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Sugata Marjit, Reza Oladi

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Abstract

In this paper, we construct an elaborate general equilibrium model with a continuum of production fragments for an intermediate good, then embed it in a growth model to address the effects of global production fragmentation, vertical specialization and trade on growth and inequality for a small developing country. Among other results, we show that a small developing economy grows faster than the rest of the world as a result of global fragmentation and trade in intermediates if it is skilled-labor scarce. We also address the effects of such trade opening on wage inequality.

JEL-Codes: F100.

Keywords: vertical specialization, trade, growth, inequality.

Sugata Marjit
Indian Institute of Foreign Trade
Calcutta / India
marjit@gmail.com

*Reza Oladi**
Department of Applied Economics
Utah State University / Logan / USA
reza.oladi@usu.edu

*corresponding author

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1 Introduction

While numerous arguments have been made in the literature on positive role of trade on economic growth, disputes remain (see Krueger , 1980; Lucas , 1990; Frankel and Romer , 1999; Baldwin and Robert-Nicoud , 2008, among others). While the canonical (neoclassical) theory may seem to suggest that trade opening and reforms has a positive impact on economic growth, numerous trade theorist cast doubt on this proposition (see Krueger , 1980; Rodrik , 1995, among others). Extensive empirical literature also provides mixed evidence (see , Sachs et al. , 1995; Rodriguez and Rodrik , 2000; Winters and Masters , 2013, among others).[1] On the other hand, growth in international trade concurrently with widening income inequality in recent decades has brought an additional dimension to these debates (see Bound and Johnson , 1989; Katz and Murphy , 1992; Jones , 1996; Cline , 1997; Baldwin and Cain , 2000; Oladi , 2008, among others). Despite the fact that these debates span about half a century, the subject matter is still unsettled both in academia and in policy circle. The recent wave of nationalism and protectionism has only intensified the public discourse both in developed and developing countries. The current paper is a theoretical attempt to

[1] For extensive review of literature see Krueger and Berg (2003) and Irwin (2019).

go beyond canonical models to present a theory of trade, growth and inequality. It also contributes to a branch of literature that deals with global production fragmentation and offshoring (see Antras and Helpman , 2004; Grossman and Rossi-Hansberg , 2008, among others). In particular, our paper is closely related to Nakanishi and Long (2020) that addresses the impact of virtual mobility of labor and global task fragmentation on endogenous growth rate as well as the effects of R&D offshoring on skilled wages and to Bandyopadhyay et. al (2020) that considers the impacts of international task fragmentation and offshoring on wages in developed and developing economies.

In particular, we attempt to address the effects of vertical specialization and global production fragmentation on economic growth and income inequality. In doing so, we construct an elaborate a dynamic general equilibrium model of trade with continuum of production fragments (or productive services). We first set up a model with three goods, two final goods and an intermediate. The intermediate good itself consists of a continuum of fragments in the spirit of Dornbusch et al. (1977), each produced with Ricardian production technology. We show that the level of capital is consequential in determining the skilled-unskilled wage gap in our setup with trade in fragments. Hence, it is paramount to cast our general equilibrium within a growth model. Despite the fact that the literature is rich and extensive, a number of important issues including the impact of trade on economic growth, its differential effects on south visa-a-vie north, and its effect on inequality are still in dispute. The current paper addresses all three aspects and contributes to these branches of literature.

We show, as our first main result, that vertical specialization, global fragmentation and trade in intermediate goods induce economic growth. This is in contrast to the view held by those trade critics that question the validity of trade being pro development (see Rodrik , 1995; **?**, among others). Our model provides yet another additional theoretical foundation that supports the old idea advocated by Krueger (1980) and Sachs et al. (1995), among others. Second, we revisit the *Catch-up hypothesis*, stating that developing countries grow faster and ultimately will catch up with developed countries. Here, again, the debate has not been settled yet although it is a decades-old idea. Lucas (1990) famously criticized this hypothesis by question of why capital does not move to the south. We contribute to this old unsettled question by providing the conditions under which the hypothesis hold. Particularly, we show that a small developing economy grows faster than the rest of the world due to vertical specialization, production fragmentation and opening of international

trade to fragments if it is skilled-labor scarce both relative to capital and unskilled labor. We also address the effects of production fragmentation and vertical specialization on skilled-unskilled wage inequality. Hence, our paper also contributes to an important growing literature on intentional production and task fragmentation (e.g, see Nakanishi and Long , 2015)

