range with almost continuous variation between those for which

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<sup>18</sup> True, this is not really the right concept—in the model the share of goods traded is not the same as the share of output traded—but it appears to be the only game in town. Thus, the trade share of GDP is commonly used as a control variable in other settings with a traded-nontraded dichotomy (see, for example, Hau 2002).

<sup>19</sup> See, for example, Findlay and O'Rourke (2003) and Estevadeordal, Frantz and Taylor (2003, Figure 1).

the cost of transport is negligibly low in relation to their value and those for which the costs of transport are so high as to be in all imaginable circumstances prohibitive.”

In principle, then, if a country became relatively *very* successful (productive) at producing a nontraded good, it might be able to overcome transport costs barriers and export the good to foreign markets. We therefore introduce a more flexible and realistic theory. The model takes a standard Ricardian model with a continuum of goods (Dornbusch, Fischer, and Samuelson 1977), allows for transport costs and endogenous tradability in Bergin and Glick (2003), and develops it to explore the implications of evolving sectoral productivity distributions.<sup>20</sup>

In the model there are two countries, home and foreign (the latter denoted \*), and each country’s output consists of a distinct continuum of differentiated goods (labels  $H$  and  $F$  will be used here).<sup>21</sup> Each country’s goods are indexed on the unit interval and are produced by monopolistically competitive firms using labor as the sole input in a linear (constant returns to scale) technology. In principle, any good can be exported but there are fixed costs of exporting  $f_x$  for any good, which are borne by the exporting firm.<sup>22</sup> Traded goods are labeled  $T$  and nontraded  $N$ . Agents preferences are standard CES and apply to home goods and importables. Key assumptions are that each country specializes in a range of goods that are unique to that country (albeit goods from different countries are substitutes) and that the continuum of goods are exogenously given.

Related problems are studied in a paper by Fitzgerald (2003) but her model differs in several ways. Our shipping technology has fixed (and possibly variable) costs, but hers is iceberg only. Instead, her fixed costs appear in production, leading to intra-industry trade and endogenous specialization through a scale-related mechanism *à la* Krugman. Her empirical sights are therefore trained, appropriately, on a restricted sample of developed countries including, especially, the EU.

Full details of the model are laid out in Appendix 1, but the essential building blocks are as follows. Home and foreign agents consume CES aggregates of their own domestic goods and the other country’s traded (export) goods. Let  $n$  and  $n^*$  denote the (endogenous) share of nontraded goods in each country, where goods are ordered such that  $[0, n]$  and  $[0, n^*]$  are the nontraded goods. Then the top-level aggregations are

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<sup>20</sup> In this application the focus is on relative productivities with application to the Balassa-Samuelson effect. For tractability only the simplest transport cost structure will be explored. The reader is referred to Bergin and Glick (2004) where the theory is further developed for a variety of transport cost and productivity scenarios.

<sup>21</sup> Note that by assuming different goods in each country, the LOOP basis of PPP is essentially discarded. This model can generalize simply to an  $N$ -country world with a distinct range of goods in each country. A different approach to the Ricardian model is to allow a common set of goods to be potentially produced in all countries, and then have only the lowest-cost supplier actually export the good to each market, as in the probabilistic model of Eaton and Kortum (2002). An interesting avenue for future research would be to explore the implications of endogenous tradability and the Balassa-Samuelson effect in that type of setting.

<sup>22</sup> Bergin and Glick (2003, 2004) consider variable (iceberg) trade costs also. The general intuition developed in this paper would generalize to this case, although the computational difficulty would, in general, be greater (for reasons to be explained later). To facilitate intuition, we study the fixed cost case where the greater range of closed form solutions obtain. It suffices to note that the model studied here does include the case of uniform iceberg costs on all traded goods. Problems arise when the iceberg cost varies by good, as noted below.

$$(5) \quad \begin{aligned} C &= \left( \theta^{1/\gamma} (C_H)^{(\gamma-1)/\gamma} + (1-\theta)^{1/\gamma} (C_{FT})^{(\gamma-1)/\gamma} \right)^{\gamma/(1-\gamma)} \\ C^* &= \left( \theta^{1/\gamma} (C_F^*)^{(\gamma-1)/\gamma} + (1-\theta)^{1/\gamma} (C_{HT}^*)^{(\gamma-1)/\gamma} \right)^{\gamma/(1-\gamma)} \end{aligned}$$

where  $\gamma > 1$  is the elasticity of substitution between home and foreign goods and  $\theta > 0$  is (now) a home-bias parameter. The indices for domestically produced goods, and their subindices, are in turn defined by

$$(6) \quad \begin{aligned} (C_H)^{(\phi-1)/\phi} &= \int_0^n (c_{Hi})^{(\phi-1)/\phi} di + \int_n^1 (c_{Hi})^{(\phi-1)/\phi} di \\ &= n \left( \frac{C_{HN}}{n} \right)^{(\phi-1)/\phi} + (1-n) \left( \frac{C_{HT}}{1-n} \right)^{(\phi-1)/\phi} \\ (C_F^*)^{(\phi-1)/\phi} &= \int_0^{n^*} (c_{Fi}^*)^{(\phi-1)/\phi} di + \int_{n^*}^1 (c_{Fi}^*)^{(\phi-1)/\phi} di \\ &= n^* \left( \frac{C_{FN}^*}{n^*} \right)^{(\phi-1)/\phi} + (1-n^*) \left( \frac{C_{FT}^*}{1-n^*} \right)^{(\phi-1)/\phi} \end{aligned}$$

At home, the *HN* goods occupy  $[0, n]$  and *HT* goods  $[n, 1]$ ; on a separate foreign interval, the *FN* goods occupy  $[0, n^*]$  and *FT* goods  $[n^*, 1]$ . Using duality, and noting symmetry, it is equivalent to proceed using the corresponding price indices for all of the above aggregates:  $P, P^*, P_{HN}, P_{HT}, P_{HT}^*, P_{FN}^*, P_{FT}^*, P_{FT}$ .

The production side is simple. Each home firm employs  $l_{Hi}$  workers and pays them the wage  $W$ , and similarly for the foreign firms. On each interval, the output of good  $i$  is given by

$$(7) \quad \begin{aligned} y_{Hi} &= A_i l_{Hi} \\ y_{Fi} &= A_i^* l_{Fi} \end{aligned}$$

Profit maximization by the monopolists leads to the standard cost-markup pricing. In the presence of iceberg shipping costs, pricing would differ across markets; but this is not crucial for intuition and is omitted in the simple case considered here:

$$(8) \quad \begin{aligned} p_{Hi} &= p_{Hi}^* = \frac{\phi}{\phi-1} \frac{W}{A_i} \\ p_{Fi} &= p_{Fi}^* = \frac{\phi}{\phi-1} \frac{W}{A_i^*} \end{aligned}$$

The crux of the model is the distribution of productivities across goods in each country. Without loss of generality, assume that the goods are ordered from least to most productive in each country, so that  $A_i$  and  $A_i^*$  are monotonically increasing in  $i$ . For tractability we consider a particular functional form,

$$(9) \quad \begin{aligned} A_i &= \alpha(1 + \lambda i)^\beta \\ A_i^* &= \alpha^*(1 + \lambda^* i)^{\beta^*} \end{aligned}$$

The  $\alpha, \alpha^* > 0$  parameters represent a balanced technological change spread over all goods. The most “backward” good at  $i=0$  is normalized so that its productivity is just  $\alpha$  (respectively  $\alpha^*$ ). The  $\lambda, \lambda^* > 0$  parameters control the rate at which productivity rises with  $i$ , and the  $\beta, \beta^* > 0$  parameters control the degree of convexity in the distribution.<sup>23</sup>

The model solves conditionally as follows. Given  $n$  and  $n^*$ , consider the set of 22 endogenous variables, consisting of  $C, C_H, C_{HN}, C_{HT}, C_{FT}, P, P_H, P_{HN}, P_{HT}, P_{FT}$ , and  $W$ , plus the foreign counterpart variables (denoted  $*$ ). Production markups link prices to wages. Standard CES demand conditions link prices to consumption quantities and, thence, via technology, to derived labor demand. Market clearing (plus balanced trade) and a numéraire choice complete the solution. It is possible to derive an equilibrium for trade, given  $n$  and  $n^*$ , as shown in the Appendix.<sup>24</sup> But what determines these nontraded shares? On the margin, the producers of the borderline traded-nontraded good must be indifferent between home and foreign sales, and, given the fixed costs of shipping, this entails two simple extra conditions that pin down  $n$  and  $n^*$  in equilibrium:

$$(10) \quad \begin{aligned} \left( p_{Hn}^* - \frac{W}{A_n} \right) c_{Hn}^* &= f_x \\ \left( p_{Fn} - \frac{W^*}{A_n^*} \right) c_{Hn} &= f_x \end{aligned}$$

Consider the first of these equations. The left hand side shows the profit per unit of home good sold in the foreign market multiplied by sales volume; the right hand side is the fixed cost of exporting. For the borderline good  $n$  the two sides are equal, and profits from export are zero. The same is true in the foreign country. Taking sales as given, the profit term (like the  $A$  term) is increasing in  $n$ , so all goods on the interval to the left of  $n$  are nontraded and all to the right are traded, confirming the maintained assumption. In

<sup>23</sup> Bergin and Glick (2004) show that the extension to good-specific iceberg shipping costs introduces similar terms to these in the markup calculation, but that the derivation of equilibrium is analogous once export goods’ productivities are adjusted for the iceberg loss.

<sup>24</sup> For nondegenerate solutions, the  $A_i$  and  $A_i^*$  cannot be uniform, given (in this case) uniformly zero iceberg costs. Our monotonicity assumptions rule out this case.

this framework, endogenous tradability arises naturally, because only goods with high enough productivity are able to surmount the transport cost barrier.<sup>25</sup>

It should also be clear how this framework allows for a more generalized approach to the Balassa-Samuelson hypothesis and its relationship to the long-run growth. Depending on the sources of growth, the shape of the  $A_i$  and  $A^*_i$  distributions could change. This, in turn, will affect the relative wages of the two countries and the range of goods traded. Based on earlier intuition from the simple model, we might expect uniform productivity growth from changes in  $\alpha$  not to generate BS effects, but tilting the distribution (through changes in  $\lambda$ ) or altering its convexity (changes in  $\beta$ ) could well generate BS effects.<sup>26</sup>

The relevant simulations are shown in Figure 3, and they suggest that such intuition is almost, but not entirely, correct. The simulations refer to two economies with initially identical parameter values. On the horizontal axis we calculate the log of relative home and foreign GDP according to the true price index of produced goods. On the vertical axis we show the real exchange rate, that is, the relative overall price levels in the two countries. In these diagrams, a positive slope indicates a BS effect: higher price levels in the higher income country. This result need not always obtain.

Figure 3(a) shows what happens when uniform productivity change (a rise in  $\alpha$ ) is applied to the home economy (holding fixed  $\lambda$  and  $\beta$ ). Unlike the simple model, this framework yields an *anti*-Balassa-Samuelson effect under balanced growth. The slope is quantitatively small, implying an elasticity of the relative price level with respect to relative real income of approximately  $-0.075$ . The intuition for this result is familiar in the New Open Economy Macroeconomic literature. As productivity advances across the board there is no comparative advantage conferred on tradables, but the home monopolists face a declining terms of trade for their products on the foreign market. As a result the real exchange rate depreciates and this result is independent of the markup parameter  $\phi$ . This logic is by no means ahistorical. Harley (1982; 1983) has shown that during the 19<sup>th</sup> century much of the British productivity advance was transferred to the rest of the world by sharp terms-of-trade effects. Indeed, even the classical economists were aware of this possibility, as we know from the arguments of Ricardo and Torrens on the gains from free trade in a large-country setting (Irwin 1988; Williamson 1990). Since the historical evidence suggests weak BS effects in the nineteenth century this could be consistent with a growth process that delivered relatively even gains throughout the economy, though, as we shall see below, interpretation is not necessarily straightforward.

Figure 3(b) shows that the outcome is as expected once we allow most of the productivity gains to accrue in a narrow range of goods. Here we vary  $\lambda > 0$  along the

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<sup>25</sup> This insight has been more extensively developed in the trade and policy literature and is not well known in the macroeconomics literature. See for example, Richardson and Rindal (1996) and Bernard and Jensen (1999). For a related equilibrium analysis, see especially Helpman, Melitz, and Yeaple (2002).

<sup>26</sup> The potential of the basic Ricardian model for detailed, sectoral, long-run economic growth diagnostics was emphasized by Temin (1997), who applied it to the British Industrial Revolution. Temin focused on quantities rather than prices. He did find evidence in the British export pattern to support the idea of relatively balanced technological progress across a wide range of industries in the nineteenth century.

paths, holding fixed  $\alpha$  for various choices of  $\beta$ , where  $\beta^*$  is chosen to have a low value of 0.01 (so that the poor country has a fixed and almost flat productivity distribution). We can see that strong BS effects are observed initially in this framework, and over a wide range for particularly high values of  $\beta$  (i.e., for more convex distributions). However, at a certain point, even in these simulations the BS effect can be attenuated or even reversed, especially for low values of  $\beta$ . (On the horizontal axis, a value of 1 corresponds to a rich-poor income ratio of  $e^1 \approx 2.7$ ).

Accordingly, in this framework we might view the simulations in Figure 3(c) as offering perhaps the most likely explanation of the emergence of the BS effect in late twentieth century data. In these exercises  $\alpha$  is fixed, and  $\beta$  varies along the paths for different values of  $\lambda$ . These slopes are higher than those in Figure 3(b). They are also closer to the empirical values seen in the recent past. And they never suffer a reversal: the BS effect continues as the Great Divergence opens up, albeit in a more muted fashion for high income ratios.

