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DYNAMICS OF GENERAL PURPOSE TECHNOLOGIES IN AN OPEN ECONOMY*

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Abstract

While the Helpman-Trajtenberg model is successful in explaining the macroeconomic cycle generated by GPT in the context of a closed economy, open-economy implications regarding GPT have received scant attention. We seek to fill such void in the previous literature by developing a dynamic North-South trade model with GPT. Our major findings are: 1) the introduction of GPT causes a product cycle from the North to the South followed by a reverse product cycle from the South to the North; 2) the presence of trading partner can cushion the macroeconomic shock experienced by the North.

Keywords: Open Economy; General Purpose Technologies; Trade Pattern; Real GDP Growth
JEL Classifications: F43, O30

I. *Introduction*

The productivity slowdown of the past quarter-century accompanied with the computerization in the U.S. has directed the attention of economists toward general purpose technology (GPT, henceforth) . GPT refers to a certain type of drastic innovation characterized by pervasiveness in use, innovational complementarities, and inherent potential for technical improvement. The clearest examples of GPTs which meet this definition are electricity and

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computer as well as the transistor. The central theme underlying the literature is that an introduction of GPT does not boost aggregate productivity immediately but may instead cause productivity slowdown at early stage (Helpman, 1998; Helpman and Trajtenberg, 1998; Jovanovic and Rosseau, 2005; Carlaw and Lipsey, 2006).

In “a time to sow and a time to reap” hypothesis, Helpman and Trajtenberg (1998) argue that when a new GPT arrives in the economy, it cannot be used right off the shelf, and a new set of ‘compatible components’ (e.g., software packages, integrated circuits for personal computer) need to be developed. More specifically, “time to sow” refers to the period where a certain amount of resources in the economy shifts to the R&D sector to develop a new set of compatible components, and such relocation of resources causes the production of final goods to shrink. Meanwhile, due to economies of scale at the national level, aggregate productivity plummets as the scale of final goods production dwarfs. However, productivity would soon bounce back and increase further during “time to reap” where the amount of R&D surpasses the required level, and the production of final goods expands as the more productive new GPT can finally be used in production.

Yet, previous literature, by confining its attention only to the closed economy, has not addressed many important questions regarding the role of openness in the dynamics created by GPT. For example, what is the implication of having trading partners on “a time to sow and a time to reap” hypothesis? Specifically, does international trade amplify or soften the macroeconomic cycle generated by an introduction of GPT? And, what is the impact of GPT on the trade pattern? We believe that these questions are particularly important for countries which have strong connections to the rest of the world through international trade.

Our research attempts to fill such void in the previous literature through incorporating the features of Ricardian international trade model into the Helpman-Trajtenberg model. To the best of our knowledge, this is the first study that examines the open-economy implications of GPT: the impact of GPT not only on the pattern of specialization (e.g., GPT-generated product cycle) but also on the nature of macroeconomic cycle. Two major findings in this paper are: 1) an introduction of GPT causes a product cycle from the North to the South during “time to sow” but a reverse product cycle from the South to the North during “time to reap”; 2) the presence of the South can cushion the macroeconomic shock to the North engendered by GPT.

This paper is organized as follows. In Section II, we develop a North-South trade model with GPTs drawing on the Ricardian model with a continuum of goods and the Helpman-Trajtenberg model. In Section III, we describe the transitional dynamics of the pattern of international trade and the number of intermediate goods, as caused by the introduction of a new GPT. We study the dynamics of real GDP of the North during the transitional dynamics in Section IV. The last section provides the conclusion.

II. *The Basic Model*

Consider the world economy composed of two regions, North and South. Each region is endowed with labor, L^N and L^S, respectively, which is the only production factor in the model. Households in both regions consume a continuum of final goods, $Y(j)$s indexed by the variable j over the interval $[0, 1]$ on the real line, and they share identical homothetic preferences:

$$U_t = \int_t^{\infty} e^{-\rho(\tau - t)} \left[\int_0^1 \log C(j, \tau) dj \right] d\tau \tag{1}$$

where ρ is the subjective discount rate and C(j, τ) is the consumption of final good Y(j) at time τ. With such logarithmically additive preferences, each household spends an equal and constant share of income on each final good Y(j).

