Openness, Technology Capital, and Development

1. TITLE. The paper I will present is 'Openness, Technology Capital, and Development.' This is joint work with Ed Prescott.

2. WHY DID THE EU-6 CATCH UP? When we compare labor productivities of different regions of the world as a percent of leader, the United States, we see vast differences. For example, take the EU-6. Between 1910 and 1960 their labor productivity hovered around 50 to 60 percent and then took off, eventually catching up. Why?

3. WHY IS ASIA STARTING TO CATCH UP. Take Asia. In 1960 their labor productivity was 8 percent of the US. It's doubled since. Why?

4. WHY IS SOUTH AMERICA LOSING GROUND. Then, for the flip side, take South America. In 1960 their labor productivity was 35 percent of the US. It has slipped to 25 percent of the US. Why?

5. QUESTIONS. For most economists, there is a simple answer: countries gain as they open up and lose if they remain closed. But what does it mean to be open, and how big are the gains?

6. OUR NOTION OF OPENNESS. Openness means different things to different people, so I want to start by telling you what we mean by openness.

   Openness, for us, is the degree to which foreign multinationals technology capital is allowed into a country to be used in production by the foreign multinationals. In a country that is closed, only domestic firms operate. In a country that is fully open, domestic and foreign firms both operate and are treated the same way.

   I'll define what we mean by *technology capital* but first let me tell you the punchline of the paper: the gains to opening are big, much bigger than estimates of the gains to trade.

7. TECHNOLOGY CAPITAL. Now let me define what we mean by "technology capital."

It is the accumulated know-how from investing in R&D, brands, and organization know-how. What distinguishes this capital from nontechnology capital is the fact that firms can use it simultaneously in multiple locations. To make this idea operational, we modify standard growth theory by adding both technology capital and locations.

8. NEW AVENUE FOR GAINS. Adding both is key and gives us a new avenue for gains. We model countries as measures of locations. Firms choose which locations to set up operations and use their technology capital. The fact that capital can be used in multiple activities simultaneously will be the key to gains in our theory. Adding locations also allows us to introduce technology capital and stay within the macro tradition of having a constant-returns-to scale production function.

9. THEORY. The talk has two parts. First I will describe the theory and then I will tell you some of the key predictions of the theory.

10. CLOSED-ECONOMY AGGREGATE OUTPUT. To get warmed up, let me start with a closed economy. Total output is given by $Y = A(NM)^{1-\phi}Z^{\phi}$.

    There are two factors of production: M and Z. M is units of technology capital. Z is a composite of labor and nontechnology capital. There are constant returns to scale in M and Z. N is the number of locations. It is not a factor of production but a key element of our aggregation theory. A is the technology parameter and ϕ determines the shares of income to technology capital and the other factor inputs.

    I will first provide a micro foundation for this aggregate production function for a closed economy. Then, I will provide a micro foundation for the aggregate production function of a country that is not totally closed.

11. A MICRO FOUNDATION FOR AGGREGATE FUNCTION. In the paper, we work with measures. It is easier to explain our aggregation if I work with discrete numbers of locations and units of technology capital. Locations are indexed by n and units of technology capital by m. To help with intuition, think of these as brands, for example, $m = 1$ is Walmart and $m = 2$ is Home Depot and so on. The objective is

to allocate factor Z—the nontechnology capital inputs—to plants indexed by n and m to maximize total output, where plant level output is $g(z)$. We put conditions on g so that we get an optimal plant size, namely we assume it is increasing and strictly concave.

12. A MICRO FOUNDATION, CUE 1. What is the result? In this closed economy, Z is split evenly across plants.

13. A MICRO FOUNDATION, CUE 2. That means total Z is divided by the total number of locations times brands or NM. Multiply by NM to get the aggregate and the result is the following aggregate production technology. Notice, if $\phi = 1$, that this nests the standard specification which is linear in Z.

14. A MICRO FOUNDATION, CUE 3. Notice also that it has constant returns to scale in the factors M and Z. I will remind you of this later.

15. PRODUCTION IN OPEN ECONOMY. Let me turn now to the open economy. We define the degree of openness for country i as σ_i. A value of 1 implies a country is totally open–so domestic and foreign firms have the same opportunities in country i.

