The convergence hypothesis in the context of multi-country computable general equilibrium modelling

by

Peter B. Dixon and Maureen T. Rimmer
Centre of Policy Studies, Monash University, Clayton, 3800

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SUMMARY

(a) We demonstrate the feasibility of using multi-country computable general equilibrium (CGE) modelling to provide detailed projections of the effects of convergence. We do this by conducting an illustrative convergence analysis with a dynamic 57-commodity model of China, Australia and the Rest of world (ROW).

(b) In interpreting convergence, we assume a central aspect is that technologies in developing countries will move towards those in developed countries. Under this interpretation, the analysis of convergence requires estimates of the initial technology gaps between developing and developed countries.

(c) For estimating technology gaps, we need *quantities* of inputs and outputs. Available input-output data give *values*. To get from values to quantities we need data on wage rates and prices of goods (includes services) in different countries.

(d) Wage data are readily available from the World Bank and from national statistical agencies. Data on the prices of goods are much harder to assemble. One possibility is to assume that prices are the same across countries when converted by market exchange rates (MER) into a common currency. However, this approach has been criticized by Castles and Henderson (2003 a & b). MER conversion leads to dramatic overestimates of the prices of non-traded goods in developing countries and corresponding underestimates of the quantities of these goods. MER conversion gives results that are inconsistent with estimates of purchasing power parity (PPP). For developing countries, estimated PPPs of two or more are common, implying that the $US cost of a typical bundle of consumption goods in these countries is less than half that in developed countries.

(e) Relevant detailed price data, consistent with PPP estimates, are held by the International Comparisons Project (ICP) conducted by the University of Pennsylvania and the World

Bank. These data are not publicly available and negotiations will be required to find a basis under which the ICP can release them.

(f) In the absence of suitable price data, in our 57-commodity, three country illustrative model, we moved from input-output values to quantities by various assumptions. In our preferred simulations we assumed that: (a) the law of one price applies approximately to all traded goods, that is, after conversion to a common currency, the price of traded-good i at a central world location is approximately the same irrespective of its source country; and (b) in accordance with measurements of PPP, non-traded goods are considerably cheaper in developing countries than in developed countries.

(g) On the basis of assumed prices, we show how input-output data can be used to obtain estimates of coefficients describing technology in each industry in each country. These estimates then provide the initial technology ratios for a convergence analysis. The technology ratio for industry i in country z is the quantity of inputs per unit of output in the leading country (ROW in our illustration) divided by the quantity of inputs per unit of output in country z.

(h) Under our preferred price assumptions, technology ratios for China range from 0.09 for Wool and silk worms to approximately 1 for Construction. The average value over all industries is 0.47.

(i) As set out by Balassa (1964), high PPP values for developing countries can be explained by technological backwardness in their production of tradeables relative to their production of non-tradeables. Consistent with this explanation, under our preferred price assumptions the average technology ratio for traded goods in China is much lower than that for non-traded goods, 0.33 compared with 0.66.

(j) We use our Australia/China/Rest-of-world dynamic CGE model in seven illustrative simulations of partial technological catch up by China to ROW. By technological catch up we mean that China closes the technology gap with developed countries by moving its technology ratios towards one.

(k) Table S1 sets out the main features of the assumptions underlying the seven simulations.

Table S1: Overview of simulation assumptions

Simulation number	Estimation of technologies: initial prices (1)	Export bias in tech change (2)	Terms of trade (3)	Capital/GDP ratio (4)	Time for closing of tech gap (5)
1	PPP-1	No	Endogenous	Endogenous	100 years
2	PPP-2	No	Endogenous	Endogenous	100 years
3	PPP-2	Yes	Endogenous	Endogenous	100 years
4	PPP-2	Yes	Fixed	Endogenous	100 years
5	PPP-2	Yes	Fixed	Approx. fixed	100 years
6	PPP-2	Yes	Fixed	Approx. fixed	50 years for tradeables
7	MER	Yes	Fixed	Approx. fixed	100 years

The simulations vary in five respects corresponding to columns (1) to (5).

Column (1). We estimate technology ratios under three sets of price assumptions denoted by PPP-1, PPP-2 and MER. Under PPP-1 we assume that that the law of one price applies to all exports. For non-exports, we assume that Chinese prices are 0.5 times those in ROW (after conversion to a common currency). Under PPP-2 (our preferred assumptions) we continue to assume that the law of one price applies to all exports. However, we assume that the price of non-exported tradeable goods in China is 0.75 times that of corresponding goods in ROW whereas the price on non-exported non-tradeable goods in China is 0.25 times that of corresponding goods in ROW. Under MER, we assume that the prices of all goods in China are the same as those in ROW.

Column (2). Where a "Yes" appears in this column, we assume that within each industry China improves its ability to produce commodities for export relative to commodities for the domestic market.

Column (3). When China's terms of trade are treated endogenously, technological catch up causes sharp deterioration. In simulations 4 to 7, we assume that the preferences of China's trading partners move sufficiently in China's favour so that there is no deterioration in China's terms of trade.

Column (4). Application of technology-catch-up shocks alone produces simulation results in which China's capital to GDP ratio falls. The experience of convergence so far indicates that this is unrealistic. In simulations 5 to 7 we approximately fix China's capital/GDP ratio by introducing further technological changes that reduce the cost of creating units of capital in China.

Column (5). In all simulations apart from 6, we assume that China's technology ratios grow smoothly over 100 years to one. In simulation 6 we assume faster technology convergence for China's tradeables: for industries producing these goods we assume that China's technology ratios grow smoothly over 50 years to one.

For all simulations we report convergence-induced deviations at the 25th year.

(l) In simulation 1 we find that after 25 years of a 100 year process, China has 75 per cent more GDP and 83 per cent higher real wages than it would have in the absence of convergence. The simulated effects of China's convergence on Australia and ROW are negligible. A problem with simulation 1 is that it produces unrealistic results for the convergence-induced movement in China's PPP. Rather than falling sharply towards one as would be expected on the basis of the Balassa argument, it moves further away from 1.

(m) For simulation 2 we re-estimate Chinese technology ratios using PPP-2 assumptions. Relative to PPP-1 assumptions, PPP-2 assumptions lower Chinese technology ratios for traded goods and raise those for non-traded goods. As expected, simulation 2 shows a lower Chinese PPP at the 25th year than simulation 1. However, the difference is only small and the convergence-induced PPP movement for China continues to be unrealistic.

(n) Comparison of simulations 2 and 3 shows the effects of assuming that China achieves relative improvements within industries in producing for export. Export bias in technical change within industries causes a convergence-induced reduction in the Chinese PPP at the 25th year. However, the reduction is unrealistically small.

(o) Comparison of simulations 3 and 4 shows that elimination of terms-of-trade effects is the key to producing convergence results with realistic PPP movements.

(p) Comparison of simulations 4 and 5 shows that extra capital accumulation in China produces a sharply higher convergence-induced GDP deviation but has only minor effects on China's consumption. China's PPP movement differs only slightly between simulations 4 and 5. On the other hand, the introduction of additional capital accumulation in China has a significant effect on the simulated movement in China's real exchange rate.

(q) Comparison of simulations 5 and 6 shows that speeding up Chinese convergence for tradeables strongly increases China's convergence-induced GDP and wage deviations at the 25^{th} year. It also strongly increases China's real exchange rate but has a relatively minor effect on China's PPP.

(r) Comparison of simulations 5 and 7 shows that the use of MERs in the estimation of initial technology ratios leads to unrealistic simulation results. These results are likely to overestimate convergence-induced GDP growth in developing countries and understate the likely effects of convergence on their PPPs and real exchange rates.

(s) The simulation results suggest four conclusions. First, in estimating technology gaps in preparation for a CGE analysis of convergence, the distinction between MER and PPP is important. Second, under convergence, the outputs of industries and related greenhouse gases in developing countries will not grow as rapidly as GDP in these countries. Third, for convergence analysis the industry detail in CGE models is valuable. Fourth, convergence of developing countries has surprisingly small effects on GDP growth in developed countries.

(t) Convergence will affect trade, the environment and the occupational composition of employment in both developed and developing countries. Planners could benefit from detailed CGE-based analysis of convergence. This paper could be considered a starting point for such an analysis.

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1. Aim and motivation

Convergence is often interpreted as meaning that GNP per capita in developing countries catches up to GNP per capita in developed countries. The aim of this paper is to show how convergence between developing and developed countries can be analysed in a computable general equilibrium (CGE) model.

Our motivation is provided by the Castles/Henderson critique (2003 a & b) of the Special Report on Emissions Scenarios (SRES) by the Intergovernmental Panel on Climate Change (IPCC, 2000). The SRES is concerned with the greenhouse-gas implications of convergence. Castles and Henderson argue that the SRES may have overestimated the increase in greenhouse gases associated with convergence by using inappropriate measures of current per capita GNP for developing countries.

Estimates of GNP per capita are readily available for most countries of the world in national currencies. When these estimates are converted by market exchange rates (MERs) into a common currency, they imply very large differences between developing and developed countries. For example, IMF statistics show that the $US value of GNP per capita in China at the MER was about $US800 in 2000. This is only about one fortieth of GNP per capita in the U.S. in 2000 (see IMF International Financial Statistics, China and U.S. pages, December 2000**)**. Figures such as these give the impression that convergence will mean enormous growth in output in developing countries. This in turn leads to fears that convergence will generate huge increases in the world volume of greenhouse gas emissions.

Against this, Castles and Henderson (2003 a & b) argue that comparisons of GNP per capita at MERs strongly understate output in developing countries relative to that in developed countries. As a consequence, convergence scenarios based on such comparisons strongly overstate the output growth in developing countries that would follow from convergence. Castles and Henderson suggest that comparisons of GNP per capita between developing and developed countries should be made in terms of purchasing power parity (PPP). A PPP of 2 for China and 1 for the U.S., for example, means that $US800 buys twice as much goods and services in China as it does in the U.S. Thus, output in China that is worth $US800 at the MER represents twice as much goods and services as output in the U.S. worth $US800. This in turn leads to the conclusion that convergence means a twenty-fold increase in Chinese output rather than a forty-fold increase. With smaller increases in output, the convergence hypothesis in PPP terms, at least at first glance, seems to imply a smaller increase in greenhouse-gas emissions than is implied by the hypothesis in market-exchange-rate terms.

However, the first-glance conclusion is not necessarily right. If we assume that a country's greenhouse-gas emissions per capita are a function of the real volume of its output per capita, then we might estimate greenhouse-gas emissions at convergence by assuming that emissions per capita in developing countries will converge to those in developed countries. Thus we could calculate the increase in world emissions by comparing the current level with the level that would apply if all developing countries were emitting at the same rate per capita as developed countries. The calculations could be made without even considering current differences in GNP per capita between developing and developed countries let alone worrying about whether these differences should be calculated in terms of MER or PPP.

But the problem with this really simple approach is that different countries have different sources of energy and different climates. Thus, even if there were convergence in output per capita, it may not be reasonable to assume convergence in emissions per capita. So, how should we go about estimating the greenhouse-gas implications of convergence?

The method we investigate in this project is simulation in a multi-country CGE model. We assume that countries have different GNP per capita mainly because they have different technologies (processes by which inputs are turned into outputs). We interpret convergence as meaning that technologies in developing countries become as efficient as those in developed countries.

A CGE model is potentially an attractive vehicle for analysing the effects of technological change. Thus, under our interpretation of convergence, a CGE model is an attractive vehicle for analysing its effects. With technological differences as the starting point for an analysis in a CGE framework, controversies concerning inter-country comparisons of GNP are avoided. At the same time, the CGE framework is potentially rich enough in structural detail to encompass differences across countries in per capita emissions which would remain even after technological convergence.

The remainder of this paper is organized as follows. In the next section we show how technology variables for different countries can be estimated from the input-output database of a multi-country CGE model. The method depends on assumptions about the prices in different countries of goods and factors. We illustrate the method in a three-country model: Australia, China and Rest of world (ROW). ROW is set up to be a wealthy country: we are thinking of North America, Japan and Europe. The differences between our estimated technology variables for China and ROW are illustrative of the differences between technology variables for developing and developed countries that we would expect to find in a more detailed study. In illustrating the method, we compute three sets of technology variables for the three countries. In computing the first two sets, we assume that prices in the three countries are broadly consistent with estimates of PPP. In computing the third set, we assume that prices reflect MERs.

In section 3, we use our three-country model to make seven simulations of the effects of partial convergence by China over the next twenty-five years, that is the effects of extra technical progress in China that partially closes the gap between Chinese technology variables and the corresponding variables in ROW. Comparisons between simulation results demonstrate the implications of different assumptions in the estimation of technology gaps. They are also used to look at the implications of different assumptions concerning terms-of-trade movements and capital accumulation in developing countries.

It should be emphasized that the numbers in this paper, including the technology-gap estimates and the seven sets of simulation results, are purely illustrative. We aim to demonstrate the feasibility and potential value of a detailed CGE analysis of convergence. As will be apparent, considerably more empirical effort than was possible in the preparation of this paper will be required to get beyond the illustrative stage.

Section 4 contains concluding remarks.

2. Estimation of technology variables in different countries for a given year

2.1 Defining technology variables and convergence

Assume that there are two varieties of commodity i produced in country z. The first variety, (1,i), is sold domestically. The second variety, (2,i), is exported. The production function in industry i (the producer of both varieties of commodity i) in year t is specified as

$$V_{iz}(t) = F_i\left(\frac{X_{1iz}(t)}{A_{1iz}(t)}, ..., \frac{X_{niz}(t)}{A_{niz}(t)}\right) \quad \text{and} \qquad (2.1)$$

$$V_{iz}(t) = G_i\left(B_{1iz}(t)Y_{1iz}(t), B_{2iz}(t)Y_{2iz}(t)\right) \qquad (2.2)$$

where

$V_{iz}(t)$ is the level of activity in industry i in country z in year t;
$Y_{kiz}(t)$ is the output of variety k produced by industry i in country z in year t;
$X_{hiz}(t)$ is the input of h to production of i in country z in year t, with h = 1, …, n covering the inputs of n-1 materials and of a primary factor (a composite of labour and capital);
$A_{hiz}(t)$ is a technology variable allowing for changes in requirements of h per unit of activity in industry i in country z; and
$B_{kiz}(t)$ is a technology variable allowing for changes in the output of variety k per unit of activity in industry i in country z.