Each final good Y(j) is produced with the aid of a currently prevailing GPT, labor, and a variety of intermediate goods which are compatible with the GPT in use. The technology to produce good Y(j) is described by the following production function:

$$Y(j) = \lambda \left[\int_0^n x(h)^{\beta} dh \right]^{\frac{\alpha}{\beta}} \left[\frac{L(j)}{\alpha^i(j)} \right]^{1-\alpha}$$
$$\lambda > 1,\ 0 < \alpha < 1,\ 0 < \beta < 1 \quad i = N, S \tag{2}$$

where λ is the productivity level of the current GPT, n is the number of intermediate goods, x (h) is the input of intermediate good h, 1/(1-β) is the elasticity of substitution between any two intermediate goods, α is the share of capital (i.e., intermediate goods), L(j) is the labor input in production of Y(j), and $1/a^i(j)$ is the productivity of labor in producing final good Y(j) in region i. We assume that there exist n_0 intermediate goods which are compatible with the current GPT.

It is worthwhile to mention some important properties of the production function. First, the productivity of a given stock of resources increases in the number of available intermediate goods. Second, unlike the previous literature, we sever the link between the share of intermediate goods (α) and the elasticity of substitution between any two intermediate goods 1/(1-β).[1] Third, we assume that the productivity of the current GPT, λ, is common to all final goods in both regions for simplicity.[2] Finally, and most importantly, for each final good Y(j), the productivity of labor, $1/a^i(j)$, is the unique source of technological difference between the North and the South.

We denote the relative labor productivity between the North and the South for final good Y(j) by $A(j) \equiv a^S(j)/a^N(j)$. We index the final goods such that A(j) is decreasing in j, and we further assume that A(j) is continuous and differentiable (i.e., $A'(j) < 0$) as in typical Ricardian trade model with a continuum of goods (e.g., Dornbusch et al., 1977). This suggests that the North (South) has a comparative advantage in final goods with lower (higher) index j, and more specifically, there exists a threshold z such that final goods $j \in [0, z]$ ($j \in [z, 1]$) are produced in the North (South). We assume that final goods are traded costlessly across regions.

R&D technology to develop intermediate goods is given by:

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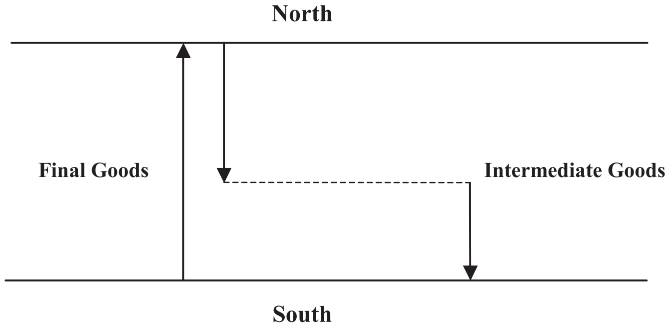
[1] For example, Barro and Sala-i-Martin (1995) and Romer (1990) make a simplifying assumption that $\alpha = \beta$.

[2] We may consider a case where the productivity of GPT is lower in the South. For example, we can assume that the Southern productivity of GPT is $\gamma\lambda$ where $\gamma \in (0,1)$. However, this new assumption does not change the main results of our paper.

FIG 1. TRADE STRUCTURE BETWEEN THE NORTH AND THE SOUTH



$$dn = \frac{l}{k^i} dt \qquad i = N, S \tag{3}$$

where l is the amount of labor devoted to the development of new intermediate good for a time interval of length dt, and k^N (k^S) is the unit labor requirement for the Northern (Southern) entrepreneurs to develop one new blueprint of intermediate good. With this specification of R&D technology, the number of newly developed intermediate goods does not jump in a discrete fashion but increases continuously.