One advantage of this model is that in these results the increasing convexity of the productivity distribution of good (captured by  $\beta$ ) may help explain the BS effect, and not just the relative advance of traded goods (captured by  $\lambda$ ). This finding also explains why our more general model could be useful, since the simple two good model, resembling the two endpoints of the distribution, is unable to capture this notion of convexity. We also observe that the increasing convexity of technology implies some “self-similarity” properties: over any stretch of the interval, however, small, the curvature of the distribution is supposedly increasing over time. Just as the productivity of good 0.5 advances more slowly than the average of good 0 and good 1, so too does good 0.25 advance more slowly than the average of good 0 and good 0.5, and so on. At all scales, technological advance is concentrating at the higher end of the distribution. This might not be a bad analogy for late 20<sup>th</sup> century growth processes, especially as we think of the phenomenal advances in certain traded goods (e.g., microprocessors improving according to Moore’s law) versus the less spectacular gains in more mundane goods.

Another advantage of this model is that it creates a rich set of possibilities for BS effects of varying size and even of different sign configurations, and this may better describe history over the very long run for the reasons already adduced. To consider this we move to a three dimensional display. Figure 4, for illustration, looks at the variation in the BS effect (the increase in the relative home price level) for various combinations of  $\alpha$  and  $\beta$  (the two dimensional page precludes consideration of  $\lambda$ ). Contours show iso-real-exchange-rate levels in the  $(\alpha, \beta)$  plane. In this figure, if technological change is sufficiently concentrated in a small range of goods (increases in  $\beta$  dominate) then BS effects will appear, which we suggest may be a description of the 20<sup>th</sup> century experience (see the arrow labeled “20”). Conversely, if technological change is sufficiently diffused over a range of goods (increases in  $\alpha$  dominate) then the BS effect will be muted or even reversed, and perhaps this was the *modus operandi* of technological change in the 19<sup>th</sup> century (see the arrow “19”). Note that the implications would have been more restricted under the standard BS model: the entire quadrant would have been a zone of positive BS effects relative to the origin (iso-real-exchange-rate contours would have been lines

parallel to the  $\alpha$ -axis), and it would have been more awkward to explain an absence of BS effects in the data except under perfectly balanced growth.

Let us remember the key mechanism for this result that is missing in the simple model: in our model, expanded output can have deleterious terms of trade effects, and if these dominate the BS effect is overpowered. This ought to be a well-known story, and our version of it may be seen as a continuum extension of the “Ricardo-Mill Exact 2-Good Model” explored by Samuelson (1994, 206–07 and especially Appendix A6). There Samuelson is careful to document the fragility of the theoretical explanations of the “Penn” [BS] effect and shows that even the original Ricardian logic fails to always generate the desired result (and can leave relative incomes unchanged) except under certain (not even the most obvious) circumstances. As in our model, his two countries specialize in distinct goods—England in cloth and nontraded (English) bricks, Portugal in wine and nontraded (Portugeuse) bricks. Factors such as the degree of substitutability in consumption (like our  $\phi$  and  $\gamma$ ) and the size of the productivity shock (i.e., a nonlinear relationship) are all shown to matter in Samuelson’s penetrating exposition. Our model shows these features, and a range of novel possibilities with a continuum of differentiated goods, transport costs, and endogenous tradability. For example, Samuelson shows an example of immiserizing English growth where the country ends up poorer, but the Penn effect still obtains (bricks end up dearer in Portugal). Our model adds even “anti-Penn effects” when the bias toward “tradables” is weak. Samuelson’s concerns as expressed in our epigram seem stronger than ever. In the theoretical realm the BS story now looks even more fragile, but on an empirical plane it is ripe with more opportunity.

Having praised the new model and its usefulness, let us now recognize some of its limitations as a description of the long-run growth process. One possible flaw is that it assumes that the measure of goods produced is an invariant interval, so that  $n$  is trapped between 0 and 1 at all times. In reality, one aspect of economic growth over many centuries has been the vast expansion of the number of goods in existence. This quibble applies with equal (or greater) force to one- and two-sector growth models, of course (they maintain a set of goods equal to one or two; we maintain an uncountably infinite set of fixed measure), and it would be an interesting exercise to explore the model with love-of-variety preferences and an (endogenous or exogenous) expanding range of goods.

Another major disadvantage of this model is its presumption that the ordering of the goods remains constant over time. As an empirical matter it seems dubious to imagine the highest productivity goods of today (like good 1) were also the highest a century ago, and the other goods were also ranked the same then as now. This is, in a manner of speaking, an analog of the simple BS model, where the identification of goods as high or low productivity (and traded or nontraded) is made a priori, and then remains fixed over time. It is also analogous to the restrictions imposed in growth models where goods are labeled as traditional and modern, or agriculture and manufactures. In fact, we have reason to believe that goods may have bounced up and down the productivity (and tradability) rankings over time. Some goods are heavily traded today that were not traded a century ago. At one time the U.S. enjoyed massive comparative advantage in certain

goods, but not any more; and increasingly the U.S. produces—and exports—formerly nontraded goods and (especially) services.

### An Example of Reordering of the Trade Pattern

This section provides a simple stylized example of how the type of re-ordering described in the previous section may take place. It shows how Balassa Samuelson effects may develop endogenously over time, as the trade pattern in an economy adjusts in response to new technological opportunities. In particular, it shows how a steady growth in technology may at first lead to a negative effect on the real exchange rate and then later to a positive effect, indicating that explaining such an observation in the data does not require assuming a particular and coincidental exogenous change in the nature of shocks, but instead simply may reflect an endogenous and natural evolution in the structure of the economy.

Such re-orderings are likely to take place whenever there are multiple sources of heterogeneity among goods, working jointly to determine their tradability. Consider here two sources of heterogeneity in production technology. First is the continuous distribution discussed in the previous model. Combine this with an additional source of technology that affects only half of the goods. Suppose that the trade pattern initially is determined by heterogeneity in the first type, but that the second type of technology grows in size over time and eventually dominates in first in size. Eventually the new technology will determine which goods are profitable to trade. To begin with, this new technology will be hitting traded and nontraded goods alike, so the pre-condition for Balassa-Samuelson will not be met, and the BS effect will be negative. But as the new technology transforms all of its goods into traded goods, the precondition of Balassa-Samuelson will be met, and the BS effect will endogenously become positive.

To be concrete, divide home goods into two identical groups, labeling one group S (for smart) and the other D (for dumb). Do the same for foreign goods. Equation (5) then may be augmented as follows:

$$(11) \quad C = \left( \theta^{1/\gamma} (C_H)^{(\gamma-1)/\gamma} + (1-\theta)^{1/\gamma} (C_{FT})^{(\gamma-1)/\gamma} \right)^{\gamma/(1-\gamma)}$$

where

$$C_H = \left( \frac{1}{2}^{1/\phi} (C_{HS})^{(\phi-1)/\phi} + \frac{1}{2}^{1/\phi} (C_{HD})^{(\phi-1)/\phi} \right)^{\phi/(1-\phi)}$$

and

$$C_{FT} = \left( \frac{1}{2}^{1/\phi} (C_{FTS})^{(\phi-1)/\phi} + \frac{1}{2}^{1/\phi} (C_{FTD})^{(\phi-1)/\phi} \right)^{\phi/(1-\phi)}$$

Equations (6) – (10) then can be duplicated for each of the two groups, with each variable having an S and D counterpart. For example, there will a share of S goods that are nontraded,  $n_S$ , and a share of D goods that are nontraded,  $n_D$ .<sup>27</sup>

To facilitate a tidy experiment, augment the definition of the technology for the S group as follows:

$$(12) \quad A_{Si} = \alpha(\psi_S + \lambda i)^\beta$$

Under the calibration of  $\alpha = \beta = \lambda = 1$ , the additional term  $\lambda_S$  allows for a shock affecting all varieties in the group by a constant level amount, which is an upward level shift in the technology for all varieties in group S.

Consider the following experiment. Begin by setting  $\alpha = \beta = \lambda = \psi_S = 1$ , so that  $A_i$  ranges from a level 1 for the least productive variety to 2 for the most productive variety. Groups S and D are identical in this initial distribution, so they will have the same share of nontraded goods  $n_S = n_D$ . But then  $\psi_S$  begins to rise above unity, representing the growth in the new technology. Looking at equation (12), it is clear that once  $\psi_S$  rises above 2, the least productive S good has become more productive than the most productive D good, and the new technology fully dominates the old in the ranking of goods. See Figure 4(a)

The change in relative productivity ranking has implications for the trade pattern. As S goods become more productive, more of them will find it profitable to pay the fixed cost and be traded abroad. This will also imply that a smaller share of D goods will be traded. Combining equilibrium conditions, it can be shown that the share of nontraded goods of the two groups are inversely related as follows:

$$(13) \quad (\psi_S + n_S) = 1 + n_D$$

In particular, it turns out for this particularly simple example that when the new technology reaches  $\psi_S = 2$ , then  $n_S = 0$  and  $n_D = 1$ . This means that the new-technology S goods have become the traded goods, and the old-technology D goods have become the nontraded goods in this economy.

This evolution in the trade pattern has implications for real exchange rates. Observe the relative price level for a shock in  $\psi_S$  from 1 to 3 in Figure 4(b). There is a negative Balassa-Samuelson effect initially, which eventually gives way to a positive Balassa-Samuelson effect.

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<sup>27</sup> A full listing of equations, analogous to appendix 1, is available from the authors.

Balassa-Samuelson requires as a precondition that technology improvements be focused on traded goods to the exclusion of nontraded. This precondition is not met here a-priori, given the initial trade pattern in which the goods experiencing the new technology are equally nontraded as goods not experiencing the new technology ( $n_s = n_d = 0.44$ ). So the rise in technology hits traded and nontraded varieties alike, and the real exchange rate falls. As more and more of the S goods become traded, the shock eventually is sufficiently concentrated on traded goods so that the relative price level begins to rise. Eventually the Balassa-Samuelson effect becomes positive.

While this simple example is useful in illustrating that the Balassa-Samuelson effect may develop endogenously, even if the pre-conditions do not exist a-priori, the example given here is not as powerful quantitatively as it is qualitatively. Note that the size of the price changes on the vertical axis is two orders of magnitude smaller than the changes in output. Yet the data suggest that the price changes eventually become an order of magnitude larger than this.

### **Theory versus History: Reconnect?**

This paper has investigated the empirical basis of, and theoretical rationale for, the venerable Balassa-Samuelson effect over the very long run. Two big surprises appear in the data. First, the absence of the BS effect in the distant past; second, the marked strengthening of this effect in the last fifty years. Given the paucity of historical data, the former claim is more conjectural, yet the two findings are quite of a piece, and the latter observation alone requires new thinking, with implications for international economists, macroeconomists, and economic historians. Our model supplies a set of tools for thinking about these results. Our simulations must be interpreted carefully, since they involve a *ceteris paribus* scenario where one country remains technologically quiescent, but the other experiences a variety of TFP advances in different sectors. It turns out that as the home country's *relative* TFP distribution advances uniformly, anti-BS effects are seen, but as the distribution gets relatively more skewed or "convex" strong BS effects kick in.

International economists will find here a new theoretical way to think about endogenous tradability and an example of how to apply the idea in practice to a central problem that is complementary to several new directions in the literature (Betts and Kehoe 2003; Fitzgerald 2003). On the empirical side, we have revealed a new stylized fact about the emergence of divergence in price levels that shorter span studies have not previously uncovered. As to why and how this effect operates, we offer just one explanation. Others may surface, but one general implication is that future studies of long-run PPP may need to allow not only for a BS effect, but a time-varying one at that. Also, though we did not dwell on them, our estimates of the parameter  $\rho$  in Table 2 tell an interesting story: half-lives  $H$  can be found to be much smaller than the "old consensus" of five years (Rogoff 1995). An allowance for long-run trends may change the picture (Taylor 2002). Here the trend has been explicitly identified with the BS effect, and it is clear why this would tend to reinforce findings of fast PPP convergence: in studies that omit such trends, the real exchange rate deviation is being calculated from a constant mean, and not the "true" equilibrium level, so it is bound to look more volatile

than it really is, and recent research has confirmed this intuition (Zussman 2001; Papell 2003). In Table 2, half-lives of 3–4 years are apparent in the 1980s and 1990s. In the longer run data, covering mostly developed countries, half-lives of around 2 years seem to be the norm after 1980, though they were often twice as high before that. Future research may find it possible to whittle half-lives down even further if the true BS-adjusted equilibrium real exchange rate can be better estimated.

Macroeconomists interested in long-run growth will also find some fresh ideas here. First, whilst labeling sectors “manufacturing” and “agriculture” is tempting as a way to develop intuition in a toy model, it is a poor fit with reality. Second, if the field is to move beyond one-sector, one-country models, prices as well as quantities must become central to our work. Then, using evidence on both together, we stand a better chance of deducing the mechanisms of growth in different eras. For example, in the recent data researchers find convincing evidence that the Great Divergence stems in large part from changes in TFP levels (Hall and Jones 1999). TFP has surged in rich countries but very little trickles down to poorer countries, and hardly any new innovative activity takes place outside the rich world (Sachs 2001). For our simulations, this may make our assumption of *ceteris paribus* in the foreign (poor) country a reasonable gross approximation for the postwar experience in rich and poor economies.

What form has innovation taken in rich countries? At the sectoral level, decades of research by Jorgenson and associates shows that TFP has been far from uniform across industries, and the latest figures for the postwar period show a marked clustering of high growth rates in a small subset of sectors (which includes agriculture), as indicated in Table 3 and Figure 6. As these growth rates compounded over several decades the implication is clear for the limiting distribution of TFP levels: a convex distribution will appear, with forceful BS effects as a corollary according to our model. Moreover, there is no clear correlation in this list between the ex ante traded goods and high productivity, another blow to BS logic. In the early 20<sup>th</sup> century the US exported in petroleum, lumber, and motor vehicles, but these come in low on the list. Hi-tech goods exported today, like equipment and instruments appear at the bottom of the list. This is, we think, *prima facie* evidence for our argument that tradability can arise (or disappear) endogenously and, with it, the BS effect.