Under specification (2.1)-(2.2), industry i is viewed as buying inputs to achieve a level of activity, with more inputs being required for more activity. With a given level of activity, the industry can produce different combinations of (1,i) and (2,i) along a concave (from below) transformation frontier. With a higher level of activity (requiring more inputs), the transformation frontier moves out allowing expansions in the output of both varieties. Notice we assume that the same functions F_i and G_i apply in all countries z. Technological differences across countries are captured by differences in the technology variables A_{hiz} and B_{kiz}.

Decreases in technology variables can be used to simulate technological improvements. A reduction in $A_{hiz}(t)$ of 10 per cent is a technological change that allows industry i in country z to maintain a given level of activity (and therefore outputs) while reducing inputs of h by 10 per cent with all other inputs held constant. A reduction in $B_{kiz}(t)$ of 10 per cent is a technological change that allows industry i in country z to maintain a given level of activity (and therefore inputs) while increasing its output of variety k by 10 per cent with no change in the output of the other variety.

We interpret convergence as being a hypothesis about relative movements between countries in the A_{hiz}s and B_{kiz}s. Complete convergence would occur at time τ if

$$A_{hiz}(\tau) = A_{hi\,L}(\tau) \quad \text{for all h, i, and z} \quad , \qquad \text{and} \tag{2.3}$$

$$B_{kiz}(\tau) = B_{ki\,L}(\tau) \quad \text{for all k, i, and z} \quad , \tag{2.4}$$

where L is the benchmark or technologically leading economy.

Convergence of 100(1-β) per cent would occur at time τ if

$$A_{hiz}(\tau) - A_{hi\,L}(\tau) = \beta * \left(A_{hiz}(0) - A_{hi\,L}(0)\right) \quad \text{for all h, i, and z} \quad \text{, and} \tag{2.5}$$

$$B_{kiz}(\tau) - B_{ki\,L}(\tau) = \beta * \left(B_{kiz}(0) - B_{ki\,L}(0)\right) \quad \text{for all k, i, and z} \quad , \tag{2.6}$$

where the present time is zero and $0 \le \beta \le 1$.

Because CGE models can be used to simulate the effects on macroeconomic, labour-market and industry variables of changes in the A_{hiz}s and the B_{kiz}s, they can be used to investigate the effects of convergence.

The main problem in applying a multi-country CGE model to simulate the effects of convergence is to decide the starting values for the technology variables, the $A_{hiz}(0)$s and the $B_{kiz}(0)$s. To do this we need data on *quantities* of outputs and inputs. What is readily available from national input-output tables is *values* of outputs and inputs in national currencies. These values can be converted easily to a common currency, e.g. dollar U.S., by using MERs. This is done for example in creating the input-output database for GTAP (Hertel *et al.*, 1997), a widely used multi-country CGE model. However, for many commodities conversion via MERs doesn't tell us anything about quantities. For example, a U.S. dollar's worth of men's haircut in China covers the top of the head, the beard, the ears and the nose. In the U.S., a U.S. dollar's worth of men's haircut covers the introductory question of "how do you want it cut?". The problem is that non-traded goods in relatively poor countries are very cheap in terms of U.S. dollars. Comparable haircuts in China and the U.S. might cost $US1 and $US15. Thus if we know the U.S. dollar values of haircuts in China and the U.S., then to work out quantities we should divide the Chinese value by 1 and the U.S. value by 15. In other words, what is necessary to get from values in national input-output tables (and databases for multi-country models such as GTAP) to quantities and then to $A_{hiz}(0)$s and $B_{kiz}(0)$s is information on input and output prices in each country.

McKibbin *et al.* (2004) have already applied a multi-country CGE model, G-cubed, in an analysis of the effects of convergence. Like us, they view convergence as a hypothesis about relative movements between countries in technology variables. They start by looking at differences across countries in GNP per capita with GNP calculated in PPP terms. If GNP per capita in country z is *x* per cent less than that in the U.S., the leading country, then McKibbin *et al.* assume that labour productivity in every industry in country z is *x* per cent less than that in the U.S. In simulating convergence, they use G-cubed to look at the effects of a steady decline in *x* towards zero over 100 years. In terms of our notation, they assume that

$$A_{\ell iz}(t) = \alpha_z(t) * A_{\ell iL}(t) \quad \text{for all i, z and t} \quad . \tag{2.7}$$

where

$A_{\ell iz}(t)$ is the technology coefficient associated with labour (ℓ) input per unit of activity in industry i in country z at time t;

$A_{\ell iL}(t)$ is the corresponding technology coefficient for the U.S., the leading country; and

$\alpha_z(t)$ is a variable whose initial value, $\alpha_z(0)$, is the ratio of GNP per capita in the U.S. to GNP per capita in country z at time zero.

In effect, the McKibbin *et al.* simulation of convergence consists of a computation of the effects of the $\alpha_z(t)$s moving steadily towards one.

The problem with this approach to convergence is that it lacks structural detail. As recognized by McKibbin *et al.*, the assumption that the productivity gap between country z and country L is uniform across industries is not ideal.[1] Following the Balassa (1964) explanation of PPP differences between developing and developed countries, we would expect productivity gaps in industries producing traded goods to exceed those in industries producing non-traded goods. More generally, we would expect technology differences between developing and developed countries to encompass not only the labour variables $A_{\ell iz}(t)$ and $A_{\ell iL}(t)$ but also variables concerned with the use of capital and materials. In the next subsection, we will show how input-output data can be combined with price data to obtain a comprehensive picture of cross-country differences in technology variables. Such a picture can then provide a more appropriate starting point and more appropriate shocks for a CGE convergence simulation than those used by McKibbin *et al.*

[1] McKibbin *et al.* (2004, p.32) mention that "If we then have evidence that a particular sector is likely to be closer to or further away from the US sectors than the average numbers suggest, we adjust the initial sectoral gaps …" However, they don't mention whether any such adjustments were made.

2.2 Deducing starting values of technology variables from multi-country input-output data

The three-country model that we use to illustrate the CGE approach to the convergence hypothesis was originally designed by Mai and Horridge (2003) to investigate a potential free-trade agreement between Australia and China. The model is dynamic, drawing on specifications in Dixon and Rimmer (2002), and distinguishes 57 commodities/industries. The input-output and trade data and most parameter values are taken from the GTAP database (Dimaranan and McDougall, 2002). Reflecting its original purpose, the model contains some features that are tangential to our current application. For example, the model: disaggregates capital in each country and industry into the parts owned by agents in the three countries; imposes imperfect substitution in each country between imports from its different trading partners; and contains an elaborate specification of trade and transport margins used in facilitating commodity flows between countries. Also, as discussed further in section 4, in the current application the three-country breakdown (Australia, China, ROW) is not ideal. However, the model was conveniently available at short notice and is adequate for illustrating our technique for analysing convergence.

Table 2.1 is a simplified version of country z's input-output data for year 0 in our three-country model. In this table, C and I refer to the number of commodities and industries. Because we assume that each commodity is produced by just one industry and each industry produces just one commodity, C = I (= 57). O refers to the number of occupations, which equals two, skilled and unskilled.

The first I columns in Table 2.1, labelled Industries, show inputs to the I industries in country z. V1BAS(c,dom,i,z) is the value in basic prices (prices to producers) of domestically produced commodity c used as an input to current production in industry i in country z. V1BAS(c,imp,i,z) is the value in basic prices (landed duty-paid) of imported commodity c used as an input to current production in industry i in country z. V1TAX(c,dom,i,z) and V1TAX(c,imp,i,z) are the collections of sales taxes on flows of domestic and imported commodity c to industry i in country z. V1CAP(i,z) is the return to capital used by industry i in country z. V1LAB(i,o,z) is the return to labour of occupation o used by industry i in country z. The sum of the input entries down the i-th industry column is the value of output in industry i, VOUTPUT(i,z). This can also be obtained by adding MAKEDOM(i,z) and MAKEEXP(i,z) which are the values of i produced in country z for the domestic market (i type 1) and for export (i type 2).

Table2.1. Simplified representation of input-output data for country z

		Industries	*Investors*	*Households*	*Exports*	*Government*
	size	← I →	*1*	*1*	*1*	*1*
Domestic commodity of type 1, used domestically	↑ C ↓	**V1BAS(c,dom,i,z)**	**V2BAS(c,dom,z)**	**V3BAS(c,dom,z)**		**V5BAS(c,dom,z)**
Domestic commodity of type 2, exported	↑ C ↓				**BAS4(c,z)**	
Imported commodities	↑ C ↓	**V1BAS(c,imp,i,z)**	**V2BAS(c,imp,z)**	**V3BAS(c,imp,z)**		**V5BAS(c,imp,z)**
Taxes on domestic commodity of type 1	↑ C ↓	**V1TAX(c,dom,i,z)**	**V2TAX(c,dom,z)**	**V3TAX(c,dom,z)**		**V5TAX(c,dom,z)**
Taxes on domestic commodity of type 2	↑ C ↓				**V4TAX(c,z)**	
Taxes on imports	↑ C ↓	**V1TAX(c,imp,i,z)**	**V2TAX(c,imp,z)**	**V3TAX(c,imp,z)**		**V5TAX(c,imp,z)**
Capital	*1*	**V1CAP(i,z)**				
Labour	↑ O ↓	**V1LAB(i,o,z)**				
Totals	*1*	**VOUTPUT(i,z)**				
MAKE (types 1&2)	↑ 2 ↓	**MAKEDOM(i,z)** **MAKEEXP(i,z)**				

The basic values of domestic and imported commodities used in investment, household consumption and government consumption are given by the V2BAS, V3BAS and V5BAS vectors in the columns of Table 2.1 labelled Investors, Households and Government. The associated sales taxes are given by the V2TAX, V3TAX and V5TAX vectors. The column labelled Exports shows the basic values of exports and associated export taxes.

Our task now is to move from data of the type illustrated in Table 2.1 to estimates of starting values for technology variables, $A_{hiz}(0)$s and $B_{kiz}(0)$s. To do this we need to convert commodity and factor values in Table 2.1 to commodity and factor quantities. This requires data on prices for commodities and factors.

Looking for price data

Our first move was to send the following message to the GTAP network[2]:

Data for the GTAP model is presented in U.S. dollars. Is this done by taking country data and converting it to $US via the average market exchange rate for the relevant year? If market exchange rates are used, does this mean that a direct comparison of the GDP figures in the GTAP database understates the share of world economic activity in countries such as China while overestimating the share in the U.S. and Europe. Has anyone done any work on a GTAP database where PPP is used instead of market exchange rates? I will be grateful for any help.

This generated about half a dozen responses which confirmed: (a) that the GTAP data are derived by using MERs; and (b) that direct cross-country comparisons of GDP figures derived from the GTAP database almost certainly understate income in developing countries relative to that in developed countries. No one appeared to have done any work on a GTAP database where PPP is used instead of MER.

The most helpful responses were from John M. Reilly from Massachusetts Institute of Technology and Joe Francois from Erasmus University. Both are senior researchers specializing in applied international trade economics. With Professor Reilly we followed up our initial questions with the following:

Dear John
Thanks very much for your response to my query. Have you any conveniently available disaggregated data on prices of goods and services in China, prices in the U.S., prices in India, prices in EU etc? All I have found so far is PPP numbers. They must rest on disaggregated price data, but I don't know how to get that data. I know the OECD has such data but it just covers OECD countries. I need a data set that includes some major developing countries.
Thanks

[2] This is a network of about 2,000 researchers around the world grouped loosely around the GTAP model (Hertel, 1997).

Peter

This elicited the following response:

Dear Peter
I'm afraid that I do not have any such data. You might contact Alan Heston at the University of Pennsylvania. It is there where these PPP indices are constructed, and he has been for many years (dating to the 1970's when I was a Ph. D student there) a central member of the group working on this project. There was a meeting at Stanford this past Feb. where Heston talked a bit about these. Indeed, they are based on product by product prices that for any particular product may vary across the country of interest. So it is a laborious and data intensive effort to get an average price for different products and then construct a country-wide price index. Heston describing it admitted, not surprisingly as you would expect with any such large data effort, the data are never as consistent, clean, and complete as one might hope. They try very hard to control for product quality, but in the end there are fundamental questions about why prices vary spatially, and what that means. I don't know what they might be prepared to share, but some form of detailed price data by product must obviously exist for all the countries covered.
John

With Professor Francois we followed up our initial questions with the following:

Dear Joe
Thanks for your response. The issue is to decide what quantities of goods are produced in different countries. We may know that $US 10 of haircuts is produced in China and $US 10 of haircuts is produced in the U.S. But the quantities of haircuts in the two countries are quite different. What I am trying to do is simulate technological convergence among countries by allowing Chinese technology, for example, to catch up to the U.S. To do this we need a starting point with quantities of inputs and outputs, not just $US values.
Have you any conveniently available disaggregated data on prices of goods and services in China, prices in the U.S., prices in India, prices in EU etc? All I have found so far is PPP numbers. They must rest on disaggregated price data, but I don't know how to get that data. I know the OECD has such data but it just covers OECD countries. I need a data set that includes some major developing countries.
Any suggestions you might have will be gratefully received.
Cheers
Peter

This elicited the following response:

What you want is the benchmark surveys on which the ICP data sit. The ICP benchmark surveys are published roughly every 5 years, and the most recent published survey is for 1996. I don't think you will get more detailed price data than this, unless you go for private data from companies that make cost of living comparisons.
Joe

Both Professors Reilly and Francois point to the International Comparison Project (ICP) conducted between the University of Pennsylvania and the World Bank. Our initial inquiry concerning the availability of detailed ICP price data met with the following:

I am afraid basic price data are not made publicly available for several reasons, including confidentiality of country level data. Thank you for your email and your interest in ICP.

If you wish, we can add you to the distribution list for ICP News, our quarterly e-newsletter. The next issue is due out later this month.
Regards
Farah Hussain

Two points emerge from all this correspondence: (a) the ICP is probably the only potential source of detailed price data that can be meaningfully compared across a large number of countries; and (b) obtaining and using these data is a task that requires resources well beyond those that could be applied to the current project.

Price assumptions

Given that it was impractical to obtain international price data, we resorted to using the three sets of price assumptions in Table 2.2. The three sets differ only in the values adopted for the basic prices of goods (includes services) produced for domestic use (type 1 goods).

In all three sets, the initial basic prices of exports (type 2 goods) are 1. With the input-output data being presented in a common currency ($US), this amounts to assuming that a shipment of plastics, for example, that is exported from China and has a value of $US1 at the Chinese factory door represents the same quantity of plastics as a shipment from Australia or ROW that has a value of $US1 at the doors of the Australian and ROW factories. Ideally, we should make the common price assumption apply to shipments once they have reached a notional world central point. However, at present we do not have suitable data on transport costs to make the world-central-point assumption operational: we know transport costs between countries but not to a central point. The initial basic price of a unit of imports is the initial basic price of a unit of exports (that is, one) *plus* export taxes per unit charged by the exporting country *plus* tariffs per unit charged by the importing country *plus* transport costs per unit between the two countries.

In making assumptions about the initial basic prices of domestically oriented goods (type 1 goods), we imagined that we have data showing that the PPP for China relative to ROW is 2. In our first set of assumptions, labelled PPP-1, we set the initial basic prices of domestically oriented goods in China at 0.5, and those in Australia and ROW at 0.9 and 1.0. With these values, our input-output data gives a PPP value for China relative the ROW of close to 2 and a PPP value of Australia relative to ROW of a little over 1.

A problem with the PPP-1 assumptions is that they make too sharp a distinction between non-services produced for the domestic market and non-services produced for export. For example, it is probably unreasonable to suppose that the basic price of a tonne of Chinese rice

Table2.2. Assumptions concerning initial prices

	Australia	China	ROW
First set of assumptions, PPP-1, used in simulation 1			
Basic prices of exports (type 2 goods)	1	1	1
Basic prices of domestic (type 1) services	0.9	0.5	1
Basic prices of domestic (type 1) non-services	0.9	0.5	1
Wage rates of skilled labour	0.9	0.1	1
Wage rates of unskilled labour	0.45	0.05	0.5
Purchasing power parity, China/ROW	-	2.0	-
Second set of assumptions, PPP-2, used in simulations 2 – 6			
Basic prices of exports (type 2 goods)	1	1	1
Basic prices of domestic (type 1) services	0.9	0.25	1
Basic prices of domestic (type 1) non-services	1	0.75	1
Wage rates of skilled labour	0.9	0.1	1
Wage rates of unskilled labour	0.45	0.05	0.5
Purchasing power parity, China/ROW	-	2.0	-
Third set of assumptions, MER, used in simulation 7			
Basic prices of exports (type 2 goods)	1	1	1
Basic prices of domestic (type 1) services	1	1	1
Basic prices of domestic (type 1) non-services	1	1	1
Wage rates of skilled labour	0.9	0.1	1
Wage rates of unskilled labour	0.45	0.05	0.5
Purchasing power parity, China/ROW	-	1.0	-

produced for the domestic market (type 1 rice) is half that of a tonne of Chinese rice produced for export (type 2 rice). Initially, we attempted to redress this problem by adopting the lower basic prices (0.5 in China and 0.9 in Australia) only for domestically oriented (type 1) services (what we will refer to as non-traded goods). For all agricultural, mineral and manufactured goods (what we will refer to as traded goods) we assumed that basic prices are one in all countries for both the type 1 and type 2 varieties. However, this produced a low value, 1.3, for China's PPP relative to ROW. If we assume that type 2 traded goods have the same basic prices in developed and developing countries, then it is difficult to produce realistically high values for PPP's for developing countries without assuming that type 1 traded goods in these countries have lower $US prices than type 1 traded goods in developed countries. Even when we assumed that basic prices of type 1 services are as low as 0.25 in China, the China/ROW PPP remained too low (about 1.7). In the end, for our second set of price assumptions, labelled PPP-2, we assumed that the prices of type 1 non-traded goods in China are 0.25, that the prices of type 1 traded goods in China are 0.75 and that the prices of all type 2 goods in China are 1. Under these assumptions the

China/ROW PPP is at our imagined observed value of 2, the same as under the PPP-1 assumptions.

In the third set of assumptions, we ignore the PPP idea and set the initial basic prices of all goods at 1 in all countries. By comparing results from simulations derived under the third set of assumptions with those derived under the first two, we will be able to illustrate the implications of using MER in convergence analysis rather than PPP.

In all sets of assumptions we fix the wage of skilled labour at twice that of unskilled labour in all countries. We assume that wage rates for both types of labour are much lower in China (the developing country) than in Australia and ROW (the developed countries). While we are confident that our wage assumptions are qualitatively realistic, we recognise that with additional effort these assumptions could be fine tuned via empirical research.

With the commodity-price assumptions in place, we can compute quantities of material inputs and quantities of outputs from the input-output flows [V1BAS, MAKEDOM and MAKEEXP] in Table 2.1. To measure quantities of primary-factor inputs, we use unskilled labour equivalents. The unskilled labour equivalent of the primary factor input to industry i in country z is the total returns to primary factors in (i,z) divided by the unskilled wage rate in z. Thus we assume that if the unskilled equivalent of primary-factor inputs to industry i in country z is twice that to industry j in country y, then (i,z) uses twice as much primary factors as (j,y).

Deducing the starting values for the technology variables

We define the quantity of output in industry i in country z as the sum of the quantities of type 1 and type 2 goods produced by the industry:

$$Y_{iz} = Y_{1iz} + Y_{2iz} \quad \text{for all i, z} \tag{2.8}$$

where

Y_{iz} is the output of industry i in country z;

Y_{1iz} is the output of good i of type 1 in country z; and

Y_{2iz} is the output of good i of type 2 in country z.

Equation (2.8) is a natural definition of output for industry i in ROW: a unit of the two types of goods produced by industry i in ROW has the same price. By adopting (2.8) for the other two countries, we are ensuring that if industry i in China, for example, produces the same number of units of good i type 1 and good i type 2 as are produced in ROW, then we record the output of industry i in China as being the same as the output of industry i in ROW.

Similarly, we define the quantity of input of commodity c into industry i in country z as a sum of the quantities of domestically produced and imported c:

$$X_{ciz} = X(c, dom, i, z) + X(c, imp, i, z) \quad \text{for all c, i, z} \tag{2.9}$$

where

X_{ciz} is the quantity of commodity c used by industry i in country z;

$X(c, dom, i, z)$ is the quantity of domestic commodity c used by industry i in country z; and

$X(c, imp, i, z)$ is the quantity of imported commodity c used by industry i in country z.

Equation (2.9) is a natural corollary of (2.8). Via (2.8) we have already assumed that a unit of good c of either type 1 or 2 produced in any country counts as a unit of good c.

Having determined the initial quantities of industry outputs, Y_{iz}, and industry inputs, X_{1iz}, …, X_{niz}, we now move to the determination of the initial values of the technology variables, $A_{hiz}(0)$ and $B_{kiz}(0)$. In our three-country model, the F_i functions in (2.1) have the Leontief form. Without loss of generality we adopt the convention that the initial values of the industry activity levels [the $V_{iz}(0)$s in (2.1)] are the same as the industry outputs, the Y_{iz}s. In these circumstances the $A_{hiz}(0)$s are simply the initial levels of inputs per unit of output:

$$A_{hiz}(0) = X_{hiz}(0) / Y_{iz}(0) \quad \text{for all h, i, z} \quad . \tag{2.10}$$

The G_i functions in (2.2) have the CET form:

$$Y_{iz}(0) = \left[\sum_{k=1}^{2} \{B_{kiz}(0) * Y_{kiz}(0)\}^{-\rho_{iz}} \right]^{-1/\rho_{iz}} \quad \text{for all i, z} \quad , \tag{2.11}$$

where

ρ_{iz} is a parameter with value less than -1, that controls the degree of transformability between the two types of good i in the production process of industry i in country z.

We set ρ_{iz} at -1.333 for all i and z. This gives transformation elasticities of 3, implying that producers can readily switch their production between domestic and export goods. With values already in place for $Y_{iz}(0)$ and $Y_{kiz}(0)$, we can use (2.11) to deduce $B_{kiz}(0)$ for all k,i,z.

3. Results

In this section we report results from seven simulations conducted with our three-country model. Each simulation consists of two runs: a basecase and a "policy". For this paper the basecase depicts a bland situation in which developments in technology variables in Australia, China and ROW are similar. In the policy runs, we assume that the A_{hiz} variables for China converge to those of ROW over 100 years. However, it does not seem informative to use our model for projections over a period this long. Consequently, we confine ourselves to reporting deviations in variables (differences between the basecase and policy results) caused by convergence 25 years into the process.

3.1. Multi-factor productivity gaps

Equation (2.10) generates initial values for 58 input technology variables [the A(0)s, 57 material inputs and 1 composite primary factor] in each industry in each country. In our convergence simulations we move all 58 variables for each industry i in China towards the values of these variables in ROW. Thus our convergence simulations give the effects of moving 58 x 57 variables. For presentation purposes, we have computed an overall indicator of the assumed movement in the technology of industry i in China by looking at a cost-weighted average of the movements in the industry's 58 A_{hiz}s. These indicators are shown in columns (1), (2) and (3) in Table 3.1. The first entry in column (1) indicates that in year 0 (1998) multi-factor productivity in the Chinese paddy rice industry was 29 per cent of that in ROW, where multi-factor productivity is the quantity of output per unit of inputs. The estimates in column (1) were made with quantities computed under our first set of price assumptions, PPP-1. Column (2) and (3) show ratios of Chinese to ROW multi-factor productivity with quantities computed under our second and third sets of price assumptions, PPP-2 and MER.

Each of our simulations can be thought of as generating the effects of movements in the numbers in columns (1), (2) or (3) towards one.[3] As already mentioned, we report the effects of these movements after 25 years of a 100 year process. In simulations using the technology estimates based on PPP-1, for example, we can think of multi-factor productivity in China's industry i as increasing at a rate x_i percentage points per annum faster than in the basecase where x_i satisfies

[3] But we should reemphasize that the simulations involve exogenous movements in all of the A_{hiz}s for z = China.

Table 3.1. Ratios of multi-factor productivities in China to those in Rest of world (ROW), and export shares in Chinese output and import shares in Chinese absorption

Commodity/industry			Technology ratios, China/ROW, estimated under			Data for 1998 (year 0)	
No.	code	Name	PPP-1 used in sim 1 (1)	PPP-2 used in sims 2-6 (2)	MER used in sim 7 (3)	Export share, % (4)	Import share, % (5)
1	pdr	Paddy rice	0.29	0.21	0.18	0.43	0.01
2	wht	Wheat	0.28	0.22	0.20	0.16	6.56
3	gro	Cereal grains nec	0.32	0.23	0.20	7.26	5.80
4	v_f	Vegetables, fruit & nuts	0.32	0.23	0.21	1.61	0.94
5	osd	Oil seeds	0.29	0.20	0.17	3.56	19.02
6	c_b	Sugar cane & beet	0.30	0.21	0.19	0.09	0.06
7	pfb	Plant-based fibres	0.45	0.32	0.33	0.06	16.84
8	ocr	Crops nec	0.21	0.16	0.15	34.93	16.72
9	ctl	Cattle, sheep, goats & horses	0.30	0.23	0.20	0.96	0.13
10	oap	Animal products nec	0.36	0.29	0.26	2.05	1.20
11	rmk	Raw milk	0.26	0.20	0.17	0.28	0.24
12	wol	Wool & silk worms	0.12	0.09	0.07	1.55	11.48
13	for	Forestry	0.29	0.19	0.18	1.09	7.32
14	fsh	Fishing	0.26	0.19	0.17	2.61	0.53
15	col	Coal	0.29	0.21	0.21	10.95	0.89
16	oil	Oil	0.23	0.16	0.14	13.00	21.61
17	gas	Gas	0.20	0.17	0.16	31.82	0.00
18	mn	Minerals nec	0.42	0.29	0.31	2.15	7.92
19	cmt	Meat: cattle, sheep, goats & horses	0.43	0.27	0.38	3.15	13.34
20	omt	Meat products nec	0.53	0.49	0.51	9.67	8.66
21	vol	Vegetable oils & fats	0.61	0.50	0.56	4.91	30.63
22	mil	Dairy products	0.31	0.19	0.26	4.17	21.79
23	pcr	Processed rice	0.32	0.25	0.25	0.82	0.83
24	sgr	Sugar	0.37	0.35	0.37	21.75	39.44
25	ofd	Food products nec	0.30	0.28	0.28	12.16	8.02
26	b_t	Beverages & tobacco products	0.35	0.27	0.26	2.62	4.16
27	tex	Textiles	0.53	0.44	0.46	17.47	20.11
28	wap	Wearing apparel	0.38	0.35	0.38	48.61	9.31
29	lea	Leather products	0.39	0.38	0.45	54.94	14.99

Table 3.1 continued …

Table 3.1 continues …

No.	code	Name	Technology ratios, China/ROW, estimated under: PPP-1 used in sim 1 (1)	PPP-2 used in sims 2-6 (2)	MER used in sim 7 (3)	Data for 1998 (year 0): Export share, % (4)	Import share, % (5)
30	lum	Wood products	0.49	0.40	0.43	19.13	8.70
31	ppp	Paper products & publishing	0.42	0.32	0.33	4.14	16.57
32	p_c	Petroleum & coal products	0.65	0.54	0.54	3.45	13.74
33	crp	Chemical, rubber & plastic prods	0.52	0.42	0.44	10.57	20.26
34	mp	Mineral products nec	0.49	0.36	0.39	5.01	3.78
35	i_s	Ferrous metals	0.57	0.44	0.49	5.97	13.28
36	nfm	Metals nec	0.56	0.45	0.50	8.12	19.39
37	fmp	Ferrous metal products	0.56	0.44	0.49	12.47	6.55
38	mv	Motor vehicles & parts	0.60	0.49	0.50	3.84	12.88
39	otn	Transport equipment nec	0.54	0.45	0.46	12.81	17.66
40	ele	Electronic equipment	0.53	0.47	0.50	44.79	45.32
41	ome	Machinery & equipment nec	0.53	0.43	0.45	16.45	23.22
42	omf	Manufactures nec	0.30	0.26	0.28	39.08	7.51
43	ely	Electricity	0.46	0.83	0.37	0.61	0.02
44	gdt	Gas manufacture & distribution	0.23	0.41	0.18	1.79	0.00
45	wtr	Water	0.35	0.61	0.24	0.23	0.66
46	cns	construction	0.45	1.02	0.36	0.26	0.72
47	trd	Wholesale & retail trade	0.33	0.62	0.24	5.00	4.89
48	otp	Road & rail transport	0.29	0.58	0.20	8.92	7.76
49	wtp	Water transport	0.24	0.43	0.23	39.11	17.52
50	atp	Air transport	0.23	0.37	0.23	56.58	37.97
51	cmn	Communication	0.22	0.44	0.14	1.86	2.03
52	ofi	Financial services nec	0.27	0.46	0.17	0.31	1.66
53	isr	Insurance	0.24	0.38	0.18	8.19	18.34
54	obs	Business services	0.24	0.48	0.17	4.62	6.71
55	ros	Recreation & other services	0.29	0.55	0.22	0.52	4.47
56	osg	Government services	0.34	0.63	0.25	0.89	1.21
57	dwe	Ownership of dwellings	0.29	0.42	0.18	0.00	0.00
		Averages	**0.42**	**0.47**	**0.35**	**10.44**	**10.72**

$$r_i\left(1+\frac{x_i}{100}\right)^{100}=1 \quad , \tag{3.1}$$

and r_i is the entry for industry i in column (1). Thus, we can think of our 25-year results as showing the effects of increases in multi-factor productivity in China given by

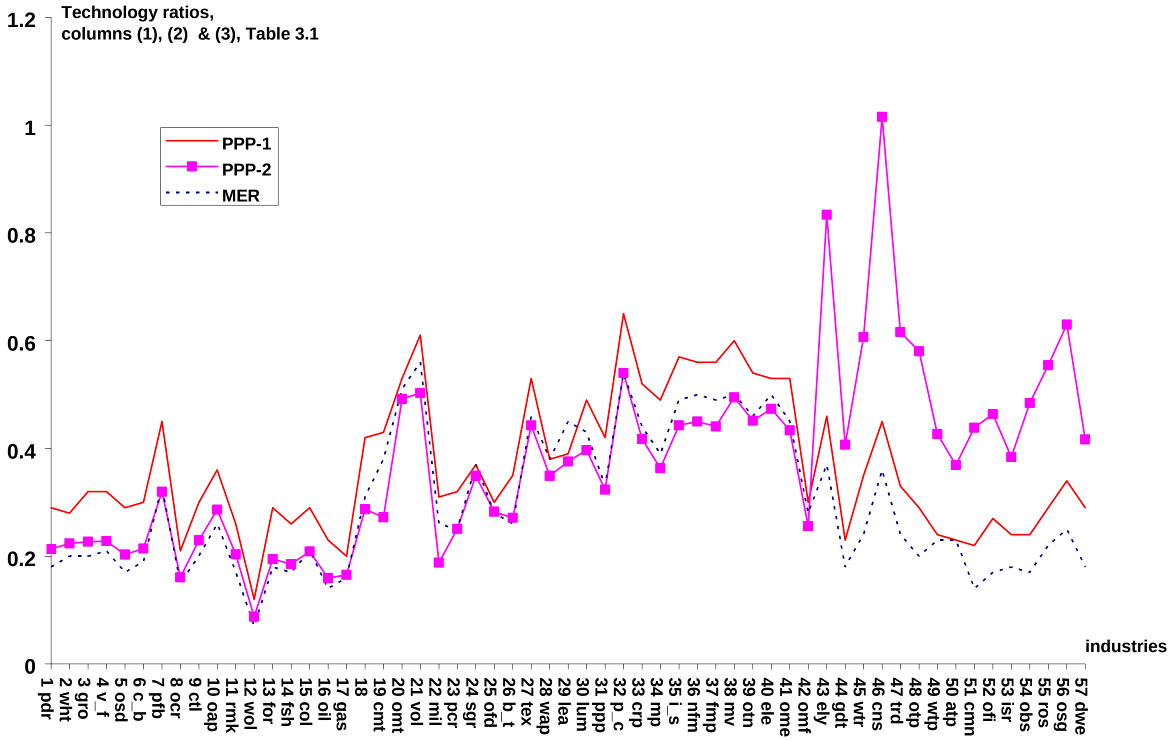
$$\%\Delta \text{ for ind } i = 100 * (r_i^{-1/4} - 1) \quad .[4] \tag{3.2}$$

The technology ratios in column (1) of Table 3.1, estimated under PPP-1 assumptions, lie between 0.12 (for Wool & silk worms, industry 12) and 0.65 (for Petroleum & coal products, industry 32), with the average ratio being 0.42. As can be seen from Figure 3.1, the column (1) technology ratios are predominantly higher than those in column (3), estimated under MER assumptions. Under the price assumptions in Table 2.2, the movement from PPP-1 to MER: (a) halves the estimated quantity of type 1 goods produced by each Chinese industry; and (b) halves the estimated quantity of domestically produced material inputs used by each Chinese industry. The technology ratios are reduced as we move from PPP-1 to MER because effect (a) generally outweighs effect (b). However, this is not true for all industries. The entry for Leather products (industry 29) in column (3) of Table 3.1 is greater than that in column (1). Leather products is highly export-oriented [an export share of 54.94 per cent, column (4)] and has a heavy reliance on domestically produced intermediate inputs. For this industry, the reduction in the estimated quantity of material inputs as we move from PPP-1 to MER outweighs the reduction in the estimated quantity of its overall output. Perhaps more important than the specific case of Leather products is the idea that the move from PPP-1 to MER involves counteracting forces on estimates of multi-factor productivity. Thus, the differences in the estimates derived under these two assumptions are not as dramatic as we initially expected.

As can also be seen from Figure 3.1, the column (1) technology ratios for traded goods (agriculture, mining and manufacturing, industries 1 to 42) are predominantly higher than those in column (2), estimated under PPP-2 assumptions. Under the price assumptions in Table 2.2, the movement from PPP-1 to PPP-2: (a) reduces the estimated quantity of type 1 goods produced by each Chinese traded-goods industry by 33 per cent; and (b) reduces the estimated quantity of the bulk of material inputs (domestically produced traded goods) used by Chinese industries by 33 per cent. Again, force (a) generally outweighs force (b). With forces (a) and (b) operating

[4] For simulation 6 we adopt a variation of equation (3.1). We assume that convergence is faster for traded-goods sectors allowing the gap between Chinese and ROW technology to close in 50 years.

Figure 3.1. Comparison of estimates of technology ratios for Chinese industries in 1998



in a similar way in the move from PPP-1 to PPP-2 as they did in the move from PPP-1 to MER, the technology ratios for traded goods industries under PPP-2 are quite close to those under MER.

For non-traded-goods industries (43 to 57), the move from PPP-1 to PPP2 approximately doubles estimated outputs. For most non-traded industries there is also a reduction in estimated material inputs (the bulk of their inputs are from traded-goods industries). Thus, in the move from PPP-1 to PPP-2, there are substantial increases in the technology ratios for non-traded industries. These increases are sufficient to outweigh the decreases for traded-goods industries: the average technology ratio under PPP-2 assumptions is 0.47, up from 0.42 under PPP-1 assumptions.

3.2. Overview of simulations

Table 3.1 sets out the main features of the assumptions underlying our seven simulations. The simulations vary in five respects corresponding to columns (1) to (5):

Column (1). We examine 3 possibilities corresponding to PPP-1, PPP-2 and MER in Table 2.2. In simulation 1 we estimate technologies for the initial year, 1998, with prices set according to PPP-1. In simulations 2, 3, 4, 5 and 6 we adopt PPP-2. In simulation 7 we adopt the MER.

Table 3.1. Overview of simulation assumptions

Simulation number	Estimation of technologies: initial prices (1)	Export bias in tech change (2)	Terms of trade (3)	Capital/GDP ratio (4)	Time for closing of tech gap (5)
1	PPP-1	No	Endogenous	Endogenous	100 years
2	PPP-2	No	Endogenous	Endogenous	100 years
3	PPP-2	Yes	Endogenous	Endogenous	100 years
4	PPP-2	Yes	Fixed	Endogenous	100 years
5	PPP-2	Yes	Fixed	Approx. fixed	100 years
6	PPP-2	Yes	Fixed	Approx. fixed	50 years for tradeables
7	MER	Yes	Fixed	Approx. fixed	100 years

Column (2). As will be explained later in section 3 in connection with Figure 3.3, when we allow for export bias we are allowing China to improve its ability to produce commodities for export (type 2 commodities) relative to commodities for the domestic market (type 1 commodities).

Column (3). As we will see, simulations 1 to 3 imply that technological catch up will cause sharp deterioration in China's terms of trade. In simulations 4 to 7, we assume that the preferences of China's trading partners move sufficiently in China's favour so that there is no deterioration in China's terms of trade.

Column (4). As we will see, simulations 1 to 4 imply that technological catch up will cause a reduction in the ratio of China's capital stock to GDP. In simulations 5 to 7, we impose extra technical change in the creation of capital goods. This reduces the cost of using capital sufficiently to leave China's K/GDP ratio approximately unaffected by technological catch up.

Column (5). In simulation 6 we adopt faster technology convergence for China's tradeables than in simulations 1 to 5 and 7.

Comparison of simulations 1 and 2 will show the effects of softening the sharp distinctions imposed in simulation 1 between the initial prices of non-export (type 1) and export (type 2) varieties of traded goods.

Comparison of simulations 2 and 3 will show the effects of assuming, in accordance with Balassa (1964), that China achieves relative technology improvements in producing for export.

Comparison of simulations 3 and 4 will show the effects of eliminating catch-up induced deterioration in China's terms-of-trade.

Comparison of simulations 4 and 5 will show the effects of eliminating catch-up induced reduction in China's K/GDP ratio.

Comparison of simulations 5 and 6 will show the effects of speeding up Chinese convergence for tradeables.

Comparison of simulations 5 and 7 will show the effects of ignoring the PPP issue and simply adopting MER in the estimation of technology ratios.

In explaining the seven simulations, our strategy is to work through the results for simulation 1 in detail. This reveals the mechanisms in our model that are important for understanding the results. We can then explain the results for simulations 2 to 7 more briefly, concentrating on how they vary from earlier results.

3.3 Macro results

Simulation 1: Initial technology estimates for China reflect PPP-1 assumptions

In our first simulation, the only exogenous variables in the policy run that take values different from those they had in the basecase are the A_{hiz}s for z = China. Rather than moving in parallel with the A_{hiz}s for Australia and ROW, in the policy run the A_{hiz}s for China move in a way that would close the gap between them and the A_{hiz}s for ROW after 100 years. In simulation 1 the initial values of the A_{hiz}s for China were set to reflect PPP-1 assumptions [column (1) of Table 3.1]. The first column of Table 3.2 shows the macro effects after 25 years of the convergence process. The figure 75.29 in the first row of the first column, for example, should be interpreted as meaning that 25 years into a 100 year convergence process, Chinese GDP is 75.29 per cent higher than it would have been in the absence of a convergence process.

The deviations shown for simulation 1 for Australia and ROW are negligible. This reflects the smallness of the Chinese economy in relation to the world economy: in our database for 1998, Chinese GDP (converted at MER) is only about 3 per cent of world GDP. To the extent that extra technological progress in China has effects in Australia and ROW, these effects are favourable. Both Australia and ROW are shown in column (1) with small gains in private and public consumption (0.23 per cent for Australia and 0.26 per cent for ROW). These consumption gains are due mainly to terms-of-trade improvements (0.87 per cent for both Australia and ROW), reflecting the interaction of outward moving export supply curves for China with downward sloping import demand curves in Australia and ROW.

Table 3.2. Marco effects of Chinese convergence over 100 years: Percentage deviations after 25 years

	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5	Sim 6	Sim 7
Results for China							
Real GDP	75.29	61.62	63.44	63.88	96.25	150.34	148.68
Aggregate employment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aggregate capital	43.39	33.94	34.60	42.06	103.03	156.55	139.37
Investment	68.39	51.08	51.31	63.20	135.92	199.70	203.14
Private & public consumption	68.38	58.49	56.96	65.25	71.86	120.94	114.18
Export volumes	47.30	48.13	89.98	95.09	107.70	172.73	84.69
Import volumes	21.38	21.60	44.90	89.48	99.03	158.54	74.65
Real exchange rate	-9.97	0.97	15.75	58.67	40.93	74.60	-3.68
PPP (China to ROW)	10.69	7.54	-8.56	-38.54	-40.19	-48.81	-4.33
Terms of trade	-15.35	-16.32	-22.11	0.00	0.00	0.00	0.00
Real post-tax wage rate	83.35	76.30	74.02	86.29	103.28	190.89	148.27
Output of tradeables	39.71	45.57	40.55	39.55	45.75	85.67	71.47
Output of non-tradeables	60.92	37.65	40.55	43.35	50.15	71.16	103.93
Basic price of tradeables	-13.42	-17.08	-4.03	22.40	22.96	15.60	0.47
Basic price of non-tradeables	-6.50	16.32	33.36	76.52	79.58	157.25	11.21
Results for Australia							
Real GDP	0.04	0.04	0.05	-0.05	-0.01	-0.06	0.02
Aggregate employment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aggregate capital	0.10	0.10	0.14	-0.04	0.08	-0.01	0.14
Investment	0.17	0.17	0.23	-0.13	-0.01	-0.17	0.12
Private & public consumption	0.23	0.24	0.34	0.03	0.08	0.07	0.11
Export volumes	-0.09	-0.11	0.07	0.05	0.01	-0.30	-0.08
Import volumes	0.88	0.92	1.53	0.25	0.40	0.10	0.43
Real exchange rate	-0.24	-0.17	-0.29	-0.08	-0.13	-0.26	-0.09
PPP (Australia to ROW)	0.24	0.18	0.28	0.03	0.08	0.14	0.05
Terms of trade	0.87	1.00	1.45	0.21	0.26	0.25	0.25
Real post-tax wage rate	0.29	0.32	0.42	0.06	0.17	0.32	0.21
Output of tradeables	-0.31	-0.49	-0.17	-0.08	-0.03	-1.17	-0.21
Output of non-tradeables	0.13	0.18	0.12	0.04	0.09	0.38	0.17
Basic price of tradeables	-0.47	-0.47	-0.63	-0.27	-0.41	-1.00	-0.41
Basic price of non-tradeables	-0.22	-0.14	-0.35	-0.08	-0.12	-0.09	-0.03
Results for ROW							
Real GDP	0.05	0.05	0.06	-0.07	-0.04	-0.05	0.00
Aggregate employment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aggregate capital	0.12	0.11	0.14	-0.12	0.01	0.00	0.10
Investment	0.28	0.26	0.32	-0.24	-0.08	-0.04	0.11
Private & public consumption	0.26	0.26	0.39	0.08	0.13	0.21	0.14
Export volumes	0.03	-0.02	0.26	-0.01	-0.04	-0.55	-0.13
Import volumes	0.99	0.94	1.71	0.38	0.57	0.41	0.52
Real exchange rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PPP (ROW to ROW)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Terms of trade	0.87	0.92	1.45	0.47	0.58	0.91	0.49
Real post-tax wage rate	0.29	0.29	0.42	-0.01	0.10	0.18	0.16
Output of tradeables	-0.33	-0.48	-0.25	-0.39	-0.39	-1.53	-0.51
Output of non-tradeables	0.19	0.25	0.17	0.11	0.17	0.65	0.27
Basic price of tradeables	-0.26	-0.29	-0.39	-0.21	-0.29	-0.62	-0.30
Basic price of non-tradeables	-0.01	0.00	-0.09	-0.03	-0.04	0.07	0.01

The GDP deviation for China, 75.29 per cent, arises mainly from the direct effect of increased technical progress that allows more output from given levels of inputs. By putting r_i in equation (3.2) at 0.42 [the average of the entries in column (1) of Table 3.1] we find that the typical Chinese industry in the 25th year of simulation 1 experiences a 24 per cent gain in multi-factor productivity. Because GDP in China is only about 37 per cent of total inputs to industries (intermediate inputs plus primary factors), a multi-factor-productivity gain of 24 per cent across all Chinese industries translates into a GDP gain of about 64 per cent (= 24/0.37). The rest of the Chinese GDP gain is contributed by increased capital. The capital share of GDP in China is about 36 per cent, implying that the 43.39 per cent increase in capital shown for China in column (1) of Table 3.2 contributes about 15 per cent to GDP. Together, these back-of-the-envelope calculations of the technology and capital contributions to GDP sum to 79 per cent (64 plus 15), closely matching the simulation result.

For understanding the increase in China's capital stock (43.39 per cent), a useful starting point is the aggregate production function:

$$Y = \frac{1}{A} * F(K, L) \quad , \qquad (3.3)$$

where decreases in A allow for technological progress. Equilibrium in the capital market requires

$$Q = P_g * \frac{1}{A} * F_k(K/L) \quad . \qquad (3.4)$$

where

Q is the rental per unit of capital;

P_g is the price of a unit of GDP; and

F_k is the partial derivative of F with respect to K. We write F_k as a function of K/L under the assumption that F is homogenous of degree one.

Equation (3.4) can be rearranged as

$$\frac{Q}{P_i} * \frac{P_i}{P_g} = \frac{1}{A} * F_k(K/L) \quad , \qquad (3.5)$$

or

$$ROR * \frac{P_i}{P_g} = \frac{1}{A} * F_k(K/L) \quad , \qquad (3.6)$$

where

P_i is the price deflator for investment goods; and

ROR is the rate of return on capital which we represent as Q/P_i, the rental price of capital divided by the asset price.

We can think of the shocks applied in the policy run of simulation 1 as being a strong negative deviation in the A variable for China. Under our long-run assumptions (which are broadly applicable when thinking about deviations in the 25^{th} year), shocks to technology do not affect rates of return (ROR). These are set by world interest rates independently of technology changes in China. As we have already seen, extra technical change reduces China's terms of trade. Because P_i includes import prices but not export prices while P_g includes export prices but not import prices, reductions in the terms of trade generate increases in P_i/P_g. However, this effect is weak relative to the increase in 1/A. Consequently, F_k in equation (3.4) declines, implying an increase in K/L. We assume that extra technical progress in China does not affect employment (L). Thus, we understand that K must increase.

Extra technical change in China produces a sharp increase in real wages (83.35 per cent). This can be easily understood via the labour-market equilibrium condition:

$$\frac{W}{P_g} = \frac{1}{A} * F_\ell(K/L) \quad , \tag{3.7}$$

where

W is the wage rate; and

F_ℓ is the partial derivative of F with respect to L.

W/P_g must increase because A decreases and F_ℓ increases via the increase in K/L.

With an expansion in Chinese GDP of 75.29 per cent, the simulated increases in volumes of Chinese exports and imports (47.30 and 21.38 per cent) and in the output of tradeables (39.71 per cent) are quite subdued.[5] Expansion of Chinese exports is checked by reductions in prices (movements down the demand curves of trading partners) reflecting limited capacity of the world economy to absorb additional products from China. The movement in imports can be thought of as being determined in the equation:

$$Y = C + I + G + X - M \quad . \tag{3.8}$$

[5] At first glance it may seem surprising that the percentage increases in the outputs of both tradeables and non-tradeables (39.71 and 60.92) are less than the percentage increase in GDP (75.29). This is explained in subsection 3.4.

With the percentage increases in C and G being less than that in Y (mainly because of the decline in the terms of trade) and with the percentage increase in I also being less than that in Y (mainly because the fixity of L means that K does not increase in line with Y), equation (3.8) implies that the increase in M must be less than that in X. To hold the increase in M below the already subdued increase in X, our model indicates that China would undergo considerable real devaluation (9.97 per cent), where we measure the movement in China's real exchange rate by the movement in China's GDP deflator relative to that of ROW.[6] [Without loss of generality, we hold nominal exchange rates fixed].

As can be seen in column (1), extra technical change in China causes PPP for China relative to ROW to increase by 10.69 per cent, that is the U.S. dollar cost of a standard bundle of consumer goods in ROW increases by 10.69 per cent relative to the U.S. dollar cost of the same bundle in China. The real exchange rate movement means that the GDP deflator for China falls by 9.97 per cent relative to the GDP deflator for ROW. With terms-of-trade decline, we expected the price deflator for consumption in China to rise significantly relative to the price deflator for GDP, and consequently we expected the percentage increase in PPP for China relative to ROW to be considerably smaller than the absolute percentage movement in the real exchange rate. However, despite the reduction in the terms of trade, our results show little change in China's price deflator for consumption relative to the price deflator of GDP, and therefore little difference in the absolute values of the movements in the real exchange rate and PPP. It happens that the technical changes assumed for China in the policy run of simulation 1 are relatively concentrated in consumer goods industries thereby lowering the price deflator for private consumption relative to the price deflators of other components of GNE, especially public consumption.

While the result in simulation 1 for China's PPP relative to ROW is understandable in terms of our model, it raises questions concerning the realism of our simulation. In accordance with the Balassa (1964) hypothesis that high PPP values for developing countries are a reflection of technological backwardness in export-oriented industries, we expected that with convergence China's PPP relative to ROW would move towards one. In simulation 1, China's PPP relative to ROW has a value of 2.57 in the 25th year of the basecase run[7]. Rather than moving towards 1 in

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[6] The movement in a country's real exchange rate is sometimes defined as the movement in the ratio of its tradeable-goods prices to its non-tradeable-goods prices. Under this definition, simulation 1 implies a devaluation in China's real exchange rate of 7.4 per cent [= 100*((1-0.1342)/(1-0.0650)-1), see the results in column (1) of Table 3.2 for the basic prices of tradeables and non-tradeables in China].

[7] This means that in the 25th year of the basecase run the U.S. dollar cost of a standard bundle of consumer goods in ROW is 2.57 times U.S. dollar cost of the same bundle in China. As mentioned earlier, PPP for China relative to

the policy run, it is moved by additional technical change to an even higher value (2.84 = 2.57*1.1069). The problem is that the additional technical change assumed in the policy run of simulation 1 is not concentrated on export-oriented activities. The industries benefiting from the greatest additional technological progress are those that initially have the lowest technology ratios. But as we can be seen in Figure 3.2, the initial technology ratios are not correlated with export shares.

Simulation 2: Initial technology estimates for China reflect PPP-2 assumptions

As explained in subsection 3.1 and illustrated in Figure 3.1, the technology ratios for China are lower for traded-goods industries (1 to 42) when initial prices are set according to PPP-2 rather than PPP-1. However, all non-traded-goods industries (43 to 57) have higher technology ratios under PPP-2 than under PPP-1, giving PPP-2 a higher average over all industries than PPP-1 (0.47 compared with 0.42, last row of Table 3.1). Thus in simulation 2 (where PPP-2 applies), China has less to catch up than in simulation 1 (where PPP-1 applies).

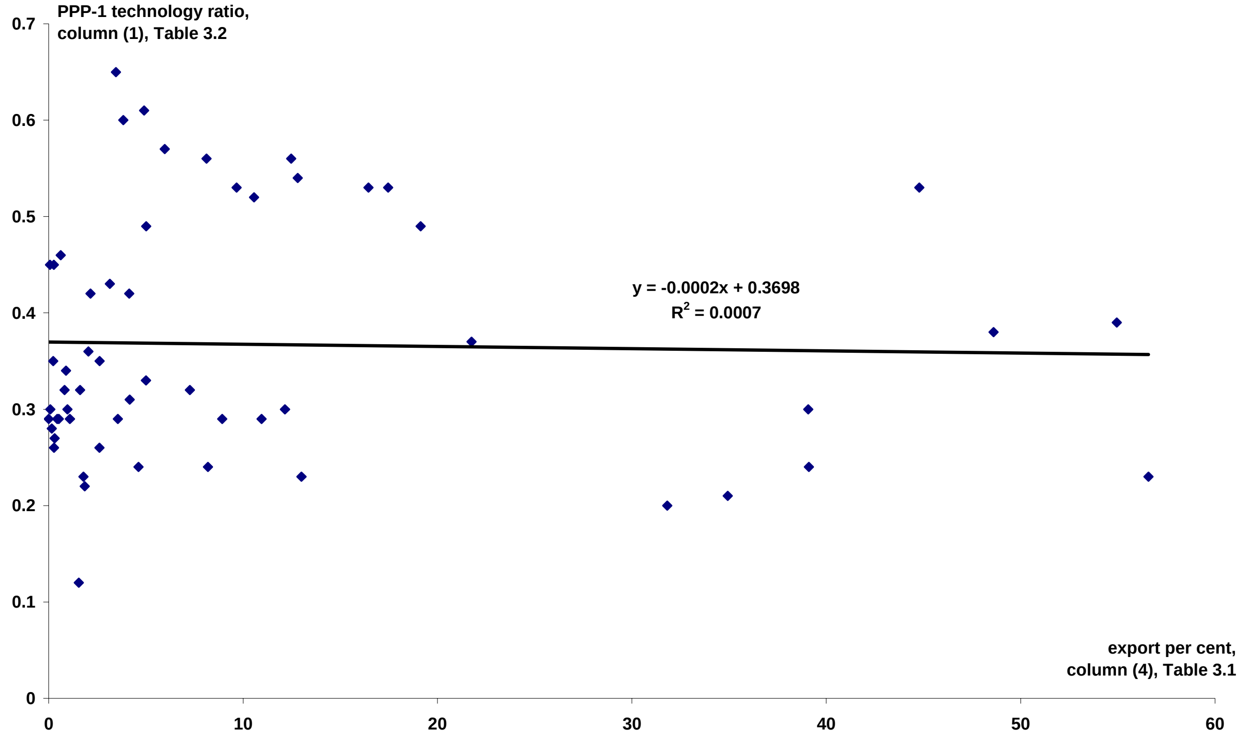
With less catch up, the GDP deviation for China is 18 per cent lower [= 100*(61.62/75.29 - 1)] in simulation 2 than in simulation 1 (see Table 3.2). Consistent with a smaller GDP deviation, simulation 2 also shows smaller deviations for aggregate capital, private and public consumption, investment and the output of non-tradeables. With catch up in PPP-2 being larger for traded goods than in PPP-1 and smaller for non-traded goods, simulation 2 shows larger increases in exports and the output of tradeables than simulation 1. Simulation 2 also shows a much sharper increase in the price of non-tradeables relative to tradeables than simulation 1 [33.40 percentage points (= 16.32+17.08) compared with 6.92 percentage points (= -6.50+13.42)]. Correspondingly, simulation 2 shows a stronger real exchange rate movement than simulation 1 (0.97 compared with -9.97). The difference in real exchange rate movements allows the import deviation in simulation 2 to be slightly higher than in simulation 1 (21.60 per cent compared with 21.38 per cent) despite the lower GDP deviation in simulation 1. The stronger real exchange rate underlies the smaller increase in the China/ROW PPP in simulation 2 than in simulation 1.

Simulation 3: PPP-2 assumptions plus bias towards exports in Chinese technology catch up

As already explained, we assume in simulations 1 and 2 that China is particularly inefficient relative to ROW and Australia in the production of the exportable (type 2) variety in all industries. With convergence we would expect this bias against exportables to gradually disappear.

ROW is 2 in the first year of the basecase. For reasons that we have not identified, PPP drifts up by about 1 per cent a year in the basecase.

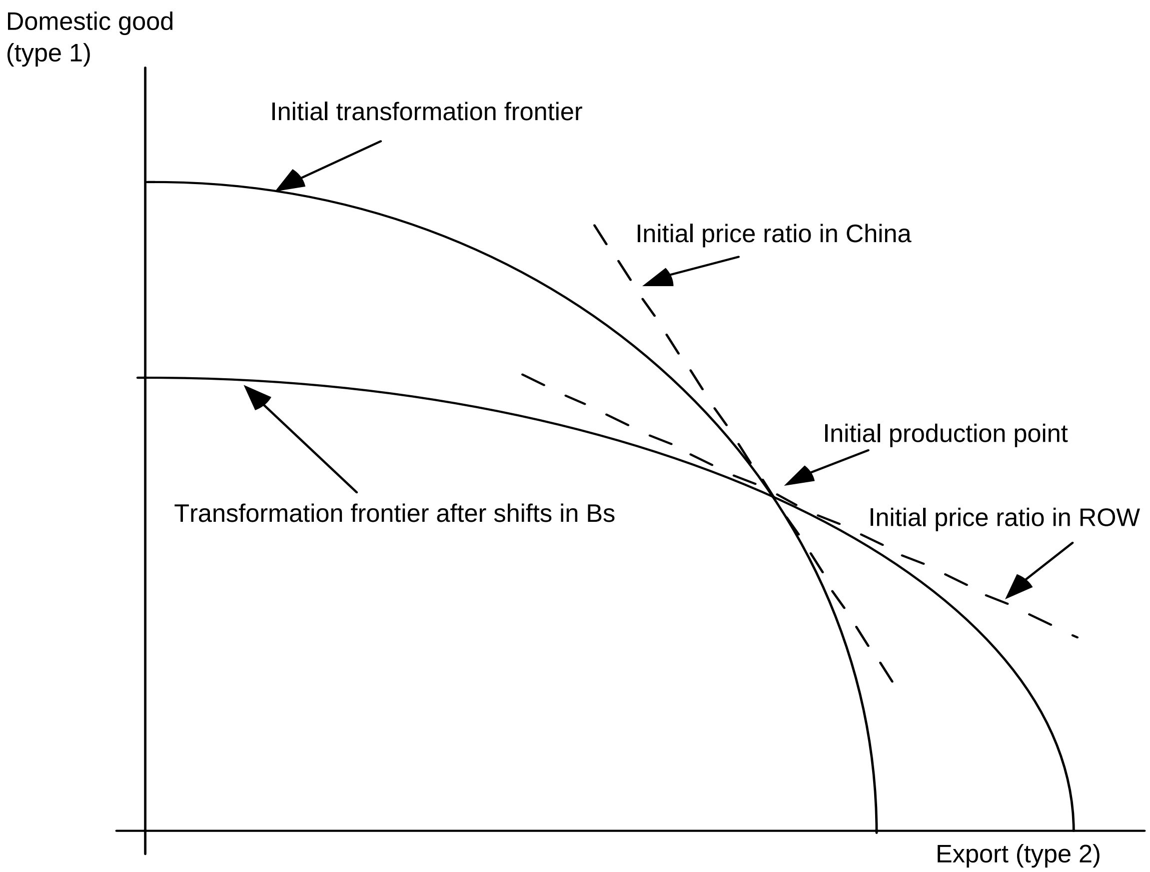
Figure 3.2. Technology ratios under PPP-1 and export shares for Chinese industries in 1998



To simulate the effects of improvements in China's technology for producing type 2 goods relative its the technology for producing type 1 goods, we add to our policy run of simulation 2 shocks to the B_{kiz}s for z = China. These additional shocks are cost neutral, that is for each Chinese industry i we make offsetting movements in B_{1iz} and B_{2iz} so that these movements do not impart extra overall technical change. They simply change the shape of industry transformation frontiers to favour the production of type 2 goods relative to the production of type 1 goods. We phase in the B movements over 25 years. As illustrated in Figure 3.3, they change the shape of the Chinese transformation frontier for industry i [equation (2.11)] so that its slope ($-P_{2iz}/P_{1iz}$) at the 1998 production point moves from its initial value (-1.33 for traded goods and -4.0 for non-traded goods) to -1.0 (the initial value for ROW).

As can be seen by comparing column (3) in Table 3.2 with column (2), the main macro implication of including export bias in the movements in Chinese technology is to increase the simulated effect of convergence on the volumes of Chinese trade. Chinese exports now increase by 89.98 per cent rather than 48.13 per cent. Additional real appreciation is necessary in simulation 3 (15.75 per cent compared with 0.97 in simulation 2) to provide extra stimulation to

Figure 3.3. Transformation frontier for industry i in China



Chinese imports in line with the technology-induced extra stimulation of Chinese exports. Chinese imports now increase by 44.90 per cent rather than 21.60 per cent. Corresponding to the more dramatic increase in the volume of Chinese trade, we see a sharper reduction in the Chinese terms of trade in simulation 3 than in simulation 2 (22.11 per cent rather than 16.32 per cent). This in turn generates greater gains for Australia and ROW, with the increases in consumption in these two areas now being 0.34 and 0.39 per cent rather than 0.24 and 0.26 per cent.

As expected, the export bias for China's technology catch up moves its PPP towards one. However, the movement (-8.56 per cent) is quite muted. While, in accordance with Balassa (1964), the relative improvement in Chinese technology for producing exportables reduces PPP, the associated additional deterioration in China's terms of trade has the opposite effect.

Simulation 4: PPP-2 assumptions plus export bias plus outward movement foreign demand curves for Chinese exports (no terms-of-trade effect)

Terms-of-trade decline for China in our first three convergence simulations is a consequence of the Armington assumption (Armington, 1969, 1970), an assumption that has been used in nearly all CGE models since the first version of ORANI (Dixon *et al.*, 1977). Under the Armington assumption, countries are viewed as producing distinctive varieties of each good. Thus each country faces downward-sloping demand curves for its products. This implies that rapid expansion of a country's economy relative to the economies of other countries, with consequent rapid expansion of its exports, must be accompanied by deterioration in its terms of trade.

The Armington assumption has been popular for many years. It serves the useful purpose of preventing CGE models from implying unrealistically large fluctuations in the shares of imports in domestic markets in response to changes in the relative prices of imported and domestic commodities. However, there seems little evidence that countries with rapidly expanding economies suffer long-term deterioration in their terms of trade. Consequently, we looked for a way to retain the Armington assumption but avoid its terms-of-trade implications.

In simulations 4 to 7 we did this by assuming that as part of the convergence scenario, China achieves favourable twists in the preferences of Australia and ROW. These twists generate outward movements in the demand curves of Australia and ROW for Chinese products. Such twists could be explained if, in the convergence process, China improved its marketing efforts, improved the quality of its products and improved its reliability as a source of supply.

The only difference in the inputs to simulation 4 compared with those in simulation 3 are twists in favour of Chinese goods that allow China's terms of trade to remain unchanged despite rapid growth in exports. As can be seen by comparing the results in Table 3.2 for simulations 3 and 4, the elimination of deterioration of China's terms of trade transfers consumption from Australia and ROW to China. In simulation 4, China's consumption deviation is 65.25 per cent, compared with 56.96 per cent in simulation 3. The Australian and ROW consumption deviations fall from 0.34 and 0.39 per cent in simulation 3 to 0.03 and 0.08 per cent in simulation 4.

With no deterioration in its terms of trade, China has a higher capital deviation in simulation 4 than in simulation 3 [see equation (3.6)], giving it higher investment and GDP deviations. As would be expected on the basis of a standard trade diagram showing the transformation frontier between exportables and importables, the elimination of terms-of-trade deterioration in simulation 4 is trade creating for China, giving it increased deviations in exports and particularly in imports.

However, the most dramatic effects a we go from simulation 3 to simulation 4 are on the price variables. In simulation 4 we can at last see a clear Balassa effect. The China/ROW PPP declines by 38.54 per cent (from 2.57 in the 25th year to 1.58). The appreciation in China's real exchange rate is 58.67 per cent, up from 15.75 per cent in simulation 3, and the increase in the ratio of non-traded to traded good prices is 44.22 per cent [=100*(1.7652/1.2240-1)], up from 38.96 per cent in simulation 3.

Simulation 5: *PPP-2 assumptions plus export bias plus outward movement foreign demand curves plus technical progress in capital creation (capital grows approximately with GDP)*

Young (e.g. 1992) and Krugman (1994) argue that convergence is largely a matter of rapid accumulation of factors. We have taken the view that it is largely a matter of technical change. To some extent this is a semantic difference rather than a difference in substance. Young and Krugman think of education as a primary factor input. They point out that developing countries on convergence paths have achieved rapid growth in output partly through large increases in inputs of educated labour. In our framework, an increase in the use of educated labour appears as a labour-augmenting technical change, that is a technical change that turns an hour of labour into the equivalent of *x* hours of labour where *x* is greater than one, a number such as two for example. Young and Krugman also point out that convergence is sometimes associated with sharp increases in labour-force participation rates. Participation rates are already very high in China and it is doubtful that they will increase further during the Chinese convergence process. However, the issue needs to be investigated for other developing countries.

One respect in which our results in simulations 1 to 4 seem clearly at odds with the experience described by Young and Krugman is the decline in China's capital to GDP ratio. In each of these simulations, technical improvements in China provide a considerably greater percentage boost to GDP than to capital, whereas on the basis of the factor-accumulation explanation of convergence, we would expect the capital stock to grow at least as fast as GDP.

Within the CGE framework, there are at least two avenues by which we can obtain convergence results with capital growth in the converging countries keeping pace with GDP growth. One possibility is to assume that convergence is associated with reductions in investment risk in developing countries, perhaps achieved by greater openness and transparency in microeconomic regulations. Another possibility is to assume that there is rapid technological improvement in developing countries in the creation of units of capital. We found that the existing version of our model will need some adaptations before it can used conveniently to analyse the first possibility (reductions in risk premia). However, we were able to simulate the effects of the second possibility (reductions in the cost of creating units of capital).

In simulation 5 we introduce sufficient cost reductions in China's capital formation to allow capital to grow approximately in line with GDP. These cost reductions are the only inputs to simulation 5 beyond those in simulation 4.

By comparing simulation 5 results for China with those for simulation 4 we see that extra capital accumulation is accompanied by strongly increased deviations in GDP (96.25 per cent compared with 63.88 per cent) and investment (135.92 compared with 63.20). By contrast, the increase in the consumption deviation (from 65.25 to 71.86) is modest. The technical change in capital creation that we have introduced in simulation 5 sharply reduces the price of capital goods in China relative to the price of consumption goods. Thus, in this simulation, the increase in real GDP overstates the capacity of the Chinese economy to increase consumption.

As we go from simulation 4 to simulation 5, there is little change in the gap between exports and imports: in the two simulations the deviations in exports are 5.61 and 8.67 percentage points greater than the deviations in imports. It happens that the strong increase in investment relative to GDP as we go from simulation 4 to 5 is approximately balanced by the decrease in consumption relative to GDP. With approximately the same balance of trade deviation in simulations 4 and 5, we see, as would expected, that the price deviations for Chinese traded goods (indicating the change in Chinese competitiveness) are also approximately the same.

Technical improvement in capital creation reduces the cost of using capital in China relative to the cost of using labour. Our data for China indicate little variation in capital/labour ratios between tradeables and non-tradeables. Consequently, simulation 5 gives similar movements in the prices of tradeables relative to non-tradeables as those in simulation 4. With all Chinese commodity price movements in simulation 5 being similar to those in simulation 4, it is not surprising that the movement China's PPP relative to ROW is similar in these two simulations (-38.54 in simulation 4 and -40.19 in simulation 5).

One puzzling aspect of the comparison between simulations 4 and 5 is the movement in the real exchange rate, from a deviation of 58.67 per cent in simulation 4 to a deviation of 40.93 per cent in simulation 5. Why do we get significantly less real appreciation in simulation 5 than in simulation 4 despite similar movements in the two simulations in the basic prices of tradeables and of non-tradeables? Why do we get approximately the same movements in the trade balances in simulations 4 and 5 associated with quite different movements in the real exchange rate?

Recall that we are holding nominal exchange rates fixed and that in these circumstances we define the movement in the real exchange rate as the percentage change in the ratio of China's

GDP deflator to that of ROW. For most simulations, this measure of the real exchange rate is a reasonable reflection of what happens to the prices of commodities produced in China relative to the prices of commodities produced in ROW. Consequently it is a reasonable measure of what happens to China's international competitiveness. However, it stops being a good measure in simulations in which shocks are applied that change the prices of components of final demand (and therefore the GDP deflator) without directly affecting the basic prices of commodities. Such shocks include the imposition of taxes on consumption and, of relevance in the present simulation, the imposition of cost-reducing technological changes in the creation of units of capital. In the comparison between simulations 4 and 5, the movement in our measure of the real exchange rate is understandable but misleading. It should be ignored. On the alternative definition, relying on movements in the basic prices of non-tradeables relative to tradeables (see footnote 6), there is little change in China's real exchange rate between simulations 4 and 5.

Simulation 6: ***PPP-2 assumptions plus export bias plus outward movement foreign demand curves plus technical progress in capital creation plus faster catch up for tradeables***

It is not known at what rate technology in developing countries will converge to that in developed countries. Nor is it clear that the rate of convergence will be uniform across industries. In simulation 6 we show that CGE models can be used to investigate the effects of different overall rates of convergence and convergence scenarios involving different rates for different industries.

In simulation 6 we adopt the same inputs as in simulation 5 except that we put China on a convergence path that would close its technological gap with ROW in 50 years in tradeable-goods industries rather than 100 years. We continue to assume 100 year closure of technology gaps in non-traded industries. As in previous simulations, we report the results at the 25th year of the convergence process.

Faster convergence in simulation 6 in traded-goods industries gives China at the 25th year about 60 per cent more overall convergence-induced technological progress than it had in simulation 5 (about 100 per cent more in traded-goods industries but no more in non-traded goods industries). Consequently, the deviations generated in simulation 6 for GDP, capital, investment, consumption, exports and imports are all around 60 per cent larger than in simulation 5.

With technological change biased towards traded goods, simulation 6 shows a much sharper increase in the price of non-tradeables relative to tradeables than simulation 5 [122 per cent (=100*(257.25/115.60-1) compared with 46 per cent (=100*(179.58/122.96-1)].

Consequently, simulation 6 shows sharper real appreciation[8] than simulation 5 (74.60 per cent compared with 40.96 cent) and a larger fall in China's PPP.

Simulation 7: MER assumptions plus export bias plus outward movement foreign demand curves plus technical progress in capital creation

In simulation 7 we adopt the same assumptions as in simulation 5 except that we use the MER estimates as the starting point for Chinese technology. In terms of Table 3.1, the initial multi-factor-productivity ratios are those in column (3) rather than those in column (2).

The MER estimates imply that Chinese technology has considerably further to go to catch up to ROW technology than do the PPP-2 estimates. Under the MER estimates, the average technology ratio for Chinese industries is 0.35 compared with 0.47 under PPP-2 [see the last row in columns (3) and (2) of Table 3.1]. Consequently, the deviation results for simulation 7 in Table 3.2 show greater stimulation of the Chinese economy than those in simulation 5. For example, the percentage increase in GDP for China is 54.5 per cent higher in simulation 7 than in simulation 5 [54.5 = 100*(148.68/96.25 – 1)]. If PPP-2 is the right basis for estimating the initial Chinese/ROW technology ratios, then 54.5 per cent is an indicator of the extent to which adoption of MER leads to overestimation of the effect of convergence on Chinese GDP after 25 years of a 100 year process.

As we go from simulation 5 to simulation 7, the percentage increases in the deviations for China's aggregate capital, investment and consumption are between 35 and 60 per cent, approximately in line with the percentage increase in the GDP deviation. Exports and imports, on the other hand, show smaller deviations in simulation 7 than in simulation 5. This is because in the move from simulation 5 to simulation 7, we are biasing technological change in favour of the production of non-tradeable goods. To understand this, we can recall Figure 3.1 which shows that the Chinese technology ratios for non-tradeables are considerably lower under MER than under PPP-2 while the Chinese technology ratios for tradeables are approximately the same under MER and PPP-2. Consequently, there is little difference in the technological catch up for tradeables under MER and PPP-2 but considerably more catch up for non-tradeables under MER than under PPP-2.

The movements in simulation 7 in the real exchange rate and China's PPP relative to ROW are quite small. The reason is that in simulation 7 the technological changes assumed in the

[8] Simulation 6 has the same rate of technological improvement in capital creation as that in simulation 5. Thus the objection to the real exchange rate result that we outlined for simulation 5 does not apply to the comparison between simulations 5 and 6.

policy run do not favour exporting to any significant extent. As in simulation 1, the technical changes in simulation 7 are not concentrated on export-oriented activities. Just as Figure 3.2 showed little relationship between technology ratios estimated under PPP-1 and export shares, Figure 3.4 shows little relationship between technology ratios estimated under MER and export shares. Unlike simulations 2 to 6, in simulation 7 there is no bias in technological change within industries towards the export variety: under MER, the initial price ratio of type 2 goods to type 1 goods in each industry is the same as in ROW (implying that there are no B movements in the convergence scenario).

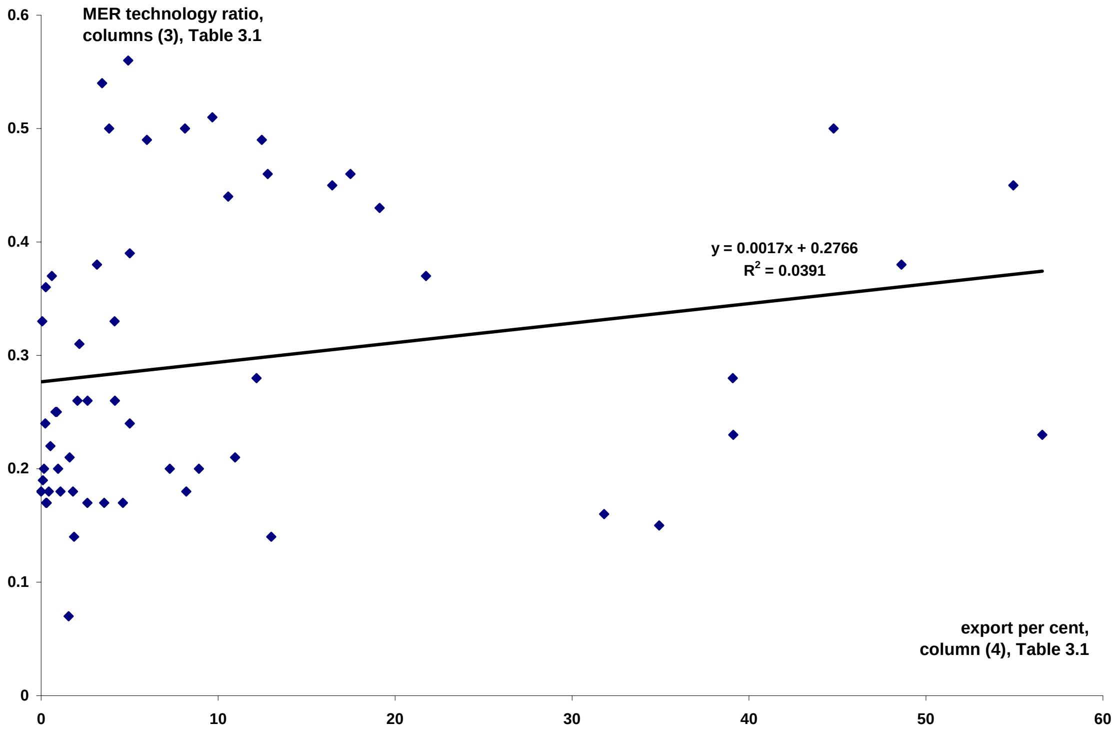
3.4. Industry results

Table 3.3 shows convergence-induced deviations in the outputs of Chinese industries at the 25th year for all seven of our simulations. Here we will discuss the industry results just for simulation 5 with a fleeting reference to simulation 7. We concentrate on simulation 5 because it produces plausible macroeconomic results. As we saw in subsection 3.3, simulation 5 generates for China: (a) a sharp increase in the real exchange rate; (b) a sharp reduction in purchasing power parity relative to ROW; (c) an increase in the capital stock that at least keeps pace with the increase in GDP; and (d) no pronounced downward movement in the terms of trade. On the basis of the history of convergence so far, (a) to (d) are all features that we would expect to accompany Chinese convergence in the 21st century.

The industry effects in the simulation 5 column of Table 3.2 vary from a maximum of 139.44 per cent for Air transport (industry 50) to a minimum of -21.09 per cent for Wool and silk worms (industry 12).

Air transport is a major winner in simulation 5 for two reasons. First, it is highly capital intensive and will benefit in China's convergence process from reduction in the cost of using capital relative to the cost of using labour. Second, Air transport is highly trade exposed: exports account for 56.58 per cent of its sales and imports account for 37.97 per cent of Chinese purchases [columns (4) and (5) of Table 3.1]. High trade exposure means that the elasticity of demand for the products of the Air transport industry is high so that favourable movements in the relative prices of capital and labour translate into a large increase in output rather than just a reduction in price.

Figure 3.4. Technology ratios under MER and export shares for Chinese industries in 1998



The first step in understanding the result for Wool and silk worms in simulation 5 is to note that 98 per cent of its sales are to Textiles (industry 27). Thus, what happens to the output of Wool and silk worms depends mainly on what happens to the input of Wool and silk worms per unit of output of Textiles and what happens to the output of Textiles. The A_{hiz} shock for h = Wool and silk worms, i = Textiles and z = China is strongly negative: by year 25 in the policy run of simulation 5, the Textile industry uses 32 per cent less Wool and silk worms per unit of output than it did in the basecase. At the same time, output expansion in Textiles is subdued [only 11.79 per cent compared with an average over all industries of 48.72 per cent]. This subdued response reflects three factors. First, Textile production is quite labour intensity and will suffer in China as wages rise relative to the cost of using capital. Second, our estimates of technology ratios in column (2) of Table 3.1 imply that the Chinese textile industry is currently efficient relative to most other Chinese industries producing traded goods: the technology ratio for Textiles in column (2) is 0.44, whereas the average technology ratio over industries 1 to 42 is only 0.26. Thus, among traded goods industries, Textiles is harmed by having a relatively small multi-factor productivity improvement in the convergence process. Third, Textiles has high trade exposure, with an export share of 17.47 per cent and an import share on 20.11 per cent [columns (4) and (5) of Table 3.1]. High trade exposure and therefore a high elasticity of demand is bad for an

Table 3.3. Effects on commodity outputs in China of Chinese convergence over 100 years: Percentage deviations after 25 years

No.	code	Commodity name	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5	Sim 6	Sim 7
1	pdr	Paddy rice	37.99	40.26	39.62	41.58	48.15	104.43	72.47
2	wht	Wheat	31.06	33.90	32.42	34.75	41.48	75.94	69.05
3	gro	Cereal grains nec	21.53	24.88	20.81	35.63	41.24	88.78	69.22
4	v_f	Vegetables, fruit & nuts	33.94	37.19	36.71	38.68	44.12	86.22	70.49
5	osd	Oil seeds	37.36	44.40	34.73	20.22	24.88	64.95	37.58
6	c_b	Sugar cane & beet	41.70	44.23	44.33	51.22	61.60	120.39	103.04
7	pfb	Plant-based fibres	-4.76	1.67	-6.31	-15.39	-11.91	-18.73	-1.35
8	ocr	Crops nec	63.20	68.24	67.70	57.18	64.35	151.03	93.41
9	ctl	Cattle, sheep, goats & horses	31.58	32.33	26.88	26.63	31.27	66.10	57.10
10	oap	Animal products nec	50.07	52.48	51.80	54.58	59.95	126.15	90.42
11	rmk	Raw milk	38.01	37.84	34.32	34.78	40.50	84.69	70.81
12	wol	Wool & silk worms	-16.25	-10.54	-16.76	-24.07	-21.09	-32.49	-9.90
13	for	Forestry	17.65	23.43	19.24	14.70	19.46	38.76	36.62
14	fsh	Fishing	26.03	30.08	29.25	33.45	37.78	87.04	61.25
15	col	Coal	22.49	31.20	31.58	33.32	41.34	66.88	64.67
16	oil	Oil	68.39	75.08	73.41	75.60	108.76	228.38	156.56
17	gas	Gas	88.95	100.64	102.05	103.14	125.50	248.66	180.53
18	mn	Minerals nec	14.95	26.29	22.69	23.37	30.03	42.23	45.72
19	cmt	Meat: cattle, sheep, goats & horses	33.34	38.76	23.53	16.27	17.79	40.65	26.36
20	omt	Meat products nec	58.88	60.81	59.73	65.67	71.34	147.39	104.59
21	vol	Vegetable oils & fats	48.49	52.34	47.74	45.51	53.18	94.78	84.61
22	mil	Dairy products	34.46	36.50	27.27	19.59	25.14	84.15	45.71
23	pcr	Processed rice	28.25	30.18	29.87	31.25	35.51	67.53	56.88
24	sgr	Sugar	97.98	100.71	102.62	117.70	129.04	337.82	187.47
25	ofd	Food products nec	79.40	82.28	80.66	86.89	95.92	203.88	139.96
26	b_t	Beverages & tobacco products	60.92	62.49	61.69	63.99	72.40	133.75	107.52
27	tex	Textiles	17.46	23.87	15.69	7.48	11.79	23.84	27.44
28	wap	Wearing apparel	59.66	60.04	50.67	43.46	46.83	105.37	62.09
29	lea	Leather products	55.07	54.96	38.51	30.29	31.66	73.91	35.72

Table 3.3 continued …

Table 3.3 continues …

No.	code	Commodity name	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5	Sim 7	Sim 7
30	lum	Wood products	58.83	71.56	69.39	66.91	73.80	126.23	100.59
31	ppp	Paper products & publishing	34.48	44.96	38.62	29.50	35.32	59.42	47.27
32	p_c	Petroleum & coal products	40.38	45.56	47.85	50.11	63.85	104.24	92.48
33	crp	Chemical, rubber & plastic prods	43.01	52.74	44.31	33.70	41.44	77.79	62.37
34	mp	Mineral products nec	24.57	39.98	39.57	46.97	53.22	89.32	67.95
35	i_s	Ferrous metals	30.26	39.57	36.22	38.49	44.83	72.28	67.66
36	nfm	Metals nec	37.85	44.23	37.59	36.00	43.42	74.14	70.17
37	fmp	Ferrous metal products	45.57	56.91	55.58	57.69	64.74	106.56	91.63
38	mv	Motor vehicles & parts	39.15	38.64	35.07	29.58	35.75	56.90	63.27
39	otn	Transport equipment nec	59.56	51.89	53.19	66.19	74.03	129.96	124.88
40	ele	Electronic equipment	61.60	61.59	43.22	42.21	51.63	116.36	85.06
41	ome	Machinery & equipment nec	37.90	38.59	35.86	42.96	49.98	87.92	85.24
42	omf	Manufactures nec	49.37	53.04	47.37	45.43	54.78	97.81	79.86
43	ely	Electricity	49.60	21.78	22.09	21.88	29.85	38.97	93.99
44	gdt	Gas manufacture & distribution	62.89	48.06	48.74	46.19	53.70	72.24	103.91
45	wtr	Water	51.00	24.97	24.62	25.34	33.42	39.57	96.24
46	cns	construction	67.63	49.59	50.18	60.82	66.75	109.82	126.85
47	trd	Wholesale & retail trade	46.52	19.04	22.53	19.90	24.84	25.00	80.04
48	otp	Road & rail transport	57.75	26.28	37.79	32.56	39.99	37.12	97.47
49	wtp	Water transport	63.42	25.16	87.29	72.84	86.42	62.67	109.04
50	atp	Air transport	98.56	48.27	112.94	98.08	139.44	107.24	143.23
51	cmn	Communication	42.96	16.77	21.98	23.83	34.75	38.35	95.91
52	ofi	Financial services nec	64.59	34.03	33.54	33.12	40.58	44.96	108.94
53	isr	Insurance	70.66	33.74	45.96	32.45	41.91	28.74	93.97
54	obs	Business services	96.40	61.24	64.46	59.63	67.39	88.93	135.37
55	ros	Recreation & other services	58.21	30.34	29.13	26.97	32.49	43.42	90.53
56	osg	Government services	64.29	51.56	51.53	57.98	63.77	103.87	110.44
57	dwe	Ownership of dwellings	88.36	49.50	49.35	56.01	85.52	102.21	202.48
		Averages	46.93	43.07	40.96	41.70	48.72	83.99	84.24

industry if its multi-factor-productivity increase is insufficient to offset wage increases generated by productivity increases in the rest of the economy. Together, the 32 per cent reduction in the input of Wool and silk worms per unit of output in Textiles and the 11.79 per cent increase in the output of textiles imply a 24 per cent reduction in demand for Wool and silk worms by Textiles [-24 = 100*(1.1179*(1-0.32)-1)]. This is approximately the result (-21.09) given by simulation 5 for the output of the Wool and silk worms industry.