We assume that the North has a comparative advantage in developing new intermediate goods when a new GPT arrives. Specifically, we assume that $k^N < k^S$ and $\frac{k^S}{k^N} > A(0)$. The second assumption suggests that the North specializes in all profitable R&D activities to develop intermediate goods. We assume that the Northern entrepreneurs hold patents for the intermediate goods or can keep the blueprint of intermediate goods in secret. Thus, the North specializes in production of intermediate goods as well. Intermediate goods are assumed to be costlessly exported from the North to the South. Figure 1 summarizes the trade structure between the North and the South.

Intermediate goods are produced under monopolistic competition. Each intermediate good is produced with the identical constant-returns-to-scale technology, and the unit labor requirement is assumed to be one. From the production function of final good $Y(j)$ in (2), we can derive the demand function for each intermediate good, and can find that the Northern firms producing intermediate goods practice the following markup pricing:

$$p_x(h) = \frac{w^N}{\beta} \tag{4}$$

where $p_x(h)$ denotes the price of intermediate good h. Each Northern firm producing an intermediate good receives a profit which is given by $\pi(h) = (1-\beta)p_x(h)x(h)$.[3]

[3] Since all of intermediate goods are symmetric, we will delete index h for intermediate good in the remaining explanation.

The value of a blueprint at time t equals the present value of profits,

$$\nu(t)=\int_t^{\infty} e^{-R(t,\,\tau)}\,\pi(\tau)\,d\tau,$$

where $R(t,\ \tau)=\int_t^{\tau} r(i)\,di$ is the cumulative interest rate. And free entry in the R&D sector generates the following equilibrium condition:

$$\nu \leq k^N w^N \text{ with equality whenever } n>0. \tag{5}$$

Also, the arbitrage between stocks and riskless bond in the capital market will dictate the following no-arbitrage condition:

$$\frac{\dot{\nu}}{\nu}+\frac{\pi}{\nu}=r, \tag{6}$$

where r is the interest rate on the riskless bond.

Next, we use the production function of final good Y(j) in (2) and the price of intermediate goods in (4) to derive the unit cost function of final good Y(j):

$$c(j)=K\frac{[a^i(j)\,w^i]^{1-\alpha}(w^N)^{\alpha}}{\lambda n_0^{\frac{\alpha(1-\beta)}{\beta}}} \quad i=N,\,S \tag{7}$$

where K is a constant and n_0 denotes the number of x(h)'s available. The unit cost function suggests that the unit cost of final good Y(j) is lower when the productivity level of the GPT in use, λ, is higher, the number of components available, n_0, is higher, productivity of labor, $1/a^i(j)$, is higher, and finally, wage rates in both regions are lower. We assume that the final good Y(j) is produced in the perfectly competitive market in both regions, and this assumption suggests that the price of final good is equal to its unit cost, p(j) = c(j) where p(j) denotes the price of the final good Y(j). Without loss of generality, we normalize the prices p(j)s such that $\int_0^1 p(j)\,Y(j)\,dj=1$.[4]

Now we turn to the labor market equilibrium in both regions. In the North, there are three sources of demand for labor: the manufacturing of both intermediate and final goods and the development of blueprints. In contrast, labor in the South is employeed only for the manufacturing of the final goods. Thus, the labor market equilibrium condition in each region is given by:

$$\int_0^z L(j)\,dj+n_0 x+k^N\dot{n}_0=L^N, \tag{8}$$

[4] This normalization assumption implies that total consumer spending in both regions is equal to one at each point in time. See Grossman and Helpman (1991) for further details about this specification.

$$\int_z^1 L(j)\,dj = L^S \tag{9}$$

Before we study the impact of arrival of a new GPT in the economy, it is useful to describe the *steady state* equilibrium of our basic model. In our basic model, the process of R&D runs into diminishing returns, and thus, the incentive to develop additional blueprint vanishes at the steady state. Since no R&D is being undertaken at the steady state ($\dot{n}_0 = 0$), the identical static equilibrium is repeated every moment of time once the economy reaches the steady state.