The rest of our paper is organized as follows. Section 2 lays out our general equilibrium framework. Then, we cast our general equilibrium model within a dynamic growth model, where we also present our main results. Section 4 concludes our paper.

2 A general equilibrium model of vertical specialization

Consider a small open economy that produces two final goods, denoted by X and Y. Good X uses capital and intermediate good M as inputs with Cobb-Douglas production technology $X = AK^{\alpha}M^{1-\alpha}$. Good Y uses unskilled labor and skilled labor as inputs with production technology $Y = S_Y^{\beta}L_Y^{1-\beta}$, where S_Y is the usage of skilled labor and L_Y denotes the unskilled labor employed by sector Y. Sector M uses a continuum of services or components $Z = [0, 1]$ to produce the intermediate good with costless assembly technology. Finally, let service z be produced both at home country and abroad using skilled labor, using Ricardian production technology. In particular, let Ricardian unit labor demand be $a_S(z), \forall z \in Z$, where $a_S(1) = 1$. For any $z \in Z$, let $\delta(z) \equiv a_S^*(z)/a_S(z)$, where an asterisk denotes foreign variables in the remainder of the paper. We assume that $\delta'(z) < 0, \forall z \in Z$. Define $\tilde{z} \in Z$ such that $\delta(\tilde{z}) = w_S/w_S^*$, where w_S denotes skilled wage rate. Therefore, all $z \in [0, \tilde{z}]$ will be produces at home and all $z \in (\tilde{z}, 1]$ will be produced in the rest of the world. Then, given our setup, the total skilled labor whose service will be assembled in M, denoted by S_M, can be given by:

$$S_M = M \int_0^{\tilde{z}} a_S(z)dz \tag{1}$$

We maintain full employment of labor, implying that $L_Y = \bar{L}$ and:

$$S_M + S_y = \bar{S} \tag{2}$$

where $\bar{L}$ and $\bar{S}$ are constant endowments of unskilled and skilled labor, respectively. Then, equilibrium price of intermediate good M is given by:

$$p_m(\tilde{z}) = B(\tilde{z})w_S + [1 - B(\tilde{z})]w_S^* \tag{3}$$

where $B(\tilde{z}) \equiv \int_0^{\tilde{z}} a(z)dz$ is share of home made components $z \in Z$ in M.[2] By our small open economy assumption, p_x, p_y and w_s^* are all given. Hence, w_s and w will be determined with $p_x = p_y = w_s^* = 1$ by appropriate choice of units. Note also that, following the definition of δ and equation (3), we have $p_m(\tilde{z}) < 1$.[3].

Profit maximization implies demand for intermediate as $M = [(1-\alpha)X/p_m(\tilde{z})$. Hence, equilibrium output of X for any amount of capital can be obtained as:

$$X = \left(A(1-\alpha)^{1-\alpha}\right)^{\frac{1}{\alpha}} \left(\frac{1}{p_m(\tilde{z})}\right)^{\frac{1-\alpha}{\alpha}} K \tag{4}$$

Using the above derived demand for M and equation (4), we can obtain instantaneous equilibrium quantity of M for any given level of capital:

$$M = \tilde{A}K\tilde{p}_m^{-\frac{1}{\alpha}} \tag{5}$$

where $\tilde{A} \equiv [A(1-\alpha)]^{1/\alpha}$ and $\tilde{p}_m \equiv p_m(\tilde{z})$ for notational simplicity. Therefore, it follows from equations (1) and (5) that equilibrium employment of skilled labor used in production of domestic components $[0, \tilde{z}]$, for any given level of capital, can be given as:

$$S_M(w_s) = \frac{\tilde{A}KB(\tilde{z})}{(B(\tilde{z})w_s + [1 - B(\tilde{z})])^{\frac{1}{\alpha}}} \tag{6}$$

Differentiating equation (6), it can be shown that:

$$\frac{\partial S_M}{\partial w_s} = \tilde{A}K \frac{B'(\tilde{z})\frac{d\tilde{z}}{dw_s} - \frac{1}{\alpha}[B(\tilde{z})]^2[\tilde{p}_m]^{-1}}{p_m^{\frac{1}{\alpha}}}$$

where we have used $(d[B(.)w_s + (1 - B^*(.))]/d\tilde{z})\,(d\tilde{z}/dw_s) = 0$, since $d[B(.)w_s + (1 - B^*(.))/d\tilde{z} = 0$

[2]Note that the share of any component $z \in Z$ in M is trivially $a(z)M/M = a(z)$.
[3]See Sanyal (1983) and Marjit (1987).

due to the envelope theorem. Recall also that $B'(.) > 0$ and $d\tilde{z}/dw_s < 0$. Hence, we conclude that $\partial S_m/\partial w_s < 0$.

Next, consider sector Y. Equilibrium in this sector implies:

$$S_Y(w_s, \bar{L}) = \left(\frac{w_s}{\beta \bar{L}^{1-\beta}}\right)^{\frac{1}{\beta-1}} \tag{7}$$

where $\partial S_Y/\partial w_s < 0$. Hence, the market clearing condition for skilled labor can be re-written as:

$$S_M(w_s) + S_Y(w_s, \bar{L}) = \bar{S} \tag{8}$$

which determines equilibrium w_s, for any given level of K, hence sectoral skilled labor demand will be determined. Then, unskilled labor market clearing condition determines unskilled wage, i.e., $w = (1-\beta)[S_Y(w_s)]^{\beta}/\bar{L}^{\beta}$. Moreover, skilled-unskilled wage gap, for given by:

$$\frac{w_s}{w} = \frac{\beta \bar{L}}{(1-\beta) S_Y(w_s, .)} \tag{9}$$

implying that any change that leads to a decrease in demand for skilled labor in sector Y will increase the skilled-unskilled wage gap. Clearly, capital accumulation has consequences on skilled-unskilled wage gap and on inequality. Particularly, equations (6) and (8) imply that an increase in capital will increase (decrease) the demand for skilled labor whose services are used in sector M (Y). Hence, we have the following result.

Proposition 1 *Any increase in capital raises skilled-unskilled wage gap in this small open economy.*

Hence, it is crucial to study capital accumulation. We shall consider this in the next section.

3 Economic growth and inequality

Our model and its analysis in the previous section is for any given capital level. We shall now allow capital to be endogenously determined and grow over time for any given initial value. Let the representative consumer's utility function be given by $u = u(c_t)$, where c_t denoted the consumption of Hicksian composite good at time t, where neoclassical assumptions are maintained. We maintain throughout the rest of the paper that u exhibits constant inter-temporal elasticity of substitution.

Our dynamic optimization problem can be written as:

$$\max_{\{c_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \xi^t u(c_t)$$
$$s.t. \quad K_{t+1} - K_t = \frac{\tilde{A}K_t}{\phi(\bar{S}, K_t)} - c_t$$
$$K_0 = \bar{K}$$

where $\phi(\bar{S}, K_t) \equiv (1-\alpha)\tilde{p}_m^{(1-\alpha)/\alpha}$ and $\xi = 1/(1+\rho)$ is the discount factor and $\rho > 0$ is the discount rate. Recall that at a temporal equilibrium w_s depends on $\bar{S}$ and K_t, implying that $\tilde{p}_m$ also depends on $\bar{S}$ and K_t. Bellman equation for this dynamic programming problem can be written as:

$$v(K_t) = \max_{c_t}\{u(c_t) + \xi v(K_{t+1})\} + \lambda_t \left[\frac{\tilde{A}K_t}{\phi(\bar{S}, K_t)} - c_t - (K_{t+1} - K_t)\right]. \tag{10}$$

The first order conditions for this problem can then be obtained as:

$$u'(c_t) = \lambda_t \tag{11}$$
$$\xi v'(K_{t+1}) = \lambda_t \tag{12}$$
$$v'(K_t) = \lambda_t \left(\frac{\tilde{A}}{\phi} - \frac{K_t}{\phi^2}\frac{\partial \phi}{\partial K_t} + 1\right) \tag{13}$$

Rewrite equation (13) for $t+1$, to get:

$$\zeta v'(K_{t+1}) = \zeta \lambda_{t+1} \left(\frac{\tilde{A}(1-\varepsilon_{mk})}{\phi} + 1\right)$$

where ε_{mk} is the elasticity of price of M with respect to the capital stock. Using this equation and equation (12) and simplifying, we can obtain:

$$\tilde{A}\left(\frac{1-\varepsilon_{mk}}{\phi}\right) + 1 = (1+\rho)\frac{\lambda_t}{\lambda_{t+1}} \tag{14}$$

Then, given constant inter-temporal elasticity of substitution, it follows from equations (11) and (14) that:

$$\tilde{A}\left(\frac{1-\varepsilon_{mk}}{\phi}\right) + 1 = (1+\rho)(1+g)^{\sigma} \tag{15}$$

where $\sigma \equiv u''(.)/u'(.)$ is (constant) inter-temporal elasticity of substitution and g is the growth rate. Recall that $u'(c^*(k_t))/u'(c^*(k_{t+1})) = [c^*(k_{t+1}/c*(k_t))]^\sigma = (1+g)^\sigma$. By solving equation (15), we obtain:

$$g(t) = \Delta \left[\tilde{A} \left(\frac{1 - \varepsilon_{mk}}{\phi} \right) + 1 \right]^{\frac{1}{\sigma}} - 1 \tag{16}$$

where $\Delta \equiv [1/(1+\rho)]^{1/\sigma}$. Recall that ϕ is monotonically increasing in p_m. Hence, we have the following result.

Proposition 2 *Vertical specialization and opening of international trade in components at time t will lead to an increase in temporal growth rate.*

To see this more clearly, let us consider an example where $u(c_t) = \ln c_t$, i.e., $\sigma = 1$. Then, it follows form equation (15) that approximately $g(t) \approx \tilde{A}[(1 - \varepsilon_{mk})/\phi] - \rho$. Hence, growth rate crucially depends on the price of intermediate. Vertical specialization and trade opening in components will lower this price, resulting in higher temporal growth rate.

Now, turning to the catch-up hypothesis, we need to establish whether our small open developing economy experiences a greater reduction in price of the intermediate good as a result of vertical specialization and trade in components. To do this, first we have to derive autarky equilibrium price of M, denoted by p_m^a. It is evident from (3) that $p_m^a = w_S$ since $B(1) = 1$. Hence, we have to evaluate the change in skilled wage due to trade opening. Using $p_m^a = w$ and equations (6)-(8) as well as their equivalence in the rest of the world, we can show that at autarky we have:

$$\frac{\tilde{A}}{w_S^a} \bar{k}_S + \left(\frac{\beta}{w_S^a} \right)^{\frac{1}{1-\beta}} \bar{l}_S = 1 \tag{17}$$

where $\bar{k}_s \equiv \bar{K}/\bar{S}$ and $\bar{l}_s \equiv \bar{L}/\bar{S}$. Using equation (17) and its equivalence for rest of the world, recalling that $w_s^* = 1$, we obtain:

$$\frac{\tilde{A}}{w_S^a} \bar{k}_S + \left(\frac{\beta}{w_S^a} \right)^{\frac{1}{1-\beta}} \bar{l}_S = \tilde{A} \bar{k}_S^* + \beta^{\frac{1}{1-\beta}} \bar{l}_S^* \tag{18}$$

Thus, it follows from equation (18) that $w_S^a > w_S^* = 1$ if $\bar{k}_S > \bar{k}_S^*$ and $\bar{l}_S > \bar{l}_S^*$. Hence, we have the following result.

