How to Reap the Induced Technological Bonus? 
A Mechanism and Illustrative Implementation

Gouranga G. Das*
Department of Economics, Hanyang University, Seoul, South Korea
E-mail: gouranga_das@hotmail.com, dasgouranga@gmail.com
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Abstract

Exogenous technical progress can have uneven impacts on productivity contingent on absorptive capacity, structural congruence and trade intensity. The paper illustrates the role of enabling behind-the-border factors for effective absorption and is pertinent for discussing issues like ‘Europe 2020’ or Lisbon strategy for inclusive growth. Drawing on our model, we illustrate that the capture-parameter is the propellant force for effective assimilation of foreign technology of recent vintage. The capture parameter is the outcome of endogenous decision-making process. The ‘productivity bonus’ mechanism leaves room for changing the results via skill-mix composition. However, it awaits implementation in a large-scale economy-wide modeling framework for further extension.

Keywords: Trade, Technology Spillover, Capture, Productivity, Congruence

1. Introduction

Of late, with the rise to dominance of new endogenous growth theory the role of international trade and foreign direct investment (henceforth, FDI) in facilitating trans-border technology flows and consequential rise in productivity can no way be underestimated. The role of international trade in transmission of technological benefits via traded intermediate inputs has been discussed at length in the literature—see Keller [1], Eaton and Kortum [2,3], Coe, Helpman and Hoffmaister [4,5]—to name a few. Participation in international trade provides a variety of benefits to developing countries through resource allocations according to comparative advantage, exploitation of economies of scale, increased capacity utilization and technology upgradation— to name a few. Upsurge in technology-intensive products is well-documented in the literature (Keller [1]; World Development Report [6], World Bank [7]; Connolly [8]; Coe et al. [4]; Guerrieri and Milana [9]; Hoekman and Javorcik [10]; Das [11-13]). In the literature of technology spillover, the importance of absorption capacity (AC) and structural similarity (SS) in appropriation of technological benefits has been discussed (Cohen and Levinthal [14,15]; Nelson and Pack [16]; Evenson and Westphal [17]; World Development Report [6]). According to the World Development Report (World Bank [6] (henceforth, WDR) trade facilitates technology flows. WDR (1999) has documented evidences of acquisition of the knowledge capital with particular emphasis on the role of AC for knowledge diffusion. In fact, WDR (1999) reports that

“even a follower country needs a labour force with a relatively high level of technical education, especially when technologies are changing rapidly”. (see p. 42, ibid)

Also, for closing ‘knowledge gaps’ between the technology creator and the recipients it emphasized the crucial roles of (see p. 25):

1) “Acquiring and adapting global knowledge—and creating knowledge locally;”
2) “Investing in human capital to increase the ability to absorb and use knowledge;”
3) “Investing in technologies to facilitate both the acquisition and the absorption of knowledge.”

Development of AC is important for effective diffusion of technology as it encompasses the “ability to imitate new process of product innovations, [and] to exploit basic research.” (Cohen and Levinthal, [15]). Nelson [18] defines AC as “the ability to learn and implement the technologies
and associated practices of... ...developed countries.”

Nelson and Pack [16] argues that
“to learn to use new technologies and to function effect-
ively in new sectors required the development of new
sets of skills, new ways of organising economic activity,
and ... [becoming] competent in new markets” (and also)
“to be sure, adopting technologies of the advanced
countries required, among other things, high rates of
investment in physical and human capital...”

We offer a stylized model formalizing the nexus be-
tween embodied technology transfer, human capital and
TFP Growth. AC is defined in terms of skill intensity of
the labor force (Das [12]; Meijl and Tongeren [19]). SS
of two sectors will be judged by the similarity of their
capital intensities, for example, by physical capital per
unit of effective labor. SS involves comparison of struc-
tural characteristics of a sector in the source of techno-
logical change and those in the destinations; the idea is
that the technical knowledge in the advanced economies
will be most ‘appropriate’ to the clients closest to them
in terms of their primary factor intensities. Our over-
arching theory focuses on the sector-specificity of the
capture parameter (CP) determined by AC, SS and trade
intensity (TI). The model developed is specifically de-
signed for illustrative simulation of a technology shock.
Section 2 rationalizes. Section 3 models. Section 4 nu-
merically illustrates. Section 5 concludes.