In describing the steady state, we focus on the determination of relative wage, $\frac{w^N}{w^S}$, and threshold z which reflects the pattern of trade. According to the unit cost function in (7), the "border-line" final good, Y(z), which can be produced in either region, satisfies the condition, $a^N(z)w^N = a^S(z)w^S$, and we rewrite this condition as:

$$A(z) = \frac{a^S(z)}{a^N(z)} = \frac{w^N}{w^S} \tag{10}$$

which describes the negative relationship between $\frac{w^N}{w^S}$ and z.

To pin down the level of both $\frac{w^N}{w^S}$ and z, we need to harness the labor market equilibrium conditions, (8)-(9). First, using the fact that the share of intermediate goods in the production of final good is α, we find that:

$$p_x n_0 x = \alpha \quad \forall j.^5 \tag{11}$$

Similarly, since the share of labor is 1-α in the production of final good, we find that:

$$w^i L^i(j) = 1 - \alpha. \quad i = N, S \tag{12}$$

Using (4), (11) and (12), we rewrite the labor market equilibrium conditions (8)-(9) as:

$$\frac{z(1-\alpha)}{w^N} + \frac{\alpha\beta}{w^N} = L^N, \tag{13}$$

$$\frac{(1-z)(1-\alpha)}{w^S} = L^S. \tag{14}$$

Now, using these two equations (13)-(14), we derive another relationship between $\frac{w^N}{w^S}$ and z,

[5] This condition readily follows from the property of production function for final good, and the normalization assumption, $\int_0^1 p(j)\,Y(j) = 1$.

denoted by B(z):

$$B(z)=\frac{w^N}{w^S}=\frac{z+\frac{\alpha\beta}{1-\alpha}}{1-z}\cdot\frac{L^S}{L^N}.^{6} \tag{15}$$

By combining A(z) and B(z), we obtain the steady state values of $\frac{w^N}{w^S}$ and z.

III. *Introduction of a New GPT*

In this section, we analyze the transitional dynamics engendered by the introduction of a new GPT. For both simplicity and tractability, we consider a one-time exogenous introduction of a GPT. The new GPT is more productive than the old GPT but we assume that it cannot be used immediately unless a new set of compatible intermediate goods are developed. The production function for the final good Y(j) with the new GPT is given by:

$$Y(j)=\lambda^2\left[\int_0^n y(h)^\beta dh\right]^{\frac{\alpha}{\beta}}\left[\frac{L(j)}{a^i(j)}\right]^{1-\alpha}\quad i=N, S \tag{16}$$

where λ^2 is the productivity level of the new GPT and y(h) denotes the intermediate good which is compatible with the new GPT. We assume that the unit labor requirement for y(h) is one.

Using (16), we find the unit cost function with the new GPT as:

$$c(j)=K\frac{[a^i(j)w^i]^{1-\alpha}(w^N)^\alpha}{\lambda^2 n_1^{\frac{\alpha(1-\beta)}{\beta}}}.\quad i=N, S \tag{17}$$

where n_1 denotes the number of y(h)'s available. By comparing the unit cost functions with the old and the new GPT, (7) and (17), we obtain the following switching condition:

$$n_1>\frac{n_0}{\lambda^{\frac{\beta}{\alpha(1-\beta)}}}. \tag{18}$$

As assumed in Helpman and Trajtenberg (1998), R&D to develop intermediate goods compatible with the new GPT cannot precede the introduction of the new GPT. Thus, the number of new intermediate goods starts to increase only after the introduction of the new

[6] Note that equation (15) can be interpreted as the trade balance equilibrium condition. In the original Ricardian model with a continuum of goods (Dornbusch et al., 1977), the trade balance equilibrium is given by $\frac{w^N}{w^S}=\frac{z}{1-z}\cdot\frac{L^S}{L^N}$. Equation (15) has an extra term, $\frac{\alpha\beta}{1-\alpha}$ in the numerator of RHS, and this is because of the presence of 'intermediate goods' in our model.