    A value less than 1 implies that domestic and foreign firms are not treated equally. In particular, there are costs to foreign firms, and these costs have the same effect as if they had lower TFP than domestic firms.

    Aggregate output is equal to the sum of (1) total output from domestic firms that have technology capital M_i at N_i locations with TFP parameter A_i and the composite of labor and nontechnology capital equal to z_d and (2) total output from foreign firms from countries j not equal to i with technology capital M_j at locations N_i with effective TFP parameter $A_i\sigma_i$ and z_f in labor and nontechnology capital. There is no j subscript on z_f because an equal amount is used by all j since we are assuming σ_i is the same for all foreigners. Therefore, the problem boils down to allocating total Z_i to domestic and foreign plants.

16. PRODUCTION IN OPEN ECONOMY, CUE 1 The maximal output in this case is

$Y_i = A_i N_i^{1-\phi} \hat{M}^{1-\phi} Z_i^{\phi}$. I have written this with ω_i which is a function of σ. ω_i can be interpreted as the fraction of foreign technology capital permitted to be brought in and used by foreign multinationals.

17. PRODUCTION IN OPEN ECONOMY, CUE 2 Take the case of $\sigma_i = 0$ which means that costs are infinite and no foreign firms are permitted. This is the closed-economy case. As I noted before, in this case, country i has constant returns in technology capital, nontechnology capital, and labor. When ω_i is greater than 0 and we sum over countries, we get more output than we would get by summing over outputs from the set of closed economies.

18. PRODUCTION IN OPEN ECONOMY, CUE 3 It is as if there were increasing returns when in fact there are none. Note also that there will be gains to opening even if countries have identical factor endowments.

    The key to the results is adding *both* technology capital and locations. Without technology capital, the gains to openness in our model world are zero. With technology capital and an unlimited number of locations, there would be no equilibrium.

19. ADVANTAGES TO OUR TECHNOLOGY. The technology has several notable advantages. It allows for standard welfare analysis; it allows for standard national accounting once you take into account that some investments are expensed rather than capitalized; and it allows for standard parameter selection.

20. REST OF THE MODEL. Before turning to predictions of theory, I need to describe the rest of the model. Households are totally standard. They own capital K_i and M_i and solve a standard utility maximization problem.

    The resource constraint is also standard. Output is used for consumption, two types of investment, and for net exports. Here there is a composite good so we pin down total net exports but not exports and imports separately.

21. PREDICTIONS OF THEORY. Next I want to highlight some of the key predictions of the model.

22. USE THEORY TO MAKE 4 POINTS. There are 4 in particular that I will focus on.

    The first is a balanced growth prediction for a set of closed economies. There is an advantage to size. I have not yet introduced the notion of size but will.

    The second and third are quantitative points. I said at the beginning that gains to opening are large. I will show you that they are conservatively one to two orders of magnitude larger than the gains of trade. They are large when countries form unions and when one country opens unilaterally.

    Finally, I will show results for a transition path with two countries that are similar in every way except that one opens before the other.

23. NEED A MEASURE OF SIZE. To make point 1 I need a measure of size. We assume that the number of locations in a country is proportional to the size of the population in that country. So, we're not thinking literally of carved up regions or locations as land. Land is in K.

    We also introduce this new $\mathcal{A}$ which is labor and location augmenting technical change. Or, more specifically, $A_i^{\frac{1}{1-\phi\alpha}}$.

    Doing this relabeling gives us a nice simple result: all formulas depend on the product $\mathcal{A}_i N_i$.

24. NEED A MEASURE OF SIZE - CUE 1. This is our measure of size. Think of it as a measure of effective persons. So when we say that their is an advantage to size, we mean that countries that are populous and have high TFP are 'big.' China is not as big as the EU or US in this sense even though its population is 3 to 4 times larger because its $\mathcal{A}$ is low.

25. GUTS OF THE THEORY. To understand the predictions of the theory, it helps to consider the simple steady state equations for the case with inelastic labor. Adding transitions and elastic labor does not change any of the main points.