2. The Rationale

Most of the relevant papers in the new growth literature
deal with non-convexities in production and dynamic
gains from trade between trade partners. The integration
of new growth theory and trade theory à la Grossman and
Helpman [21] and other researchers (mentioned above)
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places the emphasis on induced endogenous technical
change and scale economies. Typically, most of the
models assign a more prominent role to ‘technological
change’ as an explanator for varying growth episodes
across nations.

Lucas [22,23], however, is a tour de force in this genre
of growth models where the role of human capi-
tal—modelled via schooling and formal education as
well as learning by doing and on-the-job-training—has
been given due importance. Kosempel [24] also modeled
such interaction. In fact, Lucas [23] argues
“By assigning so great a role to ‘technology’ as a sou-
ence a ‘growth miracle’ whilst the Philippines had an
episode of ‘growth failure’ between 1960 and 1988; ac-
cording to him,

“The main engine of growth is the access to human
capital—of knowledge—and the main source of differ-
ce in living standards among nations is the difference in
human capital. Physical capital accumulation plays an
essential but decidedly subsidiary role”.

Using a “bottoms-up” approach, we focus not only on
the firm’s attainment of a least-cost input combination,
but also on technology transfer-induced endogenous ch-
anges in productivity. The vital elements in the latter are
skilled labor intensity (measuring AC), physical capital
intensity (proxying SS), and the trade intensity (TI, of-
fering the opportunities for capturing a technological
bonus). As shown below, for a sector “CP” is an amal-
gam of AC, SS and TI. In the context of European Un-
ion’s enlargement efforts to give accession to lower-tier
countries, this issue is pertinent. SS encapsulates social
capital and effects of physical capital amalgamated into
one ‘catch-all’ factor for ease of expositional conven-
ience. According to Dasgupta [25], TFP binds both tech-
nology and socio-economic institutions. Sen [26] as-
cribes important role to lack of social and physical infra-
structure. In a simple set up, the model purports to show
the mechanism of three pillars for cooperation between
high-tier and low-tier economies—a lesson useful from
the EU’s enlargement perspective (not discussed for par-
simony and different focus of current analysis).

A representative firm reaps the benefits of technologi-
cal improvements embodied in imported inputs. It needs
higher level skills to harness the benefits of technological
improvements. At the macro level, given the overall hu-
man capital stock and structural congruence with the
trading partners, the regions participate in trade and reap
the technological bonus (TB) out of trade flows (see Cé-
tin and Cincera [27]). Of course, at a given intensity of
trade flows, a higher bonus may be achievable if the skill
intensity of the work force is higher, which may partially
motivate building up additional skills. At the level of a
sector, the question is to find out the “optimal” level of
skilled labour for a sector so as to make the best use of
the “TB” obtainable from trade-mediated technology. Even
though the firm chooses an optimal input mix, tech-
nical progress in the foreign source is an exogenous
phenomenon. This induces a sectoral bias into technical
change as skilled labour will have an advantage in ex-
tracting the “TB” from spillovers.

Based on the theoretical insights, we adopt a neo-clas-
sical growth framework. Let us consider an economy that
produces a single homogeneous good “Y,” (output or
GDP, synonymously) using composite (i.e., skilled and
unskilled composite) labor (L), domestic capital or gross
domestic capital formation, GDI, (k^D) and foreign capi-
tal of FDI (k^F) so that the aggregate Neoclassical well-
behaved production function is written as:
where “$A_i > 0$” is an index of technological progress (parameter) representing Total Factor Productivity (TFP) index or Hicks-neutral technical progress.

Also, aggregate composite capital stock, $K_t = K^D_t + K^F_t$.

Subscript “$t$” refers to unit of time. However, for simplicity we suppress the regional subscript for each country $j$.