GPT, and it takes a certain amount of time for the switch to the new GPT to occur. Until then, the old GPT and its compatible intermediate goods are used in producing the final good. In the following section, we analyze the transitional dynamics caused by the arrival of the new GPT in two separate phases: a) the time period from the arrival of the new GPT to the adoption of the new GPT; b) the time period from the adoption of the new GPT to the new steady state.

1. Phase 1

We assume that the GPT is introduced at time t_0, and we let Δ denote the length of time which is required to develop a sufficient number of intermediate goods for the switch to occur. We focus on the transitional dynamics of the number of new intermediate goods, n, and the pattern of geographic specialization, z. First, we use the labor market equilibrium condition in the North, (13), to derive the equation of motion for n:

$$k^N \dot{n} + \frac{z(1-\alpha)}{w^N} + \frac{\alpha\beta}{w^N} = L^N \text{ for } t \in [t_0, t_0+\Delta). \tag{19}$$

Note that $k^N \dot{n}$, which is the newly created labor demand from the R&D sector, is the new term introduced during Phase 1. Moreover, using the free entry condition (5), the no arbitrage condition (6), and the normalization assumption, $\int_0^1 p(j)\,Y(j)=1$, we derive the equation of motion for w^N:

$$\frac{\dot{w}^N}{w^N} = \rho \text{ for } t \in [t_0, t_0+\Delta).^7 \tag{20}$$

Next, we use equations, (10) and (14) to substitute z for w^N in both (19) and (20). Then, we obtain the following system of differential equations with n and z:

$$\frac{\dot{z}}{z} = -\frac{\rho}{\dfrac{z}{1-z}+\varepsilon} \quad \text{for } t \in [t_0, t_0+\Delta), \tag{21}$$

$$\dot{n} = \frac{1}{k^N}\left(L^N - \frac{z(1-\alpha)+\alpha\beta}{(1-\alpha)(1-z)A(z)} L^S\right) \quad \text{for } t \in [t_0, t_0+\Delta) \tag{22}$$

where $\varepsilon = -\dfrac{A'(z)z}{A}$ is the elasticity of the A(j) curve evaluated at z.

There exist many different trajectories of n and z which are consistent with this system of differential equations. However, our analysis focuses only on the trajectory that converges to the steady state along the saddle path. We find that z keeps decreasing along the saddle path during Phase 1, which implies that there is a product cycle from the North to the South. We

[7] Note that the operating profit is zero for innovators during Phase 1.

also find that n is continuously rising along the saddle path during Phase 1. Economic intuition behind this is that as a new GPT is introduced, R&D activity in the North creates a new labor demand and bids up the wage rate in the North, which also increases the relative wage, $\frac{w^N}{w^S}$.[8] As a result of the increase in the relative wage, a certain range of final goods producers in the North lose competitiveness to the South.

2. Phase 2

The new GPT becomes profitable as a sufficient number of intermediate goods which are compatible with it are developed. Then, the economy enters Phase 2. Intermediate goods producers in the North cease to produce old intermediate goods and start to produce new ones. Innovators in the North make profits as new intermediate goods are in demand. However, R&D to develop new intermediate goods ultimately comes to a halt because of diminishing returns in the R&D technology. We let t_1 signify the point in time at which R&D stops. Since innovators make profits during Phase 2, the equation of motion for z becomes:

$$\frac{\dot{z}}{z}=\frac{1}{\frac{z}{1-z}+\varepsilon}\left[\frac{\alpha(1-\beta)L^S}{(1-\alpha)k^N(1-z)A(z)n}-\rho\right] \text{ for } t\in[t_0+\Delta,t_1]. \tag{23}$$

The equation of motion for n is the same as the one in Phase 1, as shown in equation (17).

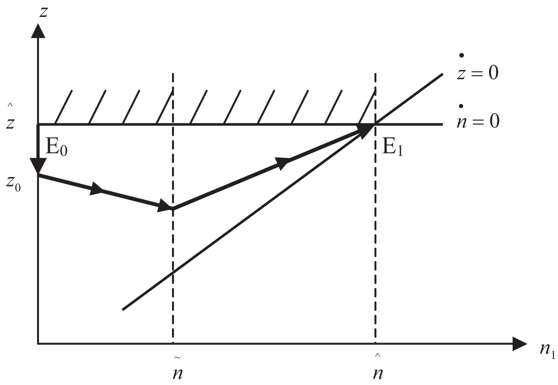
Now, we proceed to explain the behaviors of n and z in the whole process of transitional dynamics (i.e., both Phase 1 and 2) using the phase diagram depicted in Figure 2. At the beginning of Phase 1, the economy is at point E_0 ($z=\hat{z}$ and $n=0$), the original steady state. As the transitional dynamics begin, it moves along the saddle path which is represented by the thick arrowed line, and finally reaches E_1 ($z=\hat{z}$ and $n=\hat{n}$), the new steady state at the end of Phase 2.[9] Our explanation begins with characterizing the new steady state and the movement along the saddle path and back to the initial starting point of Phase 1.

The economy is at the new steady state at point E_1 where the $\dot{n}=0$ line and the $\dot{z}=0$ line intersect, and there exists a unique (upward sloping) saddle path which reaches this steady state in Phase 2. As the economy moves along this saddle path during Phase 2, both n and z increase. In this phase, the labor demand from R&D sector starts to decrease due to diminishing returns in R&D technology. Thus, R&D sector releases more labor to the final goods sector, which pushes down the relative wage, $\frac{w^N}{w^S}$. Meanwhile, the North regains competitiveness in the final goods sector which once migrated to the South during Phase 1. This suggests that there

[8] We can analyze how the relative wage, $\frac{w^N}{w^S}$, behaves during Phase 1 by using the relationship between z and $\frac{w^N}{w^S}$, $A(z)=\frac{a^N(z)}{a^S(z)}=\frac{w^N}{w^S}$. According to this equation, the relative wage between the North and the South keeps increasing during Phase 1.

[9] Since the steady state value of z does not depend on the productivity of the GPT in our model, it is the same as $\hat{z}$ in both the old and the new steady states.

FIG 2. THE DYNAMICS OF THE PATTERN OF SPECIALIZATION AND THE NUMBER OF INTERMEDIATE GOODS IN TRANSITIONAL DYNAMICS



exists a reverse product cycle from the South to the North.

The switch from Phase 1 to Phase 2 occurs when n equals $\tilde{n}_1=\frac{n_0}{\lambda^{\frac{\beta}{\alpha(1-\beta)}}}$. There exists a unique (downward sloping) saddle path which hits the saddle path of Phase 2 when $\tilde{n}_1=\frac{n_0}{\lambda^{\frac{\beta}{\alpha(1-\beta)}}}$. If we trace backwards along this path, we find a downward jump from $\hat{z}$ to z_0 at the beginning of Phase 1.

IV. *Real GDP Growth*

Our model illustrates that the introduction of a new GPT engenders a product cycle from the North to the South in Phase 1 which is followed by a reverse product cycle from the South to the North in Phase 2. These findings may render one to expect that such temporary relocation of final goods industries to the South in Phase 1 is detrimental to the North. To have a proper evaluation of the impact of the introduction of the new GPT on the North, we study the behavior of real GDP in the North during the transitional dynamics.[10]

In the North, nominal GDP consists of wages and profits. From (4), (11), and (12), we find that nominal GDP in the North is $z(1-\alpha)+(1-\beta)\alpha$ which depends only on z. Thus, if we only consider nominal GDP, we see that it decreases in Phase 1 and increases in Phase 2.

Since we are interested in the dynamics of real GDP, we need to construct a price index of final goods. We do this by solving the expenditure minimization problem where the price index is given by:

$$P=\exp\left[\int_0^1 \log p(j)\,dj\right].^{11}$$

[10] In our model, real GDP and total factor productivity are indistinguishable.