Lastly, in this paper we think economic historians will find additional reasons, if needed, to continue their disputes over the Industrial Revolution. At a basic empirical level our finding an absence of the BS effect in historical data could provoke further investigation. Being based on a smallish sample, further data collection could be fruitful to tell us whether this result holds up for countries with greater income disparities. Since several nineteenth century authors are credited with having perceived the BS effect in their own time, it might yet be too soon to answer the question “Were Ricardo and Taussig and right?” in the negative. Still, our model admits a new possibility. As noted, Samuelson (1994) devised an example where all of England’s TFP gains in textiles end up in the hands of foreigners via terms of trade effects. No real income changes, no BS effect. Regarding the terms of trade effects, Harley (1982, 1993) and Clark (2003) argue that this is precisely what happened: most of the efficiency gains of the cotton textile

revolution were exported to the rest of the world and Figure 7 shows the force of this effect. Looking at the U.K. time series alone (which was, presumably, Ricardo's perspective at the time) it was true that "home commodities" were getting relatively more expensive compared to manufactures. But this is a time-series, not a cross-section statement, and thus Ricardo was not exactly making the same claim as the BS effect. Still, even the most extreme pessimists think Britain really did get relatively richer in this period, albeit the divergence was slow. Could all this happen without a BS effect but still with biased TFP growth in traded textiles and an increasing (diverging) British income per capita? We have delivered a Ricardian model that says, for the first time: yes.

To which the response might be: And? Yet it is on the minor details of such stylized models that some of the most heated debates over the Industrial Revolution have arisen. As has been hinted at already, any discussion of the sectoral distribution of productivity gains in nineteenth century Britain can provoke combat. T. S. Ashton summed up the Industrial Revolution as a "wave of gadgets" and ever since "traditionalists" like Landes, McCloskey, and Temin have taken this to mean a broad productivity advance across many sectors. This view has been shot down by "revisionists" such as Harley, Crafts, and Clark whose downward revisions of economywide TFP have squeezed the TFP in the residual "other manufacturing" category down to zero. As Patrick O'Brien has noted, new quantity evidence is unlikely to settle the matter since the sectoral data simply do not exist, which seems to leave the "old-hat" and "new-fangled" historians in a state of permanent trench warfare (Temin 1997, 67). Temin sensibly appealed to new data to provide a check on other implications of theory, but this hardly led to an armistice. Far be it from us to hope for a ceasefire among such protagonists, but our model could, nonetheless, offer some way out of the no man's land (or maybe just another *casus belli*).

As is clear, the simple BS model always generates a BS effect. But the simple Ricardian continuum of goods model (Temin's choice) never generates a BS effect, since there are no nontraded goods. But we claim to have found no BS effect in the data. In round one, this appears to be good news for the traditional school but a more realistic model would have to admit some nontraded goods and more than three goods overall (*pace* Samuelson's numerical examples). A potential problem then, in our model, is that if the Industrial Revolution is *too* broad, then one gets a strong anti-BS effect; if it is too concentrated, a strong pro-BS effect. Neither is observed. Thus, judged by the BS yardstick, round two might be scored as a tie for both the "old hat" view and Crafts-Harley views. Common ground may be in sight.

Unfortunately, given the aforementioned lack of quantity data, we will never be able to construct something like Figure 8 for the British Industrial Revolution, neither in style nor in accuracy. Most importantly, the data that do exist apply to few sectors, and treat almost half of the economy as a residual. The best efforts to date appear in Table 4

and Figure 8. Over these data the battle is fought. The traditional view is represented by McCloskey's distribution, the new view by Crafts and Harley.<sup>28</sup>

Are these distributions impressively flat? No. Are they strikingly uneven? Hard to say: McCloskey (1981) thought this a "glass half full" sort of question.<sup>29</sup> But we might be interested in a different question: are these distributions uneven enough to generate a strongly convex distribution when integrated over time and, hence, a strong BS effect? This is also not at all clear, judging by what our model requires, and the ambiguity suggests the need for a careful calibration exercise that could be a target for future research. The distribution may appear more uneven than the Jorgenson-Stiroh postwar data but this kind of inference is very woolly because: (a) shares of GDP do not correspond to shares of goods in the model, as noted; (b) Jorgenson-type TFP residuals make much more careful corrections for the value and quality of capital services and no such sophisticated TFP calculations have been performed for the British case 1780–1860;<sup>30</sup> (c) the data are subject to large error bounds (especially the residual sector); (d) the size of each sector is so large that only an approximation to the true distribution can be achieved.

Despite these occupational hazards, we can recall the equivalence classes mentioned earlier as a basis for negotiation between the two views of the Industrial Revolution. Remember that in our solution the equilibrium depends only on the two productivity masses  $M_1$  and  $M_2$  and the productivity level of the marginal nontraded good  $n$ . Clearly, this leaves a lot of room for changes in productivity levels and rankings which could preserve such an equilibrium, and yet still allow some range of traded goods to surge ahead whilst others lagged. This would cause the list of products exported to show high persistence over time, yet terms-of-trade effects might also prevent the leading manufactures from crowding out the other manufactures. This could tally with the correlations at various benchmark dates given by Temin (1997), placating the old school. At the same time a more convex technology distribution could still arise, as is deemed necessary by the new school.

Of course there are other possible explanations afoot. Perhaps the British productivity distribution became very convex indeed, but at the same time technology innovation in (or diffusion to) other countries was fast enough (relative to the rate of innovation) to keep the gaps between the British and overseas distributions small. Recall,

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<sup>28</sup> Clark (2003) presents an alternative distribution, with slightly different sectors, but with implications very similar to the Crafts-Harley view.

<sup>29</sup> Crafts' "not pervasively innovative" description of the economy can be read two ways. Textiles could be seen as a weird exception, as if events Lancashire were really happening on some separate planet, and shouldn't affect our view of a fairly slow and flat progress elsewhere. Or, maybe the textile numbers really are a force for convexity, turning the distribution strongly up at the end. Our naïve parameterization (*b*) can't capture these distinctions very well, but see the discussion of equivalence classes below.

<sup>30</sup> Indeed this is the reason why TFP looks much lower in the postwar U.S. Data than in Britain circa 1800. This is not an error in our charts, but a result of noncommensurate concepts. Much more of total growth has been absorbed into a more refined measure of input growth.

this was not the era of the *Greatest* Divergence, and history is replete with tales of industrial espionage and the like.<sup>31</sup>

However, we hesitate to speculate further on the many ways in which our model could help explain very long-run macroeconomic history. It may seem, already, that we have succumbed to the vices of which Samuelson (1994, 205) warned:

Much of what Ricardo, Harrod, Balassa, or Samuelson say boils down to *repetition* of the brute fact of the Penn effect. Some of what is said, however, consists of specifying *sufficient* scenarios to create a Penn effect, along with explicit or implicit contention that these sufficient conditions have themselves been correct brute facts about economic history and geography....My own researches, published and unpublished, re-emphasize that sufficient conditions need not be necessary...Interesting conditions that are both necessary and sufficient, alas, are too unspecific to be much more than reiterated descriptions. As I shall show, sufficient scenarios abound that can entail anti-Penn effects. The Penn effect is important, but it is not an inevitable truth of economic history. True effects can deviate from stipulated approximations in different directions and in degree that various exogenously and endogenously from case to case and epoch to epoch. (Samuelson 1994, 205)

Indeed. Theory has its limits. Key debates about the past and present are usually resolved only with great empirical brute force, not just with pen and paper. If our claims are correct, explaining the rise of the Penn effect will be no different.

Suitably chastened we offer our analysis not to extend the universe of theoretical possibilities for its own sake, but rather, we hope, to point to profitable directions in which theory and empirics can better serve each other in untangling puzzles both historical and contemporary.

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<sup>31</sup> Temin (1997, 70) claims that the Industrial Revolution did not spread to Europe in the first half of the nineteenth century and that one can treat the foreign Ricardian technology as static for these purposes. The empirical validity of these assumptions could be a useful avenue for future research, though if the difficulty of measuring the British productivity distribution is any guide, this will be a Sisyphean task.

## Appendix. Two-Country Model with Single Differentiated Good in Each Country

Consider a model of two countries, home and foreign, in which each country completely specializes in production of a distinct differentiated good. In each country there is a separate continuum of firms each producing a different variety of the local differentiated good, denoted by H and F, respectively. All goods produced in each country have the potential to be exported, but some endogenously determined fraction will be nontraded in equilibrium. Quantities and prevailing prices for the H or F goods consumed in the foreign country are denoted by  $*$ .

$C$ ,  $C^*$  is the level of aggregate consumption by domestic and foreign agents, respectively, defined as a CES aggregate of consumption of each country's own goods ( $C_H$ ,  $C_F^*$ ) and imports of the other country's traded (export) goods ( $C_{FT}$ ,  $C_{HT}^*$ ):

$$C = \left( \theta^\gamma (C_H)^\frac{\gamma-1}{\gamma} + (1-\theta)^\gamma (C_{FT})^\frac{\gamma-1}{\gamma} \right)^\frac{\gamma}{\gamma-1} \quad (A1)$$

$$C^* = \left( \theta^\gamma (C_F^*)^\frac{\gamma-1}{\gamma} + (1-\theta)^\gamma (C_{HT}^*)^\frac{\gamma-1}{\gamma} \right)^\frac{\gamma}{\gamma-1} \quad (A1^*)$$

where  $\gamma$  is the elasticity of substitution between domestic and foreign goods and  $\theta$  is an own-goods bias coefficient.

The continuum of goods produced in each country is indexed by  $i$  on the interval  $[0,1]$ .<sup>1</sup> Let  $n$  and  $n^*$  denote the (endogenous) share of these in each country that are nontraded, where goods are ordered such that  $[0,n]$  and  $[0,n^*]$  are nontraded and  $[n,1]$  and  $[n^*,1]$  are traded.

Accordingly, consumption of each country's own-good ( $C_H$ ,  $C_F^*$ ) is defined as a CES consumption index of nontraded ( $C_{HN}$ ,  $C_{FN}^*$ ) and traded own goods ( $C_{HT}$ ,  $C_{FT}^*$ ):

$$\begin{aligned} (C_H)^\frac{\phi-1}{\phi} &= \int_0^n (c_{Hi})^\frac{\phi-1}{\phi} + \int_n^1 (c_{Hi})^\frac{\phi-1}{\phi} di \\ &= n \left( \frac{C_{HN}}{n} \right)^\frac{\phi-1}{\phi} + (1-n) \left( \frac{C_{HT}}{1-n} \right)^\frac{\phi-1}{\phi} \end{aligned} \quad (A2)$$

$$C_{HN} \equiv \left[ \left( \frac{1}{n} \right)^\frac{1}{\phi} \int_0^n (c_{Hi})^\frac{\phi-1}{\phi} di \right]^\frac{\phi}{\phi-1} \quad (A3)$$

$$C_{HT} \equiv \left[ \left( \frac{1}{1-n} \right)^\frac{1}{\phi} \int_n^1 (c_{Hi})^\frac{\phi-1}{\phi} di \right]^\frac{\phi}{\phi-1} \quad (A4)$$

<sup>1</sup> Note that, although each country produces a distinct set of goods, in our notation we use the same index  $i$  to order goods along each continuum.

$$\begin{aligned}
(C_F^*)^{\frac{\phi-1}{\phi}} &= \int_0^n (c_{Fi}^*)^{\frac{\phi-1}{\phi}} + \int_n^1 (c_{Fi}^*)^{\frac{\phi-1}{\phi}} di \\
&= (n^*) \left( \frac{C_{FN}^*}{n^*} \right)^{\frac{\phi-1}{\phi}} + (1-n^*) \left( \frac{C_{FT}^*}{1-n^*} \right)^{\frac{\phi-1}{\phi}}
\end{aligned} \tag{A2*}$$

$$C_{FN}^* \equiv \left[ \left( \frac{1}{n^*} \right)^{\frac{1}{\phi}} \int_0^{n^*} (c_{Fi}^*)^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} \tag{A3*}$$

$$C_{FT}^* \equiv \left[ \left( \frac{1}{1-n^*} \right)^{\frac{1}{\phi}} \int_{n^*}^1 (c_{Fi}^*)^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} \tag{A4*}$$

where lower cases are used to denote consumption of individual varieties  $i$  of each differentiated good and  $\phi$  is the elasticity of substitution between varieties.<sup>2</sup> Note that the this elasticity of substitution is assumed constant across countries.

Analogously, the consumption indices of the foreign good imported by domestic agents  $C_{FT}$  and the home good imported by foreign agents  $C_{HT}^*$  are defined as

$$C_{FT} \equiv \left[ \left( \frac{1}{1-n^*} \right)^{\frac{1}{\phi}} \int_{n^*}^1 (c_{Fi})^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} \tag{A5}$$

$$C_{HT}^* \equiv \left[ \left( \frac{1}{1-n} \right)^{\frac{1}{\phi}} \int_n^1 (c_{Hi}^*)^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} \tag{A5*}$$

Price indexes are defined as usual for each category of goods, in correspondence to the consumption indexes above:

$$P \equiv \left( \theta (P_H)^{1-\gamma} + (1-\theta) (P_{FT})^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \tag{A6}$$

$$\begin{aligned}
P_H^{1-\phi} &= \int_0^n (p_{Hi})^{1-\phi} di + \int_n^1 (p_{Hi})^{1-\phi} di \\
&= n (P_{HN})^{1-\phi} + (1-n) (P_{HT})^{1-\phi}
\end{aligned} \tag{A7}$$

$$P_{HN} \equiv \left( \left( \frac{1}{n} \right) \int_0^n p_{Hi}^{1-\phi} di \right)^{\frac{1}{1-\phi}} \tag{A8}$$

$$P_{HT} \equiv \left( \left( \frac{1}{1-n} \right) \int_n^1 p_{Hi}^{1-\phi} di \right)^{\frac{1}{1-\phi}} \tag{A9}$$

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<sup>2</sup> That is,  $c_{Hi} / c_{Hj} = (p_{Hi} / p_{Hj})^{-\phi}$ ,  $c_{Fi}^* / c_{Fj}^* = (p_{Fi}^* / p_{Fj}^*)^{-\phi}$  for any two goods  $i$  and  $j$ .

$$P_{FT} \equiv \left( \left( \frac{1}{1-n^*} \right) \int_{n^*}^1 P_{Fi}^{1-\phi} di \right)^{\frac{1}{1-\phi}} \quad (\text{A10})$$

where  $P$  is the aggregate price level,  $P_H$  is the price index of all home goods,  $P_{HN}$  is the price index of nontraded home goods,  $P_{HT}$  is the price index of traded home goods, and  $P_{FT}$  is the price (to domestic agents) of imported foreign goods.

Correspondingly,

$$P^* \equiv \left( \theta (P_F^*)^{1-\gamma} + (1-\theta) (P_{HT}^*)^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \quad (\text{A6}^*)$$

$$\begin{aligned} (P_F^*)^{1-\phi} &= \int_0^{n^*} (P_{Fj}^*)^{1-\phi} dj + \int_{n^*}^1 (P_{Fj}^*)^{1-\phi} dj \\ &= (n^*) (P_{FN}^*)^{1-\phi} + (1-n^*) (P_{FT}^*)^{1-\phi} \end{aligned} \quad (\text{A7}^*)$$

$$P_{FN}^* \equiv \left[ \left( \frac{1}{n^*} \right) \int_0^{n^*} (P_{Fi}^*)^{1-\phi} di \right]^{\frac{1}{1-\phi}} \quad (\text{A8}^*)$$

$$P_{FT}^* \equiv \left[ \left( \frac{1}{1-n^*} \right) \int_{n^*}^1 (P_{Fi}^*)^{1-\phi} di \right]^{\frac{1}{1-\phi}} \quad (\text{A9}^*)$$

$$P_{HT}^* \equiv \left[ \left( \frac{1}{1-n} \right) \int_n^1 (P_{Hi}^*)^{1-\phi} di \right]^{\frac{1}{1-\phi}} \quad (\text{A10}^*)$$

Note that the consumption and price indices imply the following relative demand functions for domestic agents:<sup>3</sup>

$$C_H / C = \theta (P_H / P)^{-\gamma}, \quad C_{FT} / C = (1-\theta) (P_{FT} / P)^{-\gamma} \quad (\text{A11})$$

$$C_{HN} / C_H = n (P_{HN} / P_H)^{-\phi}, \quad C_{HT} / C_H = (1-n) (P_{HT} / P_H)^{-\phi} \quad (\text{A12})$$

and for foreign agents:

$$C_F^* / C^* = \theta (P_F^* / P^*)^{-\gamma}, \quad C_{HT}^* / C^* = (1-\theta) (P_{HT}^* / P^*)^{-\gamma} \quad (\text{A11}^*)$$

$$C_{FN}^* / C_F^* = (n^*) (P_{FN}^* / P_F^*)^{-\phi}, \quad C_{FT}^* / C_F^* = (1-n^*) (P_{FT}^* / P_F^*)^{-\phi} \quad (\text{A12}^*)$$

The production sector in each country consists of constant-returns-to-scale technologies for the output of each differentiated good:

$$y_{Hi} = A_i l_{Hi} \quad (\text{A13})$$

$$y_{Fi} = A_i^* l_{Fi} \quad (\text{A13}^*)$$

<sup>3</sup> Also note that the CES specification implies for individual goods variety  $i$

$$c_{Hi} / C_H = (p_{Hi} / P_H)^{-\phi}, \quad c_{Hi} / C_{HT} = (1-n)^{-1} (p_{Hi} / P_{HT})^{-\phi} \text{ and}$$

$$c_{Fi}^* / C_F^* = (p_{Fi}^* / P_F^*)^{-\phi}, \quad c_{Fi}^* / C_{FT}^* = (1-n^*)^{-1} (p_{Fi}^* / P_{FT}^*)^{-\phi}.$$

where  $y_{Hi}$ ,  $y_{Fi}$  represent the level of output,  $l_{Hi}$ ,  $l_{Fi}$  denote workers employed in production, and  $A_i$ ,  $A_i^*$  are productivity coefficients for each individual good  $i$ . We employ the usual assumption that labor is mobile across sectors within each economy, but immobile across countries.

Profit maximization under monopolistic competition implies pricing is determined by the standard cost markup rule:

$$p_{Hi} = p_{Hi}^* = \frac{\phi}{\phi - 1} \frac{W}{A_i} \quad (\text{A14})$$

$$p_{Fi} = p_{Fi}^* = \frac{\phi}{\phi - 1} \frac{W^*}{A_i^*}, \quad (\text{A14}^*)$$

where  $W$ ,  $W^*$  denote the home and foreign wage rates, respectively. Note that, in the absence of transport costs, sales prices are equalized across markets for each good  $i$ .<sup>4</sup>

The productivity coefficients are assumed to be monotonically increasing in  $i$ , as specified by the following functional form:

$$A_i = \alpha(1 + \lambda i)^\beta, \quad \alpha, \lambda, \beta > 0 \quad (\text{A15})$$

$$A_i^* = \alpha^*(1 + \lambda^* i)^\beta, \quad \alpha^*, \lambda^*, \beta^* > 0 \quad (\text{A15}^*)$$

The parameter  $\alpha$  controls the level of the distribution, while  $\beta$  and  $\lambda$  control the rate at which productivity increases with  $i$ . An increase in  $\alpha$  represents a balanced productivity improvement that affects all goods equally. An increase in  $\lambda$  biases productivity increases towards goods with higher  $i$  indices. Higher  $\beta$  increases the rate at which productivity rises for a given percent change in the index.

Given the cutoff between nontraded and traded goods at index  $n$ , it is straightforward to compute the price index for nontraded home goods by using (A14) and (A15) to substitute for  $p_{Hi}$  in (A8):

$$\begin{aligned} P_{HN} &= \left( \left( \frac{1}{n} \right) \left[ \int_0^n \left( \frac{\phi}{\phi - 1} \frac{W}{A_i} \right)^{1-\phi} di \right] \right)^{\frac{1}{1-\phi}} \\ &= \frac{\phi}{\phi - 1} \left( \frac{W}{\alpha} \right) \left( \frac{(1 + \lambda n)^\omega - 1}{\lambda \omega n} \right)^{\frac{1}{1-\phi}} \end{aligned} \quad (\text{A16})$$

Analogously substituting into (A9) gives the price index of traded home goods:

$$\begin{aligned} P_{HT} = P_{HT}^* &= \left( \left( \frac{1}{1-n} \right) \left[ \int_n^1 \left( \frac{\phi}{\phi - 1} \frac{W}{A_i} \right)^{1-\phi} di \right] \right)^{\frac{1}{1-\phi}} \\ &= \left( \frac{\phi}{\phi - 1} \right) \frac{W}{\alpha} \left[ \frac{(1 + \lambda)^\omega - (1 + \lambda n)^\omega}{\lambda \omega (1-n)} \right]^{\frac{1}{1-\phi}} \end{aligned} \quad (\text{A17})$$

<sup>4</sup> The introduction of good-specific iceberg costs trade costs creates a gap between the domestic and foreign sales price:  $p_{Hi}^* = p_{Hi} / (1 - \tau_i)$ , where  $\tau_i$  denotes the fraction of good  $i$  that disappears in transport.

where  $\omega \equiv 1 - \beta(1 - \phi) > 0$  since  $\beta \geq 0$  and  $\phi > 1$ .<sup>5</sup> Equations (A16) and (A17) express the prices of nontraded and traded goods as functions of the share of nontraded goods  $n$ , the elasticity of substitution across domestic goods  $\phi$ , the wage rate  $W$ , and the productivity parameters,  $\alpha$ ,  $\beta$ , and  $\lambda$ . It is straightforward to observe that these prices are increasing in the wage rate and decreasing in the balanced productivity parameter  $\alpha$ . Keep in mind that  $n$  is itself an endogenous variable that will be solved as part of the general equilibrium system.

The foreign counterparts are

$$P_{FT}^* = P_{FT} = \frac{\phi}{\phi - 1} \left( \frac{W^*}{\alpha^*} \right) \left[ \frac{(1 + \lambda^*)^{\omega^*} - (1 + \lambda^* n^*)^{\omega^*}}{\lambda^* \omega^* (1 - n^*)} \right]^{\frac{1}{1 - \phi}} \quad (\text{A16}^*)$$

$$P_{FN}^* = \frac{\phi}{\phi - 1} \left( \frac{W^*}{\alpha^*} \right) \left[ \frac{(1 + \lambda^* n^*)^{\omega^*} - 1}{\lambda^* \omega^* n^*} \right]^{\frac{1}{1 - \phi}} \quad (\text{A17}^*)$$

where  $\omega^* \equiv 1 - \beta^*(1 - \phi) > 0$ .<sup>6</sup>

To help pin down the equilibrium share of nontraded goods, note that at the margin the producers of the borderline nontraded--nontraded good must be indifferent between home and foreign sales. That is, the additional (real) profits from exporting the  $n$ th home good must equal the (real) fixed cost of exporting  $f_X$ :

$$\left( P_{Hn}^* - \frac{W}{A_n} \right) \left( \frac{1}{P} \right) c_{Hn}^* = f_X \quad (\text{A18})$$

where the additional profits are defined as the export price minus marginal cost, times the volume of sales to foreign agents. Note that real profits are expressed in terms of the price of the domestic consumption basket  $P$ . Since the condition  $c_{Hi}^* / C_{HT}^* = (1 - n)^{-1} (p_{Hi}^* / P_{HT}^*)^{-\phi}$  holds for all goods  $i$  in the range  $[n, 1]$ , it can be used to substitute for  $c_{Hn}^*$

$$\left( P_{Hn}^* - \frac{W}{A_n} \right) \left( \frac{1}{P} \right) \left( \frac{1}{1 - n} \right) \left( \frac{P_{Hn}^*}{P_{HT}^*} \right)^{-\phi} C_{HT}^* = f_X$$

<sup>5</sup> The equalization of domestic and foreign sales price of each individual variety of traded goods in the absence of trade costs obviously implies price equalization should hold at the aggregate level as well.

<sup>6</sup> Note that using (A16) and (A17) to substitute for  $P_{HN}$ ,  $P_{HT}$ , respectively, in (A7) implies

$$P_H = \frac{\phi}{\phi - 1} \left( \frac{W}{\alpha} \right) \left[ \frac{(1 + \lambda)^{\omega} - 1}{\lambda \omega} \right]^{\frac{1}{1 - \phi}}. \text{ Analogously, (A16}^*), \text{(A17}^*), \text{ and (A7}^*) \text{ give}$$

$$P_F^* = \frac{\phi}{\phi - 1} \left( \frac{W^*}{\alpha^*} \right) \left[ \frac{(1 + \lambda^*)^{\omega^*} - 1}{\lambda^* \omega^*} \right]^{\frac{1}{1 - \phi}}.$$

Substituting for  $p_{Hn}^*$  with (A14) and (A15) as well as multiplying and dividing by  $P_{HT}^*$  gives

$$\left(\frac{1}{\phi}\right)\left(\frac{\phi}{\phi-1}\right)^{1-\phi}\left(\frac{W}{\alpha}\right)^{1-\phi}\left(\frac{(1+\lambda n)^{\beta(\phi-1)}}{1-n}\right)\left(\frac{P_{HT}^* C_{HT}^*}{P(P_{HT}^*)^{1-\phi}}\right) = f_X$$

Lastly, substitute with (A17) for  $P_{HT}^*$  in the denominator of the last term in brackets on the lefthand side to obtain

$$\left(\frac{1}{\phi}\right)\frac{\omega(1+\lambda n)^{\omega-1}}{\left((1+\lambda)^\omega - (1+\lambda n)^\omega\right)}\left(\frac{P_{HT}^* C_{HT}^*}{P}\right) = f_X \quad (\text{A19})$$

where (recall)  $\omega \equiv 1 - \beta(1 - \phi) > 0$ .<sup>7</sup> Observe that for given aggregate export sales  $P_{HT}^* C_{HT}^*$ , marginal export profits rise with  $n$  as productivity rises and marginal costs fall.<sup>8</sup> Analogously, the counterpart expression for the exports of the F good exported to the domestic country is

$$\left(\frac{1}{\phi}\right)\frac{\omega^*(1+\lambda^* n^*)^{\omega^*-1}}{\left((1+\lambda^*)^{\omega^*} - (1+\lambda^* n^*)^{\omega^*}\right)}\frac{P_{FT} C_{FT}}{P^*} = f_X^* \quad (\text{A19}^*)$$

Labor market equilibrium in the domestic country implies:

$$\int_0^n l_{Hi} di + \int_n^1 l_{Hi} di = L_H, \quad (\text{A20})$$

where  $L_H$  is the exogenously given domestic labor supply. Substituting for  $l_{Hi}$  with the production function (A13):

$$\int_0^n \frac{y_{Hi}}{A_i} di + \int_n^1 \frac{y_{Hi}}{A_i} di = L_H$$

$$\int_0^n \frac{c_{Hi}}{A_i} di + \int_n^1 \frac{c_{Hi} + c_{Hi}^*}{A_i} di = L_H$$

since (in the absence of transport costs)

$$y_{Hi} = c_{Hi}, \quad i \in [0, n]$$

$$y_{Hi} = c_{Hi} + c_{Hi}^* \quad i \in [n, 1]$$

Substituting with  $c_{Hi}/C_H = (p_{Hi}/P_H)^{-\phi}$  and  $c_{Hi}^*/C_{HT}^* = (1-n)^{-1}(p_{Hi}^*/P_{HT}^*)^{-\phi}$  gives

$$\int_0^n \frac{C_H}{A_i} \left(\frac{p_{Hi}}{P_H}\right)^{-\phi} di + \int_n^1 \left(\frac{1}{A_i}\right) \left( C_H \left(\frac{p_{Hi}}{P_H}\right)^{-\phi} + \left(\frac{1}{1-n}\right) C_{HT}^* \left(\frac{p_{Hi}^*}{P_{HT}^*}\right)^{-\phi} \right) di = L_H$$

<sup>7</sup> Note the relative price term  $P_{HT}^*/P$  in (A19) can be decomposed into the terms of trade, foreign relative prices, and the real exchange rate, i.e.  $P_{HT}^*/P = (P_{HT}^*/P_{FT}) (P_{FT}/P^*) (P^*/P)$

<sup>8</sup> Note, after controlling for export sales  $P_{HT}^* C_{HT}^*/P$ , that neither  $\alpha$  nor wages  $W$  enter directly into (A19) since they do not *differentially* affect the production of individual home goods.