Proposition 3 *Autarky skilled wage is higher at home economy if it is skilled-labor scarce both relative to capital and unskilled labor.*

The condition of the above proposition is sufficient for skilled wage to be higher in the home economy. However, it is not a necessary condition. The necessary condition is that one of these skilled labor intensity conditions to be met. As it is evident from equation (18), for $w_S > w_S^*$ under autarky, it must be the case that $\bar{k}_S > \bar{k}_S^*$ or $\bar{l}_S > \bar{l}_S^*$. That is, killed labor must be scarce at home at least relative of the other primary production factors.

A crucial corollary to Proposition 3 follows from equation 3: $p_m^a > p_m^{a*}$ if home country is skilled-labor scarce both relative to capital and unskilled labor. Suppose this sufficient condition is met. Then, home country will experience a bigger price drop for the intermediate good as a result of vertical specialization, global production fragmentation and trade in fragments. That is, $dp_m = p_m^a - p_m(\tilde{z}) > p_m^{a*} - p_m(\tilde{z})$ if home country is skilled-labor scarce both relative to capital and unskilled labor. This, in turn, implies from equation (16) that $g(t) > g^*(t)$ if home country is skilled-labor scarce both relative to capital and unskilled labor. Hence, we have the following formal result that addresses the catch-up hypothesis.

Proposition 4 *With vertical specialization and trade opening for components, a small home economy grows faster than the rest of the world if this economy is skilled-labor scarce both relative to capital and unskilled labor.*

This result is compatible with observation of cross-country growth convergence (e.g., see Baldwin , 2016). A small developing country with skilled labor scarcity grows faster than developed world so that ultimately the cross-country per capita income converges.

We have already established in preceding section that a higher level of capital will increase the skilled-unskilled wage gap. Hence, this and Proposition 2 conclude the following important result on skill-unskilled wage inequality.

Proposition 5 *Vertical specialization, production fragmentation and trade opening raises within country skilled-unskilled wage gap.*

Intuition of this result deserves attention. Following proposition 2, vertical specialization and trade in components will increase growth rate, hence raises capital level. As K accumulates and S does not

expand at that rate, w_s/w will go up in each group of countries. Again, this explains within country divergence that we observe from empirical evidence. This result contributes to rising inequality literature (e.g., Autor et al. , 2003; Acemoglu and Restrepo , 2018).

While the effect of global production fragmentation and vertical specialization on wage inequality is generally unambiguous, its extent differs between home country and the rest of the world. This follows from the implication of catch-up hypothesis in our setup. The following result highlights the differential effects of vertical specialization on inequality.

Proposition 6 *Skilled-unskilled wage inquality widens more in home country than the rest of the world if home country is skilled-labor scarce both relative to capital and unskilled labor.*

4 Conclusion

We constructed an elaborate general equilibrium model of trade with vertical specialization, whereby two final goods and intermediate, with potential global production fragmentation, are produced. Our objective is to employ this general equilibrium model to study within country as well as cross-country consequences of vertical specialization, global production fragmentation on inequality and economic growth. In order to analyze growth consequences, we also cast our general equilibrium model in a growth framework. We derive a number of interesting results on within country divergence and cross-country convergence (i.e., catch-up hypothesis).

We showed that changes in capital level is consequential for skilled-unskilled wage gap, hence income inequality. Our model indicates that global production fragmentation, vertical specialization and trade in fragments will have positive effect on growth. Depending on the endowment differences in skilled labor, catch-up hypothesis may hold true. Hence, our paper contributes to an unsettled dispute on cross-country convergence by providing a mechanism through which the hypothesis hold, given the conditions of our results. We also showed that global production fragmentation, vertical specialization and trade in fragments causes widening skilled-unskilled wage gap.

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