[11] See Obstfeld and Rogoff (1996) for details on how to derive the price index.

Using the unit cost function for final good, (7), we derive the price index during Phase 1 as:

$$P = \exp[\log w^N - (1-\alpha)\{(1-z)\log A(z) - \left(\int_0^z \log a^N(j)dj + \int_z^1 \log a^S(j)dj\right)\} - \frac{\alpha(1-\beta)}{\beta}\log n - \log\lambda + \Omega] \tag{24}$$

where Ω is a constant.[12] The impact of w^N, λ, and n on P is clear: the price index is increasing in w^N, and decreasing in λ and n. However, since both $(1-z)\log A(z)$ and $\int_0^z \log a^N(j)dj + \int_z^1 \log a^S(j)dj$ increase as z decreases, the net effect of z on P is ambiguous.

Considering that z plays a key role in transitional dynamics, such ambiguous behavior of the price index with respect to z suggests that our model may not necessarily generate a time to sow where real GDP falls followed by a time to reap where real GDP rises in the North as in Helpman and Trajtenberg (1998). The intuition is as follows. In our open economy version of GPT model, if R&D ever becomes profitable, the North can specialize more in R&D and less in final goods while letting the South specialize more in final goods. With such specialization, Northern consumers can consume newly imported low-priced final goods manufactured in the South. Furthermore, Northern intermediate good producers can export intermediate goods to the South with better terms of trade. These are two clear reasons why real GDP of North may not necessarily fall in Phase 1.

Yet, such advantage of specialization during the transitional dynamics can occur only when the share of final goods sector (i.e., 1-α) is large enough. In fact, we can show that our model generates the same conclusion as the Helpman-Trajtenberg model when α is close to 1 (i.e., the share of labor in manufacturing final good is negligible). By focusing on the case where α is close to 1, we can ignore the ambiguous effect of z on P, and thus we only need to consider the impact of w^N, λ, and n on P. Since λ and n stay constant during Phase 1, and we know that w^N keeps increasing in the North from equation (20), the price index keeps increasing during Phase 1. Considering that nominal GDP of the North keeps decreasing during Phase 1, we conclude that real GDP of the North falls during Phase 1.

In the beginning of Phase 2 when the switch to the new GPT occurs, while λ jumps to λ^2, we find that the price index is 'continuous' at the switching point from the switching condition of (18). During Phase 2, since w^N keeps falling and n keeps rising, the price index falls. Thus, we conclude that real GDP of the North rises in Phase 2. Intuitively, when α is large enough, the presence of the South that can provide only cheap labor, does not become a great help for the North to alleviate its macroeconomic shock.

V. *Conclusion*

By incorporating the Ricardian model with a continuum of goods into the Helpman and Trajtenberg GPT model, we developed an open economy growth model with GPTs. The

[12] Note that we use the relationship between the relative wage and z, $A(z)=\frac{w^N}{w^S}$ in rewriting the price index.

prediction of our model can be summarized as follows. With the introduction of a new GPT, resources in the North move to the R&D sector to develop intermediate goods compatible with the new GPT. Due to resource competition in the North, Northern wages increase, and because of this domestic wage hike, Northern firms in certain final goods sectors lose competitiveness to the South. However, the boom in the South turns out to be temporary as the North regains competitiveness in these industries when the required R&D process comes to an end. We further showed that the presence of trading partner can be helpful to the North in alleviating the macroeconomic shock caused by the new GPT.

This paper is not without limits. First, the set of final goods normally changes after the introduction of new GPT (for example, electronic vacuum cleaner did not exist before the introduction of electricity). Therefore, it would be interesting to elaborate on the nature of product cycle generated by GPT when the set of final goods changes. Second, by considering the North-South trade model, this paper studies the role of 'bilateral' trade only in final goods. Future research may consider the North-North trade model with GPT through which we can study the role of bilateral trade in both intermediate and final goods when both regions actively engage in R&D.

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