Assuming linear homogeneity (constant returns to scale), this production function can be expressed in per worker (intensive form) terms as:

$$y_t = A_t f(k^D_t, k^F_t)$$

(2)

where lower case letters represent per worker values of the corresponding variables. Note that $y_t$ is the productivity per worker in period $t$.

Assuming log-linearity and taking a total differential of (1), we derive the following expression for growth-accounting relation as:

$$y_t / y_{t-1} = A_t / A_{t-1} + \beta \dot{k}^D_t / k^D_t + \gamma \dot{k}^F_t / k^F_t$$

(3)

In (3), generically $x_t = \frac{dx}{dt}$ is the time rate of change of variable $x$ or the growth rate.

The above expression shows that the growth-rate of per capita GDP depends on the growth rates of FDI and GDI intensity per worker and the rate of TFP growth. It is to be noted that the TFP changes, being influenced by shares of FDI and GDI in aggregate output, occur endogenously to escalate the growth in per capita GDP. Under perfect competition in product and factor markets, the coefficients are the corresponding output elasticities (equivalently, factor cost shares of foreign and domestic capital in per capita terms) of FDI and GDI per capita (in terms of growth rates).

The implication of this model is that since at higher level of capital stock, it will be subject to diminishing returns, the countries with lower level of productivity will experience a higher growth as a result of increased FDI. On the other hand, for the advanced countries the growth of productivity will be slower. Thus, this model suggests that the productivity differential across countries will be smaller owing to FDI-induced foreign capital inflows. The convergence of growth rates is in line with the catch-up hypothesis put forward for the newly emerging and rapidly industrializing economies of East and South-East Asia. This has important bearing for the EU’s integration effort with potential and candidate member states with lack of appropriate constellation of enabling factors (Shankar and Shah [28]). With sufficient human capital and skill formation, a country will have ample opportunity to break this diminishing returns and hence, will be able to reap spillover benefits via harnessing the technologically sophisticated capital goods or imported input embodying superior state-of-the-art. Thus, “$k$” in the above stylizations could be interpreted broadly to encompass human capital or knowledge-capital of superior quality. As Pack and Westphal [29] argued, “effort is required in using technological information and accumulating technological knowledge...to create new technology. This takes the form of investments in.....effective use of knowledge.”

In what follows, we just present an illustrative analytical model to show the role of human capital intensity to absorb sophisticated technology, assuming that physical capital intensity does not hinder the growth process.2

3. A Model of Productivity Bonus

Newer technology embodied in traded goods demands its own types of skills. The profile of skills embodied in the workers interacts with other inputs and the available state of the art to determine the TFP. The underlying assumption is that workers differ in the appropriateness of their skills to achieve any given productivity level with a particular vintage of technology. Competition ensures that each labour type is paid according to its marginal product.

The incentive of reaping a technological bonus from embodied spillovers modifies the representative firm’s choice of an optimal occupational mix. Thus, the bonus hypothesis is: the representative firm, in the process of maximizing profit (or minimizing costs), takes into account the benefits of technological improvements embodied in imported intermediate inputs. Capturing these benefits requires an appropriate mix of skilled and unskilled labour, which is recognized by the representative firm in its production decisions. The benefits available, moreover, depend positively on the structural similarity of the source and the recipient (as measured by the ratio of capital to quality adjusted labour). Technological improvement is exogenous in this theory which is restricted to the propagation of technology. We assume that for a sector “Bonus Embodied Spillover of Technology (BEST)” is achieved in consonance with the representative firm’s static optimization exercise: firstly, three variables viz., sectoral skill intensity, structural congruence and trade intensity in production of the sector combine to produce a capture-parameter. This subsequently transforms the potential productivity improvement into an actual productivity bonus—BEST—accrued via the traded intermediates. Figure 1 shows the transmission mechanism behind the productivity bonus.

The production function is generically written as:
\[ Y = \text{function}(M_F, M_D, L_S, L_U) \]

where \( Y \): output,
\( M_F \): imported material input,
\( M_D \): domestic material input,
\( L_S \): skilled labour input and
\( L_U \): unskilled labour input.

\( M \): composite (aggregate) materials of \( M_F \) and \( M_D \).

\( V \): Value-added composite of primary factors.

Figure 1. Principal pathways underlying the mechanism of technological bonus capture by sector \( j \) in region \( s \).
Assuming the production function Leontief (at the top level) in M and in value added measured in efficiency units, \( bV \):

\[
Y = \min \{ M, bV \} \quad (5)
\]

where:

\[
M = M_F^\alpha M_D^{(1-\alpha)} \quad (6)
\]

\[
V = L_S^\beta L_U^{(1-\beta)} \quad (7)
\]

\[
b = f \times g \quad (8)
\]

\[
\ln f = h \left( \ln \frac{M_F}{M_D} \right) \quad (9)
\]

\[
\ln g = H \left( \ln \frac{L_S}{L_U} \right) \quad (10)
\]

\[
h, H > 0 \quad (11)
\]

\[
h', H' > 0 \quad (12)
\]

The function \( b \) in (8) allows for changes in TFP via two intensity ratios, the import intensity of material inputs and the skill intensity of labor, entering multiplicatively. The optimization problem facing the representative perfectly competitive firm is formalized as:

Maximize \( Y \) with respect to \( M_F, M_D, L_S, L_U \), subject to:

\[
C = P_F M_F + P_D M_D + W_S L_S + W_U L_U \quad (13)
\]

where \( C \) is the cost of inputs, while \( P_F, P_D, W_S, \) and \( W_U \) are the prices of the inputs. Note that \( P_F, P_D, W_S, \) and \( W_U \) are all exogenous. \( C \) is a real anchor in this constant-returns-to-scale world and hence, is set exogenous.

Taking a monotonic logarithmic transformation, maximize \( Y \) subject to:

\[
\ln C = \ln \{ P_F M_F + P_D M_D + W_S L_S + W_U L_U \} \quad (15)
\]

Since (5) is non-analytic, we invoke the (Leontief) restriction (18) below; as a second constraint in the Lagrangean.

\[
\ln Y = \ln M = \ln \left( b + \ln V \right) \Rightarrow \ln Y = \ln M_F + (1-\alpha) \ln M_D \quad (16)
\]

\[
\ln b + \beta \ln L_S + (1-\beta) \ln L_U \Rightarrow \ln b = h \left( \ln M_F - \ln M_D \right) + H \left( \ln L_S - \ln L_U \right) \quad (17)
\]

Form the Lagrangean:

\[
L = \alpha \ln M_F + (1-\alpha) \ln M_D + \lambda \left[ \ln C - \ln \{ P_F M_F + P_D M_D + W_S L_S + W_U L_U \} \right] \quad (19)
\]

The first-order conditions [other than the constraints (15) and (18)] are:

\[
\frac{\partial L}{\partial \ln M_F} = \alpha + \alpha \lambda - \lambda h' - \lambda P_F M_F / C = 0 \quad (20)
\]

\[
\frac{\partial L}{\partial \ln M_D} = (1-\alpha) + \alpha \lambda + \lambda h' - \lambda P_D M_D / C = 0 \quad (21)
\]

\[
\frac{\partial L}{\partial \ln L_S} = -\lambda H' - \lambda \beta W_S L_S / C = 0 \quad (22)
\]

\[
\frac{\partial L}{\partial \ln L_U} = \lambda H' - \lambda (1-\beta) - \lambda W_U L_U / C = 0 \quad (23)
\]

Adding (22) and (23) yields:

\[
\lambda = -\lambda W_L / C \quad (24)
\]

Adding (20) and (21) yields:

\[
\lambda = \lambda P_M / C - 1 \quad (25)
\]

Solving (20) through (23) for the input shares, we obtain:

\[
P_F M_F / C = \{ (1+\lambda) - \lambda h' \} / \lambda \quad (26)
\]

\[
P_D M_D / C = \{ (1-\alpha) + (1+\lambda) + \lambda h' \} / \lambda \quad (27)
\]

\[
W_S L_S / C = -\lambda (H' + \beta) / \lambda \quad (28)
\]

\[
W_U L_U / C = \Lambda (1-1-\beta) / \lambda \Rightarrow H' < