Comments on
'Productivity convergence and international openness'
(by Gavin Cameron, James Proudman, and Stephen Redding)

by

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This Chapter studies the economic mechanism relating (i) growth and (ii) openness to trade. It investigates how openness to economic exchange influences total factor productivity (TFP) convergence across economies.

This Chapter stands as the natural limit point of the sequence of findings reported in earlier Chapters. At the Conference, we had previously seen correlations and tabulations and distribution-dynamic characterizations all suggesting a positive connection between (i) and (ii) above. Arriving at this Chapter, the reader is primed for the payoff. When does openness to trade induce higher economic growth and improved productivity? What is the economic mechanism that makes this work? The reader is ready to see all kid gloves taken off, and the findings laid bare.

Indeed, the Chapter does not disappoint. It provides a simple partial-equilibrium economic model showing how a less advanced economy might "catch up" with a more advanced one through technology transfer. It studies the predictions of that model through a range of panel data econometric analysis. The key finding is that openness to trade improves matters for the follower economy, and TFP convergence can occur. But there are limits. Even in the very long run, if nothing else were to change and the convergence process were to continue, TFP in the UK (the less advanced economy, in this instance) will remain permanently behind that of the leading economy.

The central empirical result is, to be clear, more precise than what I have just stated. Openness to trade matters for the *speed* with which TFP convergence occurs: The more open is the less advanced economy, the more rapidly does convergence occur. Openness does not influence—at least not in any robust way—the rate of inherent domestic innovation, or the level of technology that can ultimately be transferred. Why this happens is far from obvious, and calls for further work, but it is a nice solid fact that emerges from the authors' empirical research.

My comments on this Chapter are in 3 parts. The first comprises technical remarks on the model, and suggests one dimension along which further empirical work might be useful. The second describes some conceptual difficulties I have with the Chapter's theoretical and empirical analyses. Finally, the third section concludes with a number of general comments on growth and productivity.

## 1. The model

The authors (hereafter denoted CPR) follow the standard model, and assume that output is generated by

$$Y = AF(K, N),$$

with $A$ denoting TFP, $K$ physical capital, $N$ labour input, and $F$ a neoclassical production function. Domestic economy TFP $A$ is distinguished from the foreign economy's $A_*$, with $A \leq A_*$; the foreign economy has higher TFP and thus is relatively advanced. While $A_*$ is assumed to evolve as

$$\dot{A}_*/A_* = g, \tag{1}$$

its domestic counterpart $A$ evolves *endogenously* as

$$\dot{A}/A = \gamma + \lambda \log(\omega A_*/A), \qquad \gamma,\ \lambda > 0 \text{ and } 0 \leq \omega \leq 1, \tag{2}$$

with $\gamma$, $\lambda$, and $\omega$ parameterising the economic effects to be studied.

Equation (2) describes technology transfer from the foreign relatively advanced economy to the domestic. To understand how (2) works and to see the roles that $\gamma$, $\lambda$, and $\omega$ play, suppose that $\omega = 1$ and $A = A_*$. Then $\lambda$ is irrelevant, and $A$ just grows exponentially at rate $\gamma$. We can therefore interpret $\gamma$ as the rate of *domestic innovation*—it is how fast $A$ would grow when technology transfer is inoperative. If any technology transfer occurs, it simply adds to this underlying rate $\gamma$.

By the same reasoning, we see that $\omega$ is the *transferable ratio* of foreign technology. When $A$ is less than the threshold value $\omega A_*$, the term $\lambda \log(\omega A_*/A)$ is positive and thus adds to the growth rate of $A$. However, once $A$ exceeds $\omega A_*$, the term becomes negative, and slows down growth in $A$. Finally, $\lambda$ can be interpreted as the *rate of technology transfer*; the higher is $\lambda$, the larger is the impact of $\log(\omega A_*/A)$ on $\dot{A}/A$.

All these economic interpretations remain valid if we replace the log function in (2) by *any* function $f$ to get

$$\dot{A}/A = \gamma + \lambda f(\omega A_*/A), \tag{3}$$

provided only that $f$ is monotone increasing and satisfies $f(1) = 0$.

Letting equations (1) and (3) run, from given initial conditions in $A_*(0)$ and $A(0)$, we get time paths in $A_*(t)$ and $A(t)$, with the latter's properties depending on the economic parameters and function $f$. It is useful to note that regardless of whether equation (2) or the more general equation (3) determines $\dot{A}/A$, it is *not* $\omega$ alone that fixes the steady-state relative levels of $A$ and $A_*$. To see this, we solve the system in $(A_*, A)$.

Take the more restrictive case (1) and (2). Because the domestic economy does not feedback onto the foreign, equation (1) implies that $A_*$ follows

$$\forall t \geq 0: \quad A_*(t) = A_*(0)e^{gt}.$$

Rewrite (2)

$$\frac{d}{dt} \log A = \gamma + \lambda \log \omega - \lambda \left[\log A - \log A_*\right]$$

so that

$$\frac{d}{dt}[\log A - \log A_*] = (\gamma - g) + \lambda \log \omega - \lambda \left[\log A - \log A_*\right].$$

Defining

$$\bar{A}(t) \stackrel{\text{def}}{=} A_*(t) \times \exp\left(\frac{\gamma - g}{\lambda} + \log\omega\right), \tag{4}$$

we have

$$\frac{d}{dt}[\log A - \log\bar{A}] = -\lambda\left[\log A - \log\bar{A}\right]. \tag{5}$$

These last two equations completely characterise the dynamics of domestic TFP $A$. Equation (4) gives the underlying steady-state time path for $A$. It says that in steady state, the time path of domestic TFP $A$ parallels that of foreign TFP $A_*$, and is shifted by the multiplicative factor

$$\exp\left(\frac{\gamma - g}{\lambda} + \log\omega\right).$$

This scale factor equals $\omega$ when $\gamma$ equals $g$, i.e., when the underlying innovation rates across the two economies are equal. In general, however, if $\gamma$ exceeds $g$, then the scale factor is larger than $\omega$, and conversely if $\gamma$ is less than $g$. Note, moreover, that $\lambda$, the *rate* of technology transfer also affects steady-state levels. When, without technology transfer, the domestic economy innovates more slowly than the foreign, i.e., $\gamma < g$, then faster technology transfer *raises* domestic steady-state TFP levels. This seems a little peculiar, and warns us that equation (2), although widely-used in the literature, might have some unexpected implications: To repeat, the *rate* coefficient affects the steady-state *level*.

Equation (5) describes dynamics around the underlying steady-state path. It says $A$ is globally stable around $\bar{A}$, and that convergence towards the steady-state path occurs at rate $\lambda$. Fig. 1 shows a range of behaviour consistent with the dynamics just described: the observable predictions of the model are not tightly restrictive, and so testing the model specification is likely not fruitful.

While specialising $f$ to the log pays off in giving the explicit solution (4) and (5), doing so comes with a cost. Since, under the log specification,

$$\dot{A}/A = \gamma + \lambda \log \omega + \lambda \log(A_*/A),$$

it is apparent that $\gamma$ and $\omega$ will not be separately identified. Variation in $A_*/A$ in the cross section and across time identifies $\lambda$ the rate of technology transfer, but then $\gamma + \lambda \log \omega$ does not allow disentangling $\gamma$ from $\omega$. Using an appropriate (non separable) $f$, of course, restores the possibility of identifying $\gamma$ and $\omega$, although then one has to be careful to select $f$ that retains the economic interpretation of these parameters, keeps the computation transparent and tractable, and maintains the credibility of the identification procedure.

## 2. Interactions, followers, and leaders

The model, given in (1) and (2), does not immediately make clear why *varying* degrees of openness might affect outcomes. Instead, the more natural interpretation is that of a dichotomy: When a follower economy is open, then equation (2) applies to describe its TFP dynamics; when it is closed, however, then the channel for technology transfer shuts down, and versions of only equation (1) apply to both follower and leader countries.

Countries are, in reality, not conveniently characterized as just open or just closed: the authors, therefore, parameterise $\lambda$ to depend on (a continuous measure of) openness. Having done so, it is natural to allow the same dependence for $\gamma$ and $\omega$—to the extent that under-identification does not increase.

This procedure is the logical one when the UK (the less advanced economy) trades only with the US. The UK's TFP $A$ then evolves as dictated by equation (2). However, the UK trades with many more countries than just the US, and measures of openness assess only how much the UK trades in total, *not* how much it trades with the US or technologically more advanced economies.

Table 1 shows that of UK trade in 1994—whether measured by imports, exports, or their sum—only about one-eighth was with the US. Put differently, the bulk of UK trade was with countries that cannot naturally be taken to be a "leading" economy relative to the

UK. (Even if Germany were included, that would still leave three-quarters of UK trade with economies less advanced than itself.) For comparison, I have included in the Table patterns of trade for the USA and Germany as well. The top 3 trading partners typically account for only between 30% and 40% of total trade. A picture of trade influencing technology transfer through pairwise trading seems inappropriate. How these more complex trade patterns affect growth and convergence is hard to model, but Quah [4] is a first step, showing the importance of taking into account these rich dynamics of interaction across economies.

Fig. 2, taken from Quah [4], shows 15-year horizon distribution dynamics for per capita incomes across over 100 countries. The figure contains the graph of a stochastic kernel, and is usefully viewed as the continuous analogue of the transition probability matrices used at the Conference by various combinations of authors, or in work such as Quah [2, 3]. Think of the *Period* $t$ axis as the rows of the transition matrix, and the *Period* $t + 15$ axis as the columns. The values indicated on the axes are incomes relative to the world average. (That 15 years has been selected as the horizon is only for convenience and clarity—nothing hinges on the precise figure.)

Starting from any point on the *Period* $t$ axis and extending parallel to the other, the stochastic kernel traces out a probability density, exactly as a row of a transition probability matrix gives a probability vector. This probability density describes the likelihood of transitions, over 15 years, into different parts of the income space, conditional on beginning at a specific income value at time $t$.

Because the kernel has been estimated for a continuous range of values, there is no difficulty with the researcher having chosen, say, an "incorrect" discretisation. The twin-peaks character of these distribution dynamics is evident. As one looks along the principal diagonal of the kernel, there is a dip in the middle, with probabilities rising towards higher and lower income values.

I noted above that patterns of trade—who trades with whom—are intricate and might not be usefully captured just by measures of openness. Fig. 3 attempts to assess the importance of this observation. The Figure shows the stochastic kernel for how the cross-country distribution of (per capita) income changes, conditioning not on the passage of time but on the incomes of an economy's major trading partners.[1] The mass of probability now rotates to essentially parallel the *Original* axis. The most direct interpretation of this is that rich economies trade mostly with other rich ones, and similarly poor economies mostly with other poor ones. But if openness is important for technology transfer and convergence, why doesn't every economy attempt to trade only with the most advanced leader economy? Does trade openness also aid convergence when a less advanced economy trades exclusively with other less advanced ones? If so, then the model of technology transfer in equation (2) misses important elements. If not, is the concept of trade openness economically meaningful?

Fig. 4 attempts to shed a little more light on these patterns of convergence. The conditioning here is now on countries physically contiguous with a given economy (hence the label *Spatial conditioning*). The stochastic kernel in this Figure too shifts to parallel the *Original* axis, although not as dramatically as in the previous trade-conditioning exercise. Just as trade patterns matter for convergence, so too does physical location. In a technology-transfer interpretation, this says that countries learn well from those surrounding them—perhaps because ideas and cultures translate better with physical proximity.

### 3. Conclusion

This Chapter has provided strong evidence on the importance of openness for technology transfer, and thereby for TFP convergence. That trade matters for growth and convergence—not just theoretically but empirically—is now an increasingly established fact. The authors' work adds to a body of evidence that includes the impressive analyses of Ben-David [1], Sachs and Warner [5], and others.

Where I have drawn attention to difficulties, those are not unique

[1] Doing this by taking different time periods (other than 1994, say) or alternative definitions of major trading partners—top 5 trading partners or the top trading partners covering at least 50% of total trade—and so on does not affect the conclusion.

to the current Chapter. First, the theoretical model of convergence is one where rates of short-run catch-up influence levels in long-run steady-state. There is, therefore, no clean separation between what happens in the long-run and what happens in the short-run. This confounding might, of course, be desirable and useful but it should then be reflected in the authors' discussion.

Second, I have indicated where the parameterisation of the catch-up dynamics that the authors use provides a useful payoff and where it unnecessarily restricts. Whether a richer econometric specification will be useful cannot be known a priori, but is something that could be investigated in future research.

Finally, I have pointed out that the notion of "openness to trade" appropriately captures neither the theoretical insights of technology transfer nor the empirical reality of cross-country trade. Whether taking this into account matters is, again, a subject for future research.

**References**

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|---|---|---|---|---|---|---|
| | UK | | | | | |
| $M$ | Germany | (14%) | USA | (12%) | France | (10%) |
| $X$ | USA | (13%) | Germany | (12%) | France | (10%) |
| $M+X$ | Germany | (13%) | USA | (12%) | France | (9%) |
| | USA | | | | | |
| $M$ | Canada | (17%) | Japan | (16%) | Mexico | (6%) |
| $X$ | Canada | (19%) | Japan | (9%) | Mexico | (8%) |
| $M+X$ | Canada | (18%) | Japan | (13%) | France | (7%) |
| | Germany | | | | | |
| $M$ | France | (12%) | Netherlands | (9%) | Italy | (9%) |
| $X$ | France | (12%) | USA | (9%) | UK | (8%) |
| $M+X$ | France | (12%) | Italy | (9%) | Netherlands | (8%) |

**Table 1: Top 3 trading partners in 1994** Imports and exports are denoted $M$ and $X$ respectively. Thus, e.g., the first row of the Table shows that 14% of the UK's 1994 imports came from Germany, 12% from the USA, and 10% from France.

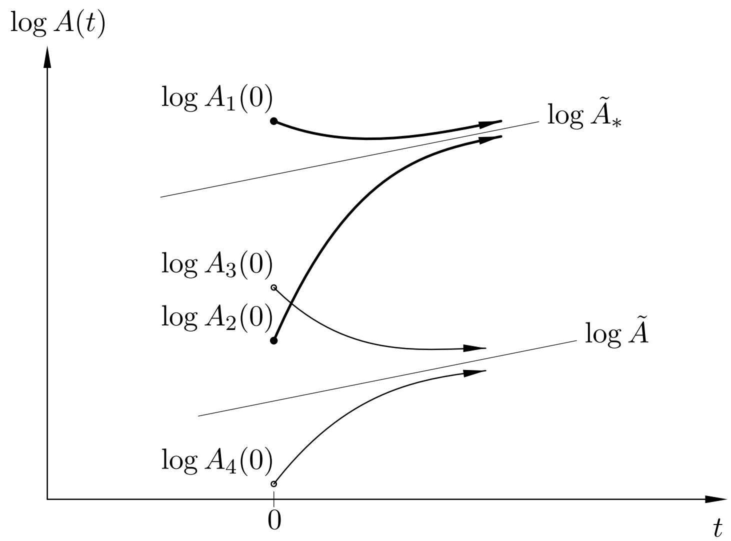


**Fig. 1: TFP growth and convergence** The Figure shows the underlying steady-state paths for leader and follower countries, corresponding to $\log \tilde{A}_*$ and $\log \tilde{A}$, respectively. Relaxing equation (1) to allow only gradual convergence to steady state permits quite elaborate patterns of cross-country convergence to be consistent with the model. As drawn, leader economies at $A_1(0)$ and $A_2(0)$ converge to $\log \tilde{A}_*$ while follower economies at $A_3(0)$ and $A_4(0)$ converge to $\log \tilde{A}$. Thus, economies 1 and 2 converge towards each other, and similarly economies 3 and 4. At the same time, however, economies 2 and 3 approach one another, criss-cross, and then diverge.

**Fig. 2**: Stochastic kernel
Relative income dynamics across 105 countries

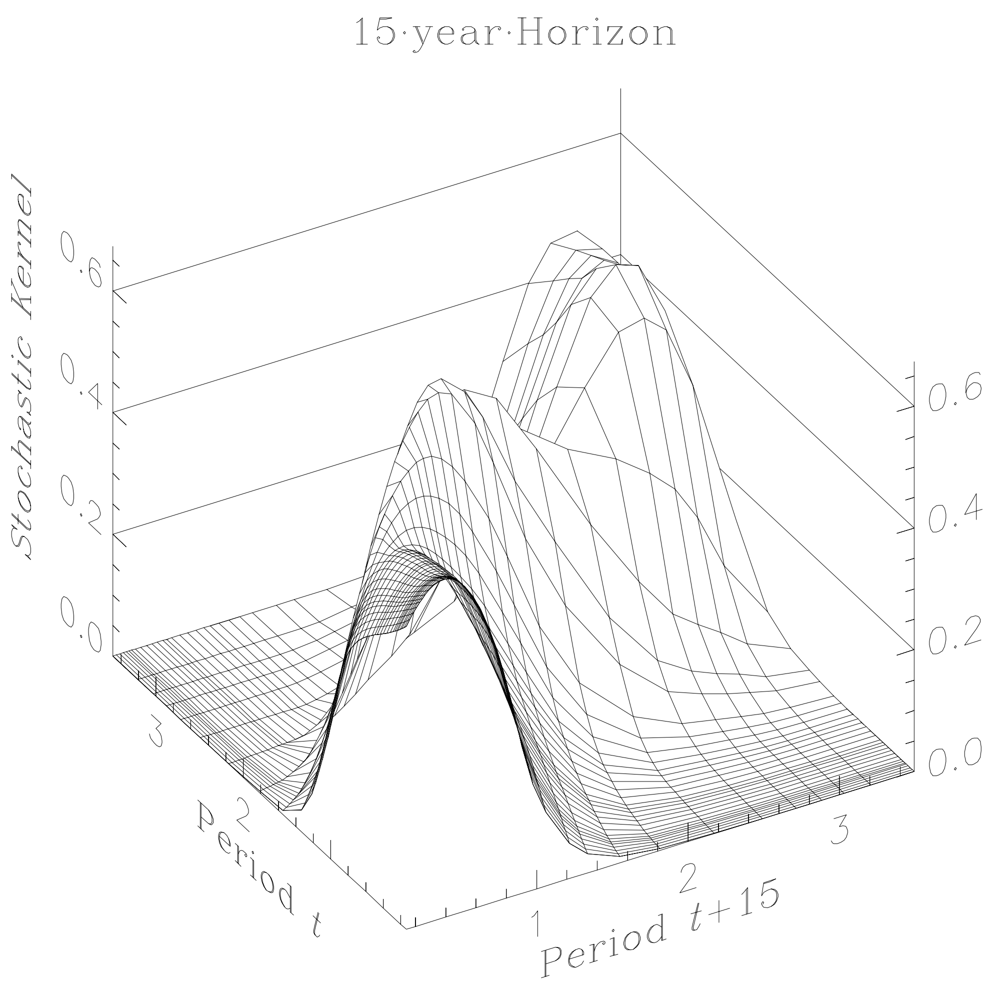

**Fig. 3**: Trade conditioning stochastic kernel
Relative incomes across 105 countries

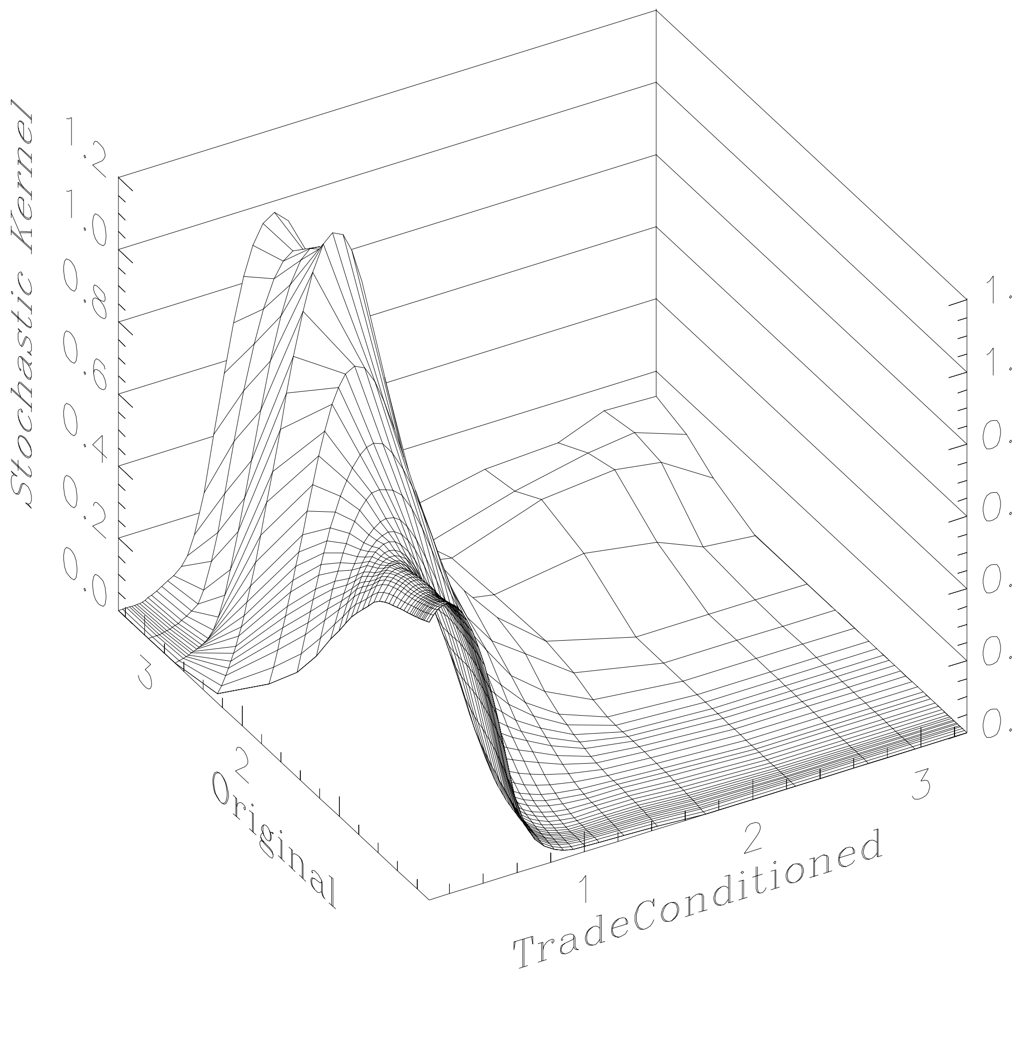

**Fig. 4**: Spatial conditioning stochastic kernel
Relative incomes across 105 countries