    Assuming preferences and depreciation rates are the same in all countries, the tangi-

ble capital-output ratio is the same in all countries. Rewriting output, imposing that capital to output is constant and imposing that labor is equal to N yields this expresssion: $Y_i = \psi \mathcal{A}_i N_i (M_i + \omega_i M_{-i})^{1-\phi/1-\alpha\phi}$. Three things to notice. First, $\mathcal{A}_i$ and N_i appear together as I noted earlier. Second, output per effective persons depends positively on all elemens of the vector of technology capitals. Third, when the world is totally open, output per effective person is a function of the world level of technology capital which is the same for everyone, implying no advantage to size in this case.

Next consider the equilibrium condition that compares total rents of i's T-capital and the discount rate plus the depreciation rate. This holds with equality if M_i is positive. If ω_i is zero, all countries must do investment in technology capital so these constraints don't bind. As the ω_i parameters approach 1, however, some constraints bind. Which countries do the investment in technology capital will depend on size and openness. For example, suppose there are two countries—a big country like the US and a small country like Canada—and they open up together. If ω is large enough, Canada would asymptotically reduce its technology capital to zero. But, the effective technology capital in Canada, which is $M_{can} + \omega M_{us}$, would still be positive.

I will also show you that timing of opening can matter for who does the investment in technology capital.

26. SIZE ADVANTAGE WHEN CLOSED. Now let me be specific. When countries are closed $\omega_i = 0$ for all i. No foreign technology capital is permitted. Like tangible capital, technology capital-output ratios in this case are the same in all countries. Therefore, we can rewrite output per effective person as proportional to size raised to the power $(1-\phi)/(\phi(1-\alpha))$. Recall that $1-\phi$ is the output share for technology capital and $\phi(1-\alpha)$ is the output share of labor.

    As you'll see next, quantifying differences between big and small countries that are closed is like quantifying the gains from forming unions. Big countries are like economically open unions of small countries.

27. BIG GAINS FROM FORMING UNIONS. Suppose we have I equally-sized countries.

This is analogous to the big country-small country example. Forming the union is like making one big country. Therefore, the relative productivities are I raised to the same power as in the last example. Suppose the capital share in the composite Z is .3 and suppose the share of technology capital is 6 percent, implying a value for ϕ of .94. Then this superscript is equal to 0.091. The gain to 10 countries forming a union is 23 percent. The gain to 100 countries forming a union is 52 percent.

I should note that the estimate of ϕ is conservative and based on observed investments in R&D and advertising. We don't have good estimates of organization know-how, but it could well be significant and we could well be understating the true gains.

28. BIG GAINS FROM UNILATERALLY OPENING. It turns out that the gains can be large to opening even if most countries remain closed. The reason is simple. Their multinational companies will want to come in to the country opening up. As a result the country opening up can exploit the others technology capital and effective T-capital will be high. It is like having a big increase in TFP.

    The expression y_o/y_c is the productivity of the open country relative to those that are closed. This is essentially equal to I times the capital of the closed economies relative to 1 times the capital of the closed economy. The superscript is the same as that appearing on effective technology capital in the production function after substituting for the other factors. Using the same paramters as before, we find that the gain to the opening country if they can use the capital of 10 other countries is 21 percent. The gain is 47 percent if they can use the capital of 100 other countries.

    This example, like the last one, shows that the gains are 1 to 2 orders of magnitude larger than typical gains associated with lowering tariffs.

29. My last point is that countries can be seemingly similar, have similar populations, similar tangible capitals, similar institutions and yet their international accounts can look very different. Here, I am motivated by the experiences of the EU and US. For decades following WWII, we see a lot foreign direct investment and income flowing from Europe but little flowing back. If the EU were more open to US firms than the

US to European firms, we would expect that.

Here is an example with two equally sized countries with the same initial capital stocks. One opens before the other. Call that the EU. The other, call it US, follows but with delay. In this example, the second country ultimately does more investment in technology capital, permanently. This happens because the barriers to EU technology capital are higher. What we find interesting is that the specialization in production could be permanent.

One final note about measurement. In our model world: GDP is total output less investment in technology capital. When countries are making large investments in technology capital, GDP may remain low or even fall. Thus, we have to be careful about interpreting what looks like bad news following formations of economic unions as truly bad news.

30. SUMMARY. The paper adds locations and technology capital to a standard neoclassical growth model. Without them, the gains to openness in our model world would be zero. With them, and plausible income shares, we find that the gains to openness are large.