Using (A14) and (A15) to substitute for  $p_{Hi}$ ,  $p_{Hi}^*$  and evaluating gives the following expression for the domestic wage as a function of domestic and foreign demand for the home good as well as the nontraded goods share and the productivity parameters:

$$W = (L_H)^{-1/\phi} \left( \frac{\phi}{\phi-1} \right)^{-\phi} \alpha^{\phi-1} \left\{ \left( \frac{P_H C_H}{(P_H)^{1-\phi}} \right) \left( \frac{(1+\lambda)^\omega - 1}{\lambda \omega} \right) + \left( \frac{P_{HT}^* C_{HT}^*}{(P_{HT}^*)^{1-\phi}} \right) \left( \frac{(1+\lambda)^\omega - (1+\lambda n)^\omega}{\lambda \omega (1-n)} \right) \right\}^{\frac{1}{\phi}} \quad (\text{A21})$$

Correspondingly,

$$W^* = (L_F)^{-1/\phi} \left( \frac{\phi}{\phi-1} \right)^{-\phi} (\alpha^*)^{\phi-1} \left\{ \left( \frac{P_F^* C_F^*}{(P_F^*)^{1-\phi}} \right) \left( \frac{(1+\lambda^*)^{\omega^*} - 1}{\lambda^* \omega^*} \right) + \left( \frac{P_{FT}^* C_{FT}^*}{(P_{FT}^*)^{1-\phi}} \right) \left( \frac{(1+\lambda^*)^{\omega^*} - (1+\lambda^* n^*)^{\omega^*}}{\lambda^* \omega^* (1-n^*)} \right) \right\}^{\frac{1}{\phi}} \quad (\text{A21}^*)$$

We close the model with the balanced trade condition that the value of exports equals the value of imports

$$P_{HT}^* C_{HT}^* = P_{FT} C_{FT} \quad (\text{A22})$$

and the normalization condition<sup>9</sup>

$$P^* = 1 \quad (\text{A23})$$

Equilibrium determines the 24 variables  $C$ ,  $C_H$ ,  $C_{HN}$ ,  $C_{HT}$ ,  $C_{FT}$ ,  $P$ ,  $P_H$ ,  $P_{HN}$ ,  $P_{HT}$ ,  $P_{FT}$ ,  $W$ , and  $n$  and their foreign counterparts (denoted by  $*$ ) by solving the system of 24 equations (A1)-(A7), (A16)-(A17), (A19), and (A21) plus their foreign counterparts, together with (A22) and (A23).

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<sup>9</sup> An alternative normalization is  $P^* = 1$ .

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**Table 1**  
**The Balassa-Samuelson Effect in History**

Estimates from an OLS regression of the log relative price level on log relative real income per capita

Year(s)	Price source	GDP source	N	Coefficient
(a) Postwar Sample 1950–2000				
1950	PWT	PWT	53	0.08 (0.07)
1955	PWT	PWT	69	0.11 (0.07)
1960	PWT	PWT	108	0.19 (0.05) ***
1965	PWT	PWT	109	0.20 (0.05) ***
1970	PWT	PWT	111	0.20 (0.05) ***
1975	PWT	PWT	112	0.20 (0.05) ***
1980	PWT	PWT	118	0.20 (0.05) ***
1985	PWT	PWT	118	0.27 (0.04) ***
1990	PWT	PWT	128	0.36 (0.04) ***
1995	PWT	PWT	142	0.41 (0.04) ***
(b) Historical Sample 1870–1990				
1870	Taylor/PWT	Maddison	7	0.58 (0.39)
1872	Ward-Devereux (B)	Ward-Devereux (B)	12	0.00 (0.13)
1872	Ward-Devereux (M)	Ward-Devereux (M)	12	0.13 (0.22)
1880	Taylor/PWT	Maddison	6	0.00 (0.19)
1884	Ward-Devereux (B)	Ward-Devereux (B)	12	0.13 (0.14)
1884	Ward-Devereux (M)	Ward-Devereux (M)	12	0.02 (0.23)
1890	Taylor/PWT	Maddison	19	0.32 (0.17) *
1900	Taylor/PWT	Maddison	20	0.27 (0.16)
1905	Ward-Devereux (B)	Ward-Devereux (B)	12	-0.07 (0.13)
1905	Ward-Devereux (M)	Ward-Devereux (M)	12	0.00 (0.25)
1910	Taylor/PWT	Maddison	20	0.14 (0.14)
1913	Maddison	Maddison	24	-0.11 (0.11)
1920	Taylor/PWT	Maddison	19	0.41 (0.18) **
1930	Taylor/PWT	Maddison	20	0.33 (0.14) **
1930	Ward-Devereux (B)	Ward-Devereux (B)	12	0.15 (0.12)
1930	Ward-Devereux (M)	Ward-Devereux (M)	12	0.28 (0.43)
1940	Taylor/PWT	Maddison	20	0.67 (0.17) ***
1950	Taylor/PWT	Maddison	20	0.16 (0.18)
1950	Ward-Devereux (B)	Ward-Devereux (B)	12	0.21 (0.09) **
1950	Ward-Devereux (M)	Ward-Devereux (M)	12	0.56 (0.25) *
1960	Taylor/PWT	Maddison	20	0.39 (0.13) ***
1970	Taylor/PWT	Maddison	12	0.28 (0.14) *
1980	Taylor/PWT	Maddison	13	0.56 (0.13) ***
1990	Taylor/PWT	Maddison	13	0.83 (0.11) ***

Notes: (a) using GDP deflator; (b) using CPI or, if unavailable, GDP deflator.

Significance levels: \* 10%, \*\*5%, \*\*\* 1%.

**Table 1 (continued)****The Balassa-Samuelson Effect in History**

Estimates from an OLS regression of the log relative price level on log relative real income per capita

Year(s)	Price source	GDP source	N	Coefficient
(c) Prados revisions to Maddison data 1820–1990				
1820	Prados/Maddison	Prados/Maddison	6	-0.51 (0.63)
1830	Prados/Maddison	Prados/Maddison	7	-0.97 (0.63)
1840	Prados/Maddison	Prados/Maddison	8	-0.89 (0.53)
1850	Prados/Maddison	Prados/Maddison	13	-0.05 (0.23)
1860	Prados/Maddison	Prados/Maddison	17	0.31 (0.26)
1870	Prados/Maddison	Prados/Maddison	19	0.19 (0.19)
1880	Prados/Maddison	Prados/Maddison	22	0.28 (0.16) *
1890	Prados/Maddison	Prados/Maddison	22	0.27 (0.14) *
1900	Prados/Maddison	Prados/Maddison	23	0.34 (0.16) **
1913	Prados/Maddison	Prados/Maddison	24	0.14 (0.12)
1913†	Prados/Maddison	Prados/Maddison	26	0.17 (0.11)
1929	Prados/Maddison	Prados/Maddison	29	0.22 (0.11) *
1938	Prados/Maddison	Prados/Maddison	29	0.22 (0.13)
1950	Prados/Maddison	Prados/Maddison	23	0.15 (0.08) *
1960	Prados/Maddison	Prados/Maddison	23	0.34 (0.11) ***
1970	Prados/Maddison	Prados/Maddison	19	0.01 (0.35)
1975	Prados/Maddison	Prados/Maddison	23	0.51 (0.13) ***
1980	Prados/Maddison	Prados/Maddison	23	0.60 (0.10) ***
1985	Prados/Maddison	Prados/Maddison	23	0.61 (0.11) ***
1990	Prados/Maddison	Prados/Maddison	23	0.66 (0.11) ***
(d) Broadberry-Gupta European Cities (using real wages), 1500–1850				
1500–49	Braodberry/Gupta	Braodberry/Gupta	14	-0.51 (0.37)
1550–99	Braodberry/Gupta	Braodberry/Gupta	14	-0.18 (0.41)
1600–49	Braodberry/Gupta	Braodberry/Gupta	14	-0.47 (0.33)
1650–99	Braodberry/Gupta	Braodberry/Gupta	14	-0.07 (0.54)
1700–49	Braodberry/Gupta	Braodberry/Gupta	14	0.22 (0.30)
1750–99	Braodberry/Gupta	Braodberry/Gupta	14	-0.07 (0.28)
1800–49	Braodberry/Gupta	Braodberry/Gupta	14	0.14 (0.24)

Notes: † denotes 1913 data using interwar borders.

Significance levels: \* 10%, \*\*5%, \*\*\* 1%.

**Table 2**  
**The Balassa-Samuelson Effect Since 1870 in Short Panels**

Estimates from a panel regression of the log relative price level on log relative real income per capita

Year(s)	Price source	GDP source	N	Coefficient	SE		Rho	H
(a) Postwar Sample 1950–2000								
1950–9	PWT	PWT	649	0.12	(0.03)	***	0.87	4.91
1960–9	PWT	PWT	1089	0.14	(0.02)	***	0.89	5.78
1970–9	PWT	PWT	1127	0.15	(0.03)	***	0.88	5.35
1980–9	PWT	PWT	1188	0.28	(0.04)	***	0.82	3.47
1990–9	PWT	PWT	1253	0.32	(0.03)	***	0.84	4.07
(b) Historical Sample 1870–1990 (N=20)								
1880–9	Taylor/PWT	Maddison	140	0.20	(0.12)	*	0.94	12.09
1890–9	Taylor/PWT	Maddison	164	0.05	(0.11)		0.93	9.17
1900–9	Taylor/PWT	Maddison	200	0.13	(0.06)	**	0.91	7.48
1910–9	Taylor/PWT	Maddison	192	-0.18	(0.15)		0.84	3.88
1920–9	Taylor/PWT	Maddison	199	0.24	(0.09)	***	0.90	6.76
1930–9	Taylor/PWT	Maddison	199	0.36	(0.12)	***	0.81	3.30
1940–9	Taylor/PWT	Maddison	193	-0.07	(0.10)		0.88	5.21
1950–9	Taylor/PWT	Maddison	200	0.11	(0.14)		0.91	7.01
1960–9	Taylor/PWT	Maddison	200	0.29	(0.11)	***	0.91	7.11
1970–9	Taylor/PWT	Maddison	200	0.42	(0.12)	***	0.86	4.52
1980–9	Taylor/PWT	Maddison	200	1.06	(0.19)	***	0.73	2.24
1990–9	Taylor/PWT	Maddison	104	0.68	(0.11)	***	0.68	1.78

Notes: Standard errors are corrected for errors with a common AR1 parameter and cross-sectional correlation.

**Table 3**  
**Sources of Productivity Growth in the United States, 1958-96**

	(a)	(b)	(a) x (b)
	TFP growth	Domar weight	Contribution
Government Enterprises	-0.516	0.022	-0.011
Printing and Publishing	-0.445	0.024	-0.011
Construction	-0.442	0.113	-0.050
Petroleum and Gas	-0.437	0.022	-0.010
Gas Utilities	-0.241	0.016	-0.004
Tobacco Products	-0.2	0.004	-0.001
Services	-0.19	0.208	-0.040
FIRE	-0.176	0.131	-0.023
Lumber and Wood	-0.02	0.015	0.000
Private Households	0	0.137	0.000
General Government	0	0.131	0.000
Other Transportation Equipment	0.183	0.027	0.005
Primary Metals	0.224	0.04	0.009
Motor Vehicles	0.242	0.043	0.010
Leather Products	0.285	0.004	0.001
Petroleum Refining	0.327	0.033	0.011
Stone, Clay, and Glass	0.414	0.014	0.006
Paper Products	0.416	0.022	0.009
Metal Mining	0.44	0.003	0.001
Nonmetallic Mining	0.461	0.003	0.001
Electric Utilities	0.515	0.026	0.013
Food Products	0.535	0.076	0.041
Furniture and Fixtures	0.562	0.007	0.004
Chemical Products	0.584	0.048	0.028
Fabricated Metals	0.648	0.035	0.023
Apparel and Textiles	0.804	0.022	0.018
Miscellaneous Manufacturing	0.821	0.008	0.007
Coal Mining	0.837	0.005	0.004
Transport and Warehouse	0.863	0.061	0.053
Communications	0.882	0.033	0.029
Trade	0.979	0.195	0.191
Rubber and Plastic	1.043	0.016	0.017
Instruments	1.121	0.017	0.019
Agriculture	1.169	0.062	0.072
Textile Mill Products	1.23	0.013	0.016
Industrial Machinery and Equipment	1.461	0.048	0.070
Electronic and Electric Equipment	1.975	0.036	0.071

**Table 4**  
**Sectoral TFP in the British Industrial Revolution, 1780–1860**

	Output share	TFP growth rate (% per annum)			
		McCloskey	Crafts	Harley	
Cotton	0.05	2.6	2.6	1.9	
Worstedes	0.02	1.8	1.8	1.3	
Woolens	0.02	0.9	0.9	0.6	
Iron	0.01	0.9	0.9	0.9	
Canals and railroads	0.05	1.3	1.3	1.3	
Shipping	0.04	2.3	2.3	0.5	
Agriculture	0.19	0.45	0.45	0.7	
Others	0.60	0.65	0.08	0.02	

Sources: McCloskey (1981), Crafts (1985), Harley (1993).

Figure 1a  
Log price level versus log per capita income, US=0, 1995 PWT sample (N=142)

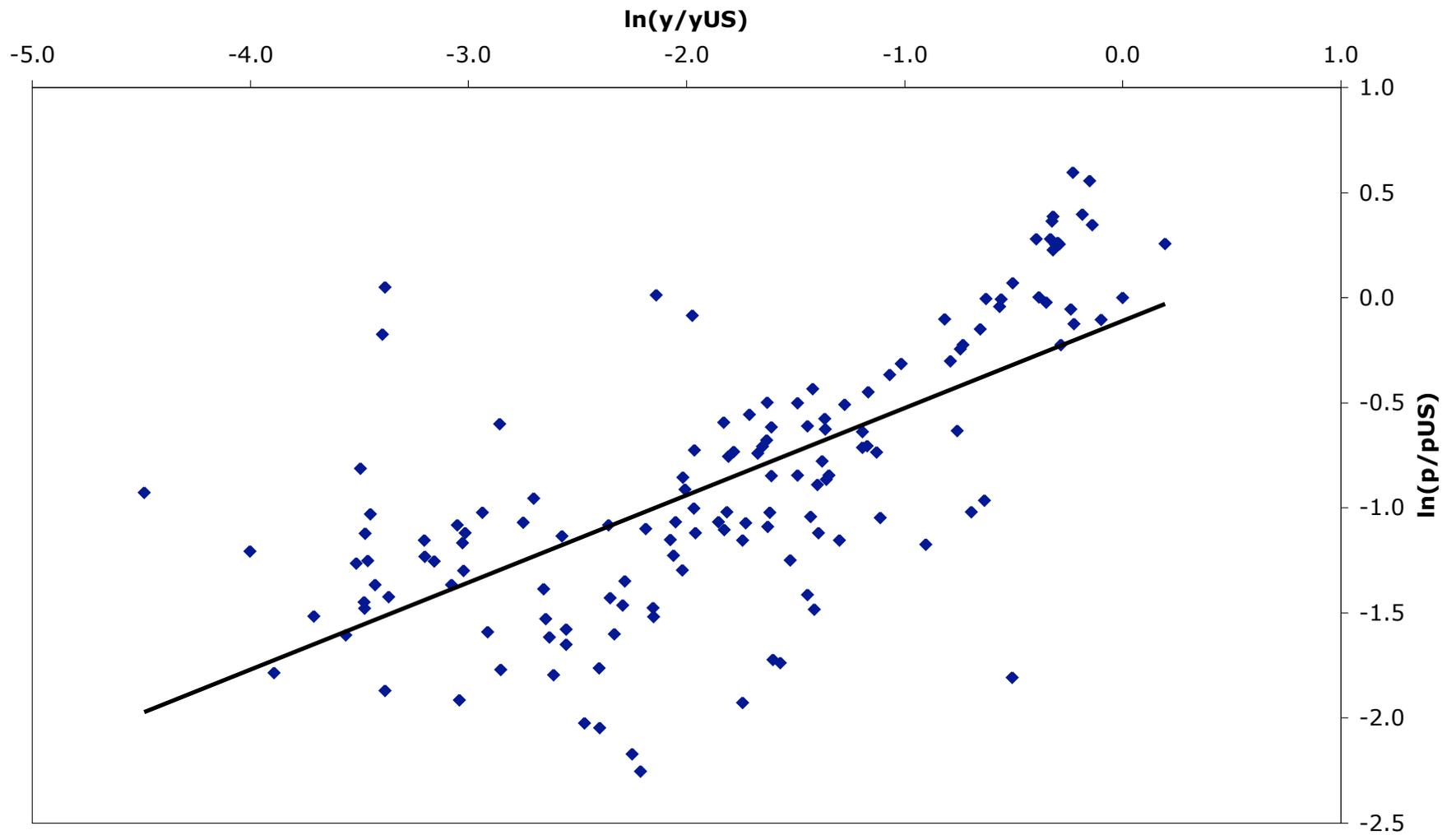


Figure 1b  
Log price level versus log per capita income, US=0, 1950 PWT sample (N=53)

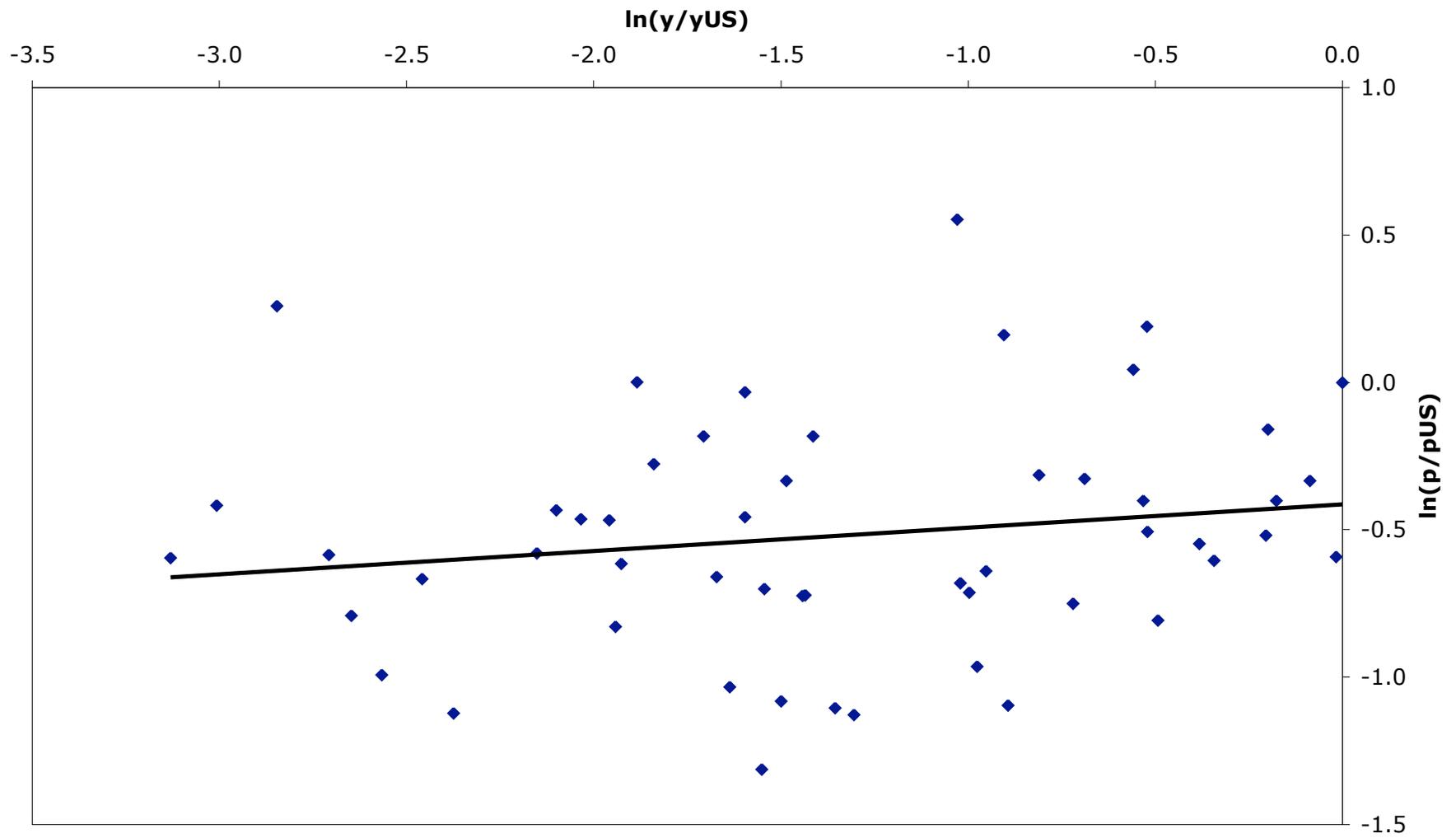
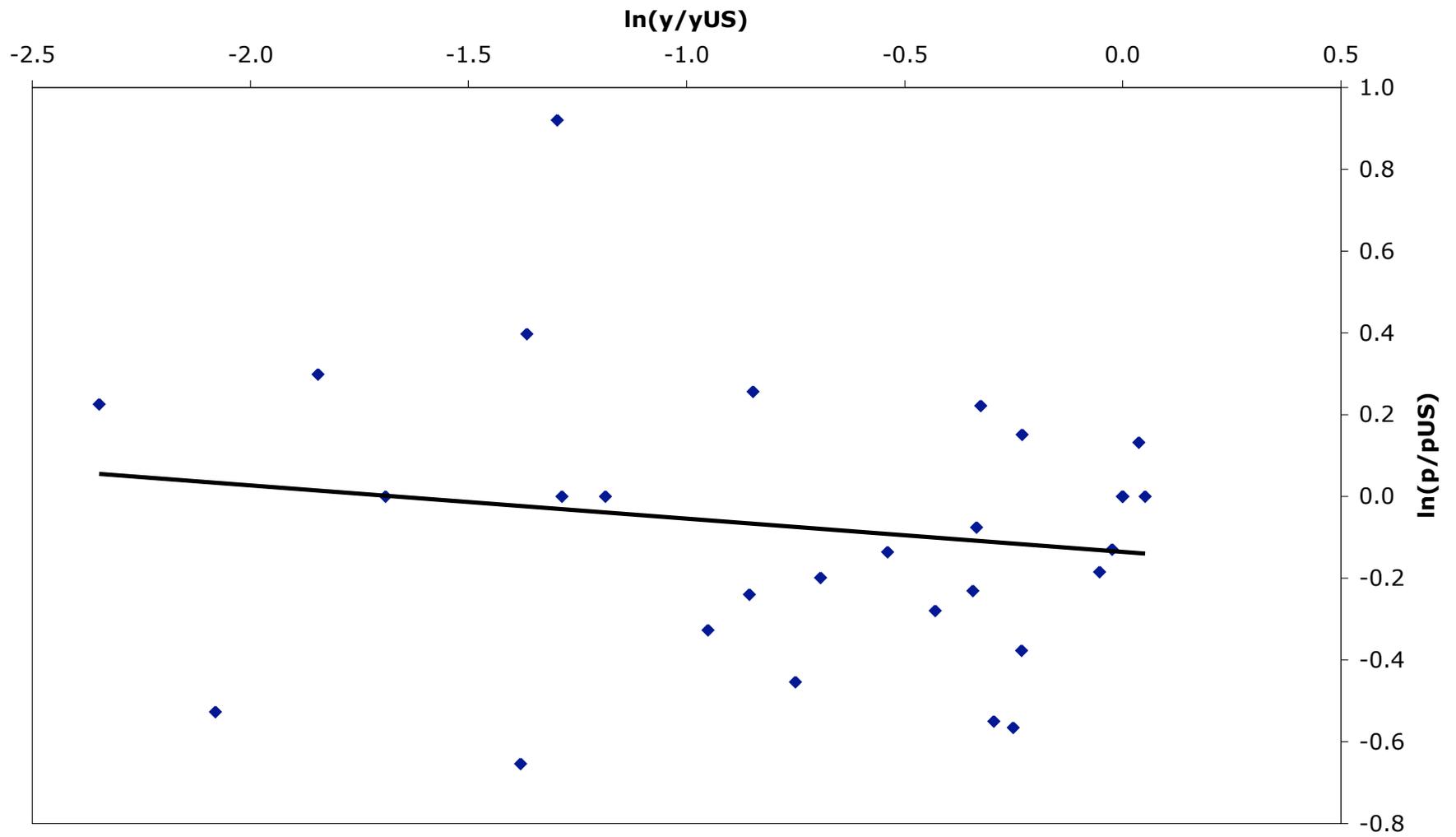
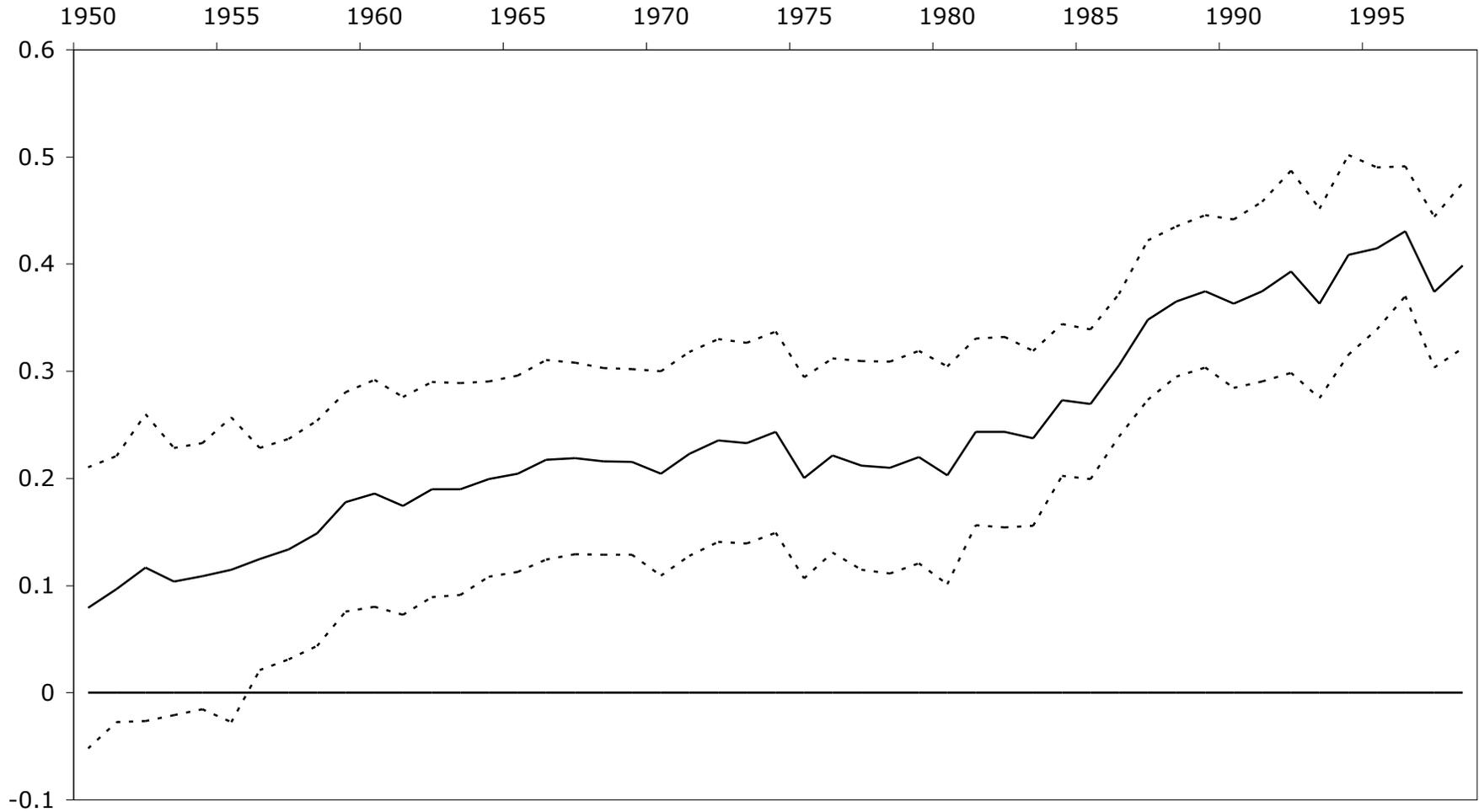


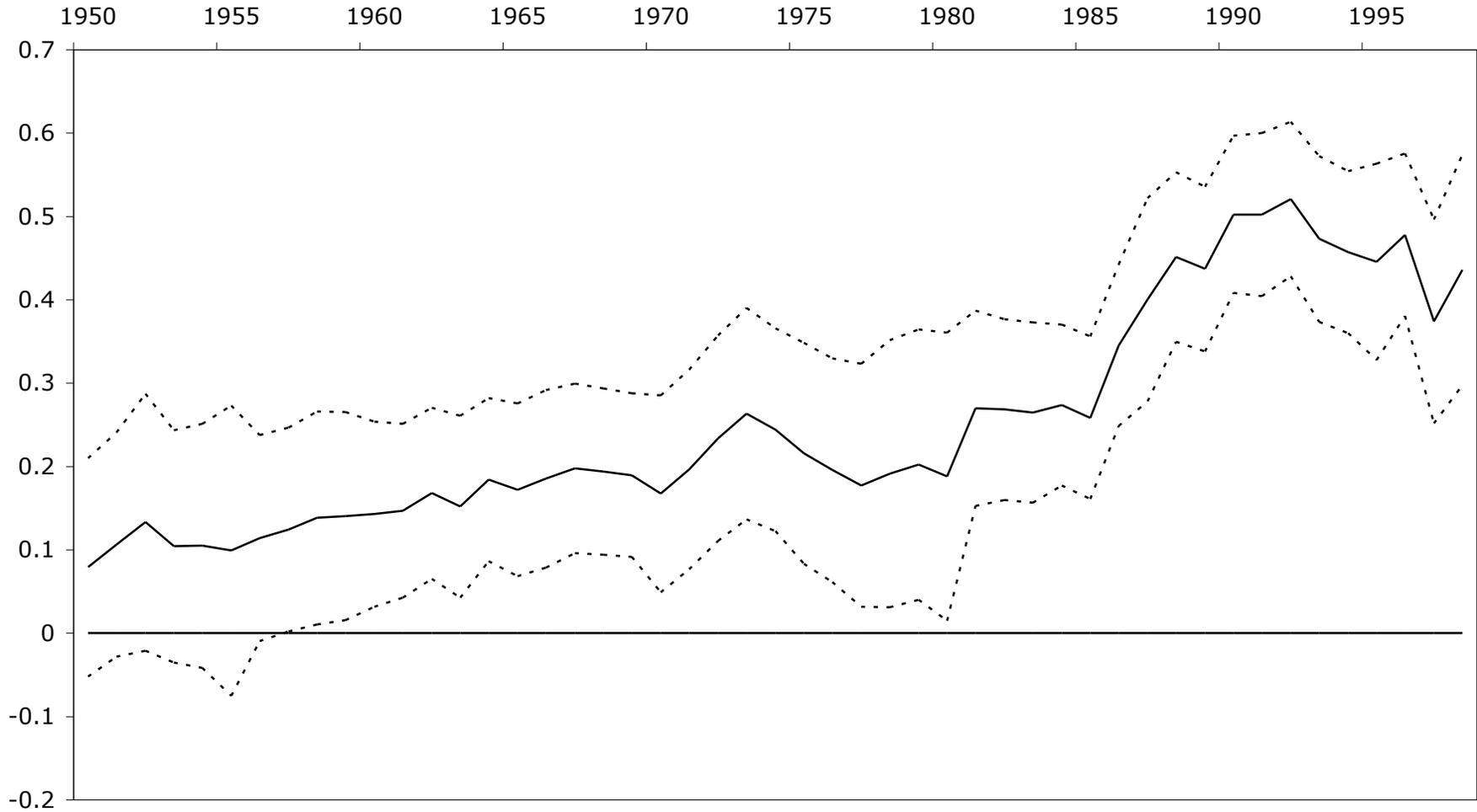
Figure 1c  
Log price level versus log per capita income, US=0, 1913 Maddison sample (N=24)



**Figure 2a**  
**The Balassa-Samuelson Effect in Cross Sections**  
PWT data 1950–1998, full sample ( $53 \leq N \leq 165$ )



**Figure 2a**  
**The Balassa-Samuelson Effect in Cross Sections**  
PWT data 1950–1998, 1950 sample of countries (N=53)



**Figure 2c**  
**The Balassa-Samuelson Effect in Cross Sections**  
Taylor/Maddison data 1870-1994 (N=20)

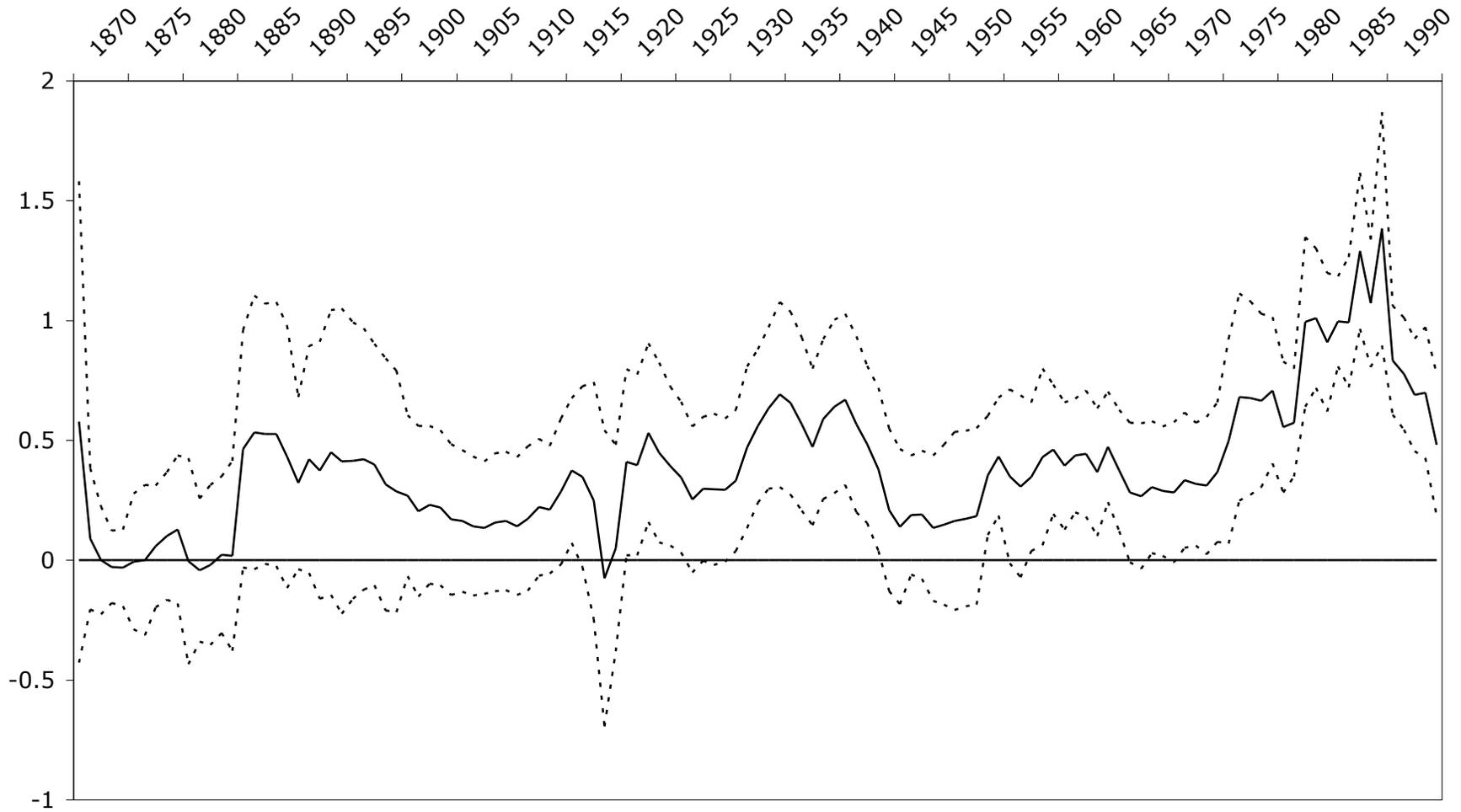


Figure 3(a): Alpha varies  
Under alternative values of phi (phi = 3, 6, and 10)

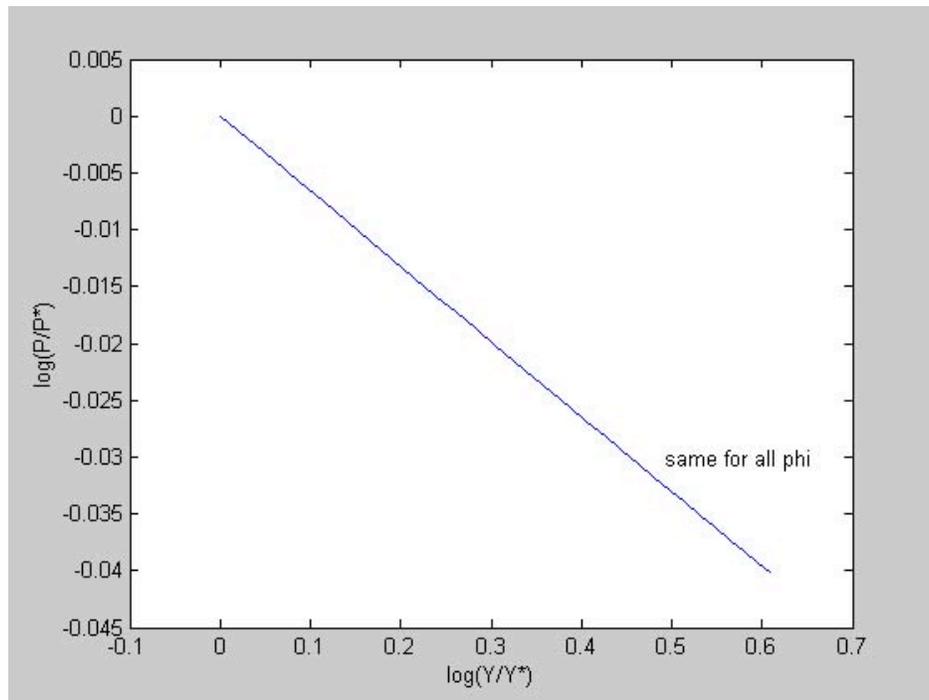


Fig. 3(b): lambda1 varies  
Under alternative values of betaa (under betaa\*=0.01)  
phi=gamma=6