Perhaps the most interesting aspect of the results for simulation 5 in Table 3.3 is that the average output deviation is only 48.72 per cent, whereas the increase in GDP is 96.25 per cent (first row of Table 3.2). The gap between the average percentage increase in industry outputs and the percentage increase in GDP arises from intermediate-input-saving technical progress (reductions in A_{hiz}s for h = material input, z = China). This type of technical progress can reduce industry outputs while increasing GDP. Of relevance to the greenhouse debate is that simulation (5) shows percentage output increases for China's main greenhouse industries, Coal (industry 15, 41.34 per cent increase), Electricity (industry 43, 41.34 per cent increase) and Road & rail transport (industry 48, 39.99 per cent increase) that are considerably less than the percentage increase in real GDP. An implication is that analysis based on a fixed coefficient linking energy use and GDP is likely to overstate the greenhouse-gas implications of Chinese convergence.

On average, the industry output results for simulation 5 in Table 3.3 are only 58 per cent as large as those for simulation 7 [58 = 100*(48.72/84.24 – 1)]. For the greenhouse gas industries, Coal, Electricity and Road & rail transport, the output increases for simulation 5 are only 64, 32 and 41 per cent of those in simulation 7 [41.34 cf 64.67, 29.85 cf 93.99 and 39.99 cf 97.47]. As with the GDP result discussed earlier, we conclude that if PPP-2 is the right basis for estimating the initial Chinese/ROW technology ratios, then adoption of MER leads to a considerable overestimate of the effect of convergence on the output of Chinese greenhouse-gas industries with the attendant danger of a considerable overestimate in the emission of greenhouse gases.

4. Concluding remarks

We interpret convergence as meaning that technologies in developing countries will move towards those in developed countries. Under this interpretation, the analysis of convergence requires estimates of the initial technology gaps between developing and developed countries. Estimates of these gaps are not readily available. What is available through the Global Trade Analysis Project (GTAP) is input-output tables for about 50 countries, distinguishing about 60 industries and commodities. Input-output tables show *values* of commodity and factor flows. For estimating technology gaps, we need *quantities*. To get from values to quantities we need price data for different countries and comparable products.

In conducting the research for this paper we found that the most promising source of relevant price data is the International Comparisons Project (ICP) conducted by the University of Pennsylvania and the World Bank. The ICP makes Purchasing Power Parity (PPP) estimates based on detailed price information for many countries. However, it appears that extensive negotiation will be required to find a basis under which the ICP can release the detailed price data that underlies its PPP estimates. Certainly it was beyond the scope of this project to undertake these negotiations.

In the absence of suitable price data, we moved from input-output values to quantities by assuming: (a) that the price of a traded good, after conversion into a common currency by market exchange rates, is broadly the same across countries; and (b) that the price of a non-traded good, after conversion into a common currency by market exchange rates, is considerably lower in developing countries than in developed countries. These assumptions are consistent with: (a) the law of one price applied to heavily traded goods; and (b) the often observed phenomenon that PPP for developing countries relative to developed countries is high, that is a dollar U.S. buys a lot more in a developing country than it does in a developed country.

Having made price assumptions, we showed how input-output data can be used to obtain estimates of coefficients describing technology in each industry in each country. These estimates then provided the initial technology gaps for a convergence analysis.

To work out the implications of convergence (closing of technology gaps) the most promising approach is simulation through a multi-country computable general equilibrium (CGE) model. These models are capable of accepting scenarios at a detailed industry level on technological change, including material-saving, labour-saving, capital-saving, land-saving and margin-saving technological change. They can also be used to simulate the effects of twists in technologies in favour or against the production of goods for export relative to goods for the home-market and in favour or against the use of imported inputs relative to domestic inputs.[9] Standard outputs from CGE models include projections of effects on macroeconomic variables

[9] The first CGE model with a comprehensive specification of technology variables was ORANI (Dixon *et al*., 1977 and 1982). ORANI has been used many times to simulate detailed technological scenarios. In more recent years, ORANI's dynamic successor, MONASH (Dixon and Rimmer, 2002), has been used not only to simulate the effects of technological changes but to estimate movements in detailed technological variables over given historical periods.

and on industry outputs and employment. CGE models have often been extended to cover occupations, sub-national regions and environmental variables.

In this paper, we used a three-country dynamic CGE model to illustrate the estimation of technology gaps and the simulation of partial catch up by developing countries . The model, which is based on GTAP data, distinguishes 57 industries and commodities. For each industry in each country we estimated technology coefficients describing the use of 57 commodity inputs and of primary factors. While this level of industry/commodity detail seems satisfactory, the level of country detail in our model was not ideal. The countries in the model are Australia, China and Rest of world (ROW). We used China as a representative developing country and ROW and Australia as representative developed countries. Ideally, convergence analysis should be carried out in a model that identifies: several major developing countries and areas, e.g. China, India, Indonesia and Sub-Sahara Africa; several major middle income countries and areas, e.g. Brazil, Mexico, Rest of South America and Eastern Europe; and several high income countries and areas, e.g. North America, Japan, and Western Europe. Using GTAP data such an analysis is possible. However, it would be a major project. To make it worthwhile, it would probably be necessary to arrange access to detailed price data of the type held by ICP, and it would certainly be necessary to do more work on factor prices, particularly wage rates, than was undertaken for the present project.

Despite its restricted country detail, our model suggests four interesting conclusions.

First, the MER/PPP distinction matters. When we use market exchange rates we obtain distinctly different estimates of initial technology gaps to those obtained when we use price assumptions broadly consistent with PPP. In simulating the effects of convergence, we found that MER-based estimates of initial technology gaps lead to considerably higher estimates of convergence-induced growth in developing countries than do PPP-based estimates. In our example, where China converges to ROW over a 100 year period, the MER-based simulation (simulation 7) shows a convergence-induced increase in the real GDP of China of 149 per cent after 25 years of the convergence process. In simulation 5, conducted under the same macro assumptions as simulation 7, but with technology gaps estimated with our preferred version of PPP (namely PPP-2), the increase in the real GDP of China after 25 years is only 96.25 per cent. If PPP-2 is the right basis for estimating technology gaps, then the use of MER-based analysis runs the danger of significantly overestimating convergence-induced growth in developing countries and thereby overstating environmental concerns such as the emission of greenhouse gases.

Second, under convergence, the outputs of industries in developing countries will not grow as rapidly as their GDPs. This reflects intermediate-input-saving technical change. As part of the process of convergence, developing countries will use less materials per unit of output in many industries. This means that analysis based on fixed-coefficient relationships between environmental variables and GDP is likely to overstate the environmental damage (including greenhouse-gas emissions) associated with convergence. It is possible to avoid overstatement by building trends into environment/GDP coefficients. However, CGE analysis provides an attractive alternative to such a procedure. CGE modelling can explain changes in environment/GDP relationships and make explicit the technological assumptions underlying such changes.

Third, for convergence analysis the industry detail in CGE models is valuable. Our simulations showed a wide range of convergence-induced changes in output across industries. For example, at the 25 year mark of a 100 year convergence process, we estimate the convergence-induced change in the output of the Chinese Wool and silk worm industry at -21.09 per cent (simulation 5). At the other extreme, our estimate of the convergence-induced change in the output of the Chinese Air transport industry after 25 years is 139.44 per cent (simulation 5). If we are to understand the environmental, occupational and trade implications of convergence, then results such as these suggest that the use of models with a detailed industrial structure is unavoidable.

Fourth, convergence by developing countries has only minor implications for consumption and GDP in developed countries. In our simulations, massive additional growth in China, generated only tiny changes in macro variables for Australia and ROW.

As well as suggesting potential conclusions about the implications of convergence, our modelling raised technical issues. The most important of these concern PPP, real exchange rates and the terms of trade.

Balassa (1964) explained high PPP numbers for developing countries as the outcome of relatively inefficient technologies for producing exports. In accordance with this explanation, we expected our convergence simulations to show sharp reductions in China’s PPP relative to ROW. However, our initial results (in simulations 1 and 2) indicated small increases. Even when we built in considerable bias (simulation 3) in China’s technological catch up in favour of the production of exports, we obtained only a small reduction in PPP. The explanation is simulated deterioration in China’s terms of trade with associated real devaluation. As explained in section

3.3, simulated terms-of-trade deterioration is a consequence of the Armington assumption under which a country is viewed as producing a distinctive variety of each good. Thus each country faces downward-sloping demand curves for its products implying that rapid expansion of its exports is associated with reductions in its terms of trade. When we eliminated seemingly unrealistic deterioration in China's terms-of-trade (simulation 4) by assuming that expansion of Chinese exports is accompanied by outward movement in foreign demand curves for its products, the Balassa result emerged: Chinese convergence generated sharp real appreciation and a sharp reduction in its PPP.

Another technical issue concerned capital accumulation. As described by Young, Krugman and others, converging economies in the second half of the 20th century achieved very rapid rates of accumulation of human and physical capital. We have treated accumulation of human capital as exogenous labour-augmenting technical change. A preferable treatment, beyond the scope of this paper, is to trace out the process of investment in education and the resulting increase in labour-force skills. With regard to physical capital, our initial simulations showed reductions in China's capital/GDP ratio. While sharp increases in wage rates in China led to simulated substitution of capital for labour, capital-saving technical change was sufficiently strong to leave China with a net reduction in its capital requirements per unit of output. In subsequent simulations (simulations 4 to 7), we captured the Young/Krugman effect by introducing technological changes that reduced the cost in China of assembling units of capital. This encouraged even further substitution of capital for labour allowing capital growth in the convergence process to at least match GDP growth. In future work, it would be interesting to experiment with scenarios in which capital accumulation in converging countries is stimulated by reductions in risk premia on investment.

As explained in the introduction, the initial motivation for this paper was provided by the ongoing discussion of the greenhouse implications of convergence. However, convergence is a much broader topic. Convergence will affect patterns of trade and the occupational composition of employment in developed countries as well as in developing countries. As part of its long-term planning, countries such as Australia could benefit from detailed analysis of the implications of convergence. The research in this paper demonstrates that multi-country CGE models have the potential to: (a) generate convergence results that are consistent with convergence experience in the second half of the 20th century and (b) provide detailed projections of the implications of convergence in the 21st century. To realize this potential, considerable effort will be required in the assembly of data for the estimation of technology ratios and in the translation of convergence experience to date into scenarios for the future.

References

Armington, Paul S. (1969) “The Geographic Pattern of Trade and the Effects of Price Changes”, *IMF Staff Papers*, XVI, July, pp. 176-199.

Armington, Paul S. (1970) “Adjustment of Trade Balances: Some Experiments with a Model of Trade Among Many Countries”, *IMF Staff Papers*, XVII, November, pp. 488-523.

Belassa, Bela (1964), “The Purchasing-Power Parity Doctrine: A Reappraisal”, *The Journal of Political Economy*, Vol. 72, No. 6, December, pp. 584-596.

Castles, I. and D. Henderson (2003a), “The IPC Emission Scenarios: An Economic-Statistical Critique”, *Energy & Environment*, 14 (2&3): 159-185.

Castles, I. and D. Henderson (2003b), “Economics, Emission Scenarios and the Work of the IPCC”, *Energy & Environment*, 14 (4): 415-435.

Dimaranan, B.V. and R.A. McDougall (2002), *Global Trade, Assistance and Production: The GTAP 5 Data Base*, Centre for Global Trade Analysis, Purdue University.

Dixon, P.B., B.R. Parmenter, G.J. Ryland and J. Sutton (1977), *ORANI, A General Equilibrium Model of the Australian Economy: Current Specification and Illustrations of use for Policy Analysis*, Vol. 2 of the First Progress Report of the IMPACT Project, Australian Government Publishing Service, Canberra, pp.xii + 297.

Dixon, P.B., B.R. Parmenter, J. Sutton and D.P. Vincent (1982), *ORANI: A Multisectoral Model of the Australian Economy*, Contributions to Economic Analysis 142, North-Holland Publishing Company, Amsterdam, pp. xviii+372.

Dixon, P.B. and M.T. Rimmer (2002), *Dynamic General Equilibrium Modelling for Forecasting and Policy: a Practical Guide and Documentation of MONASH,* Contributions to Economic Analysis 256, North-Holland Publishing Company, Amsterdam, pp.xiv+338.

IPCC (2000), *Emissions scenarios, special report of the Intergovernmental Panel on Climate Change*, Nebojsa Nakicenovic and Rob Swart (eds.), Cambridge University Press, UK.

McKibbin, W.J., D. Pearce and A. Stegman (2004), “Long run projections for climate change scenarios”, Working Paper in International Economics, No. 1.04, Lowy Institute for International Policy, May, pp. 66.

Krugman, Paul (1994), “The Myth of Asia’s Miracle”, *Foreign Affairs, Vol. 73 (6),* published by the Council of Public Relations.

Mai, Y-H and M. Horridge (2003), “Modelling the Potential Benefits of an Australia-China Free Trade Agreement”, final report from the Centre of Policy Studies to the Economic Analytical Unit, Department of Foreign Affairs and Trade, available from the Centre of Policy Studies, Monash University, pp. 25.

Hertel, T.W, editor, (1997), *Global Trade Analysis: Modeling and Applications*, Cambridge University Press, Cambridge, U.K.

Young, Alwyn (1992), “A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore”, *NBER Macroeconomics Annual,* MIT Press, Cambridge Massachusetts, pp. 13-63..