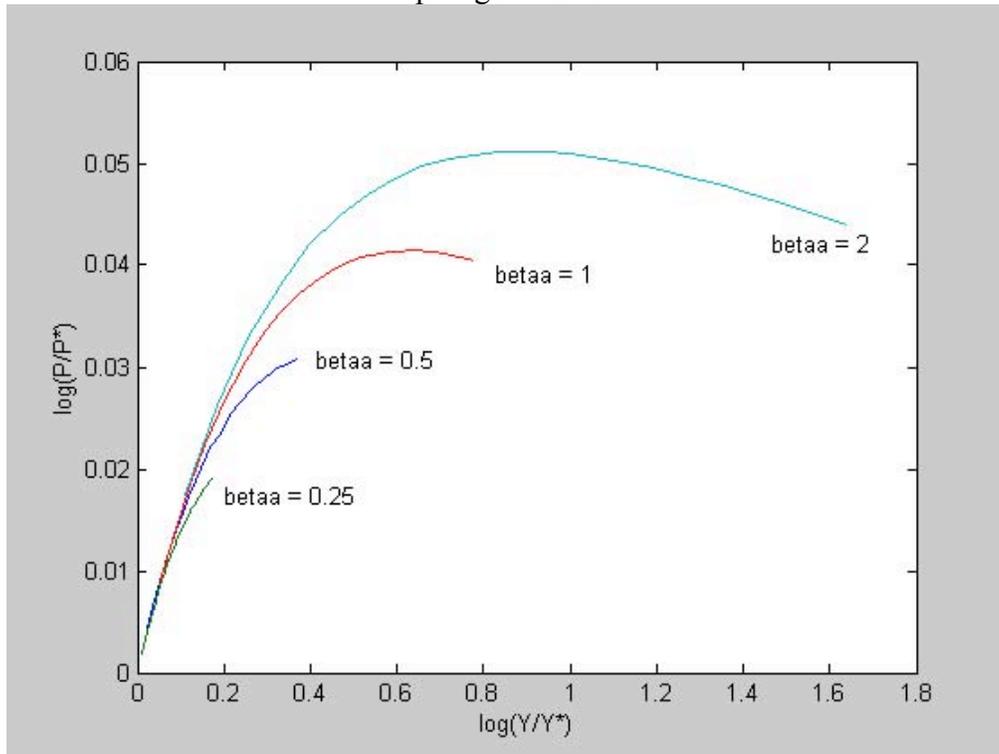


Fig. 3(c): beta varies  
Under alternative values of lambda1

phi=gamma=6

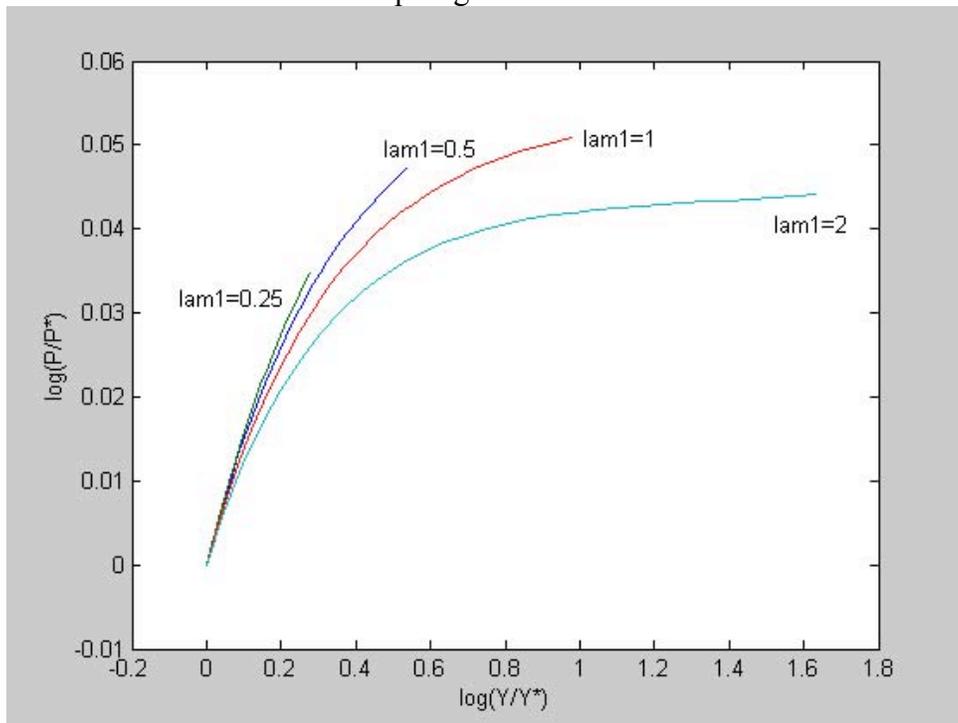
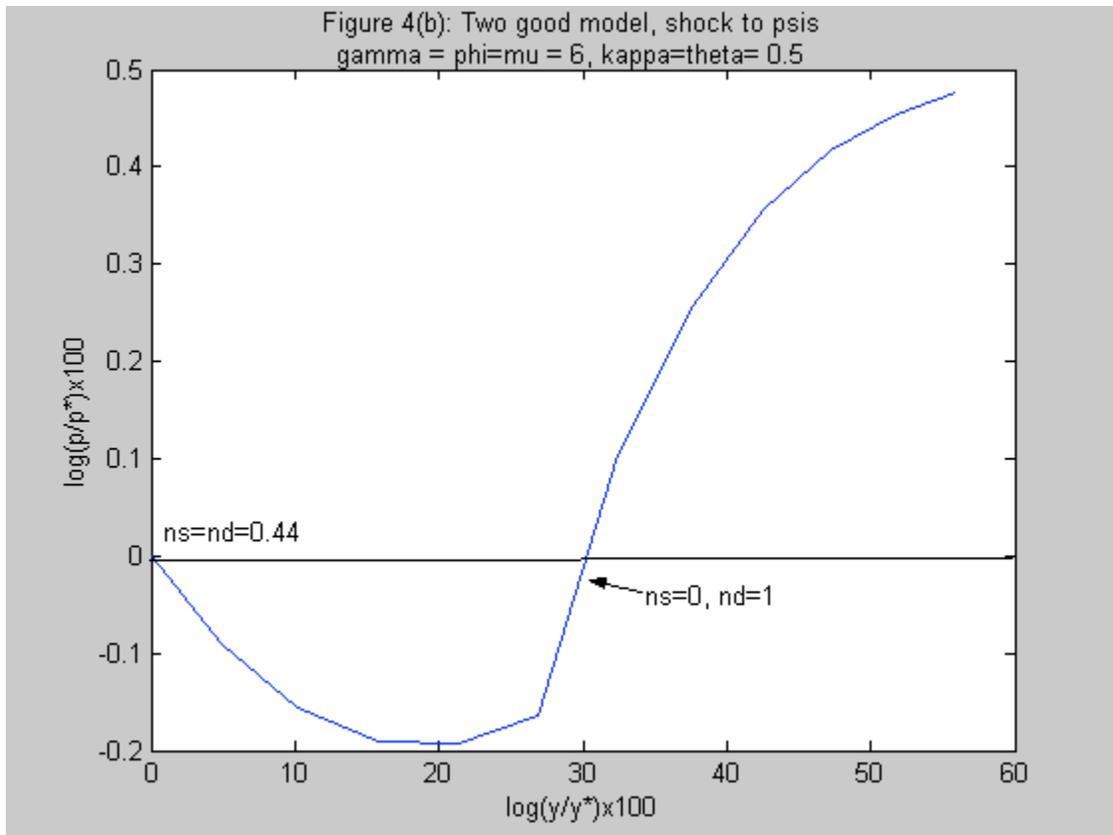
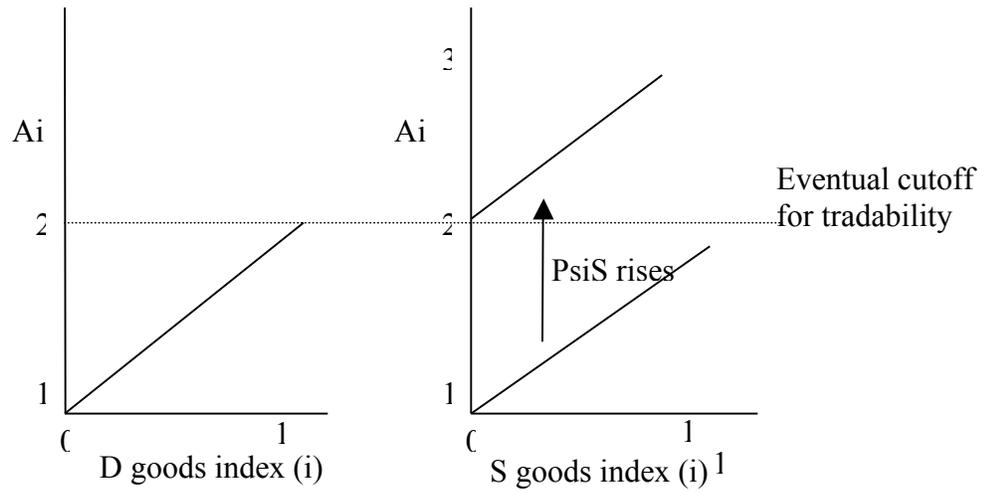
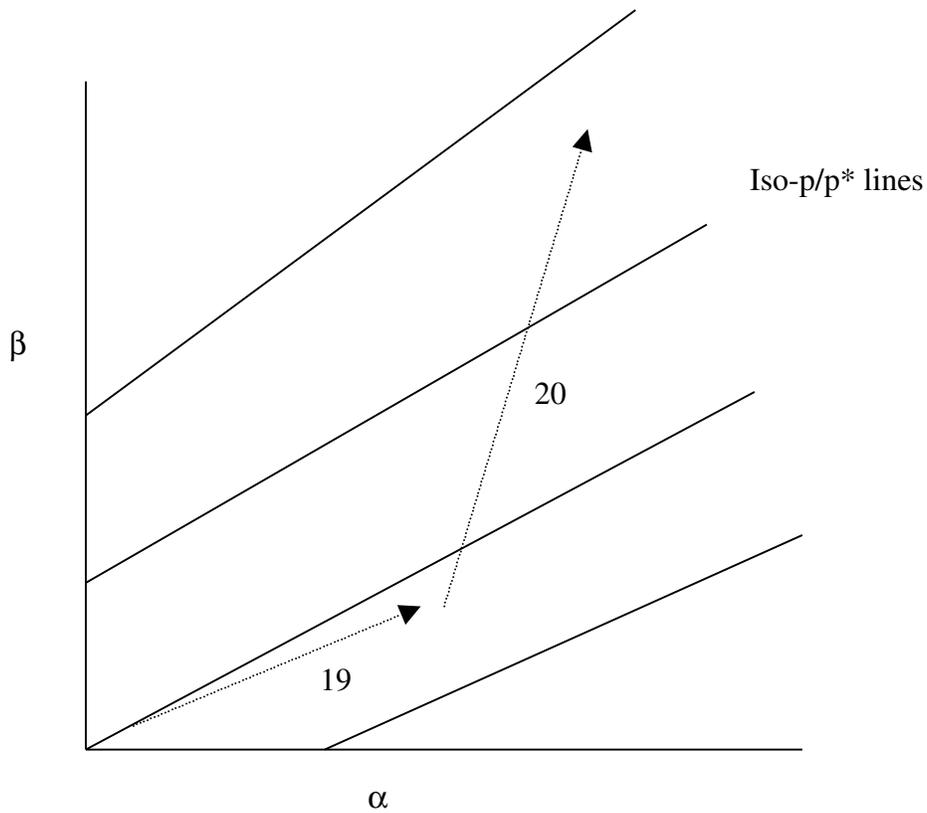


Fig. 4(a): Two good model, effect of  $\psi_S$  on productivity



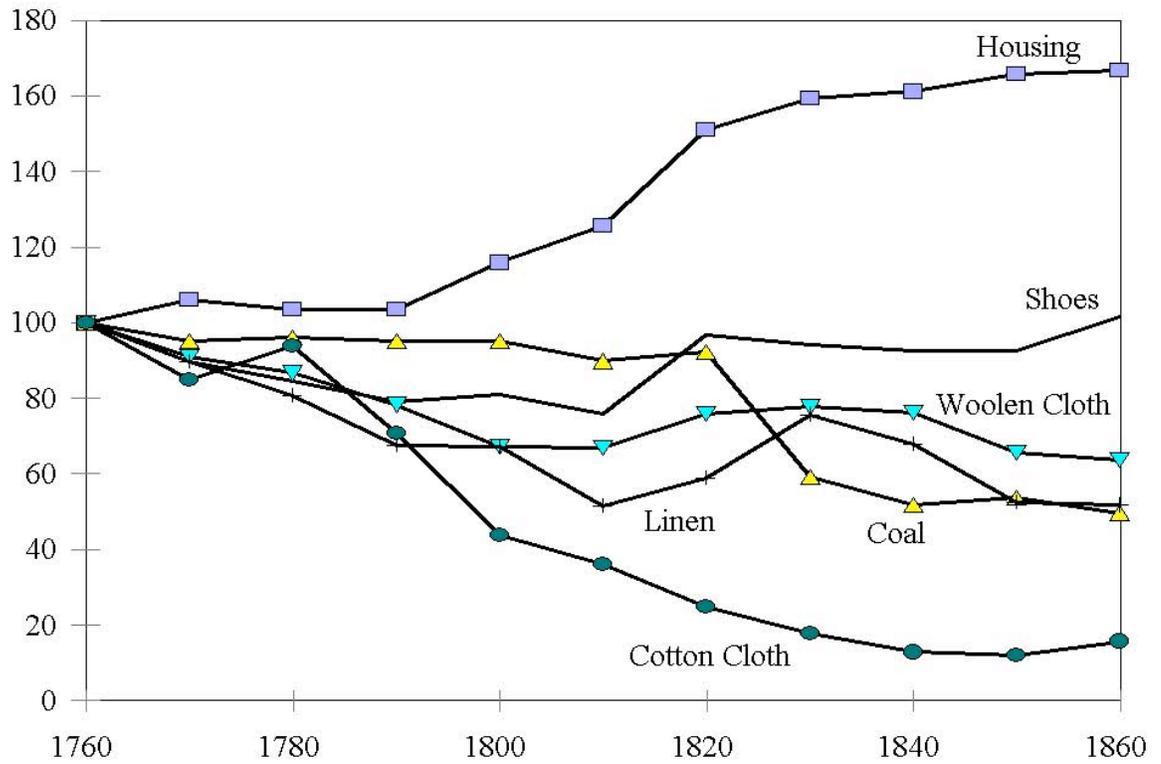
**Figure 5**  
**Sources of Growth and the BS effect**

In the model, economic growth derives from an increase in  $\alpha$  or  $\beta$ . If the early stages of modern economic growth (19) are evenly spread over sectors, and then progress starts to concentrate later (20) in the traded sectors (possibly endogenously) then the BS effect only emerges with a delay and then strengthens. In this thought experiment, arrows depict possible 19<sup>th</sup> and 20<sup>th</sup> century paths for a now-developed country. Still underdeveloped countries remain near the origin. Hence, the cross-section correlation of income with price levels increases over time.





**Figure 7**  
**UK Price Indices 1760–1860**



Source: Clark (2003).

**Figure 8**  
**UK TFP by sector, 1780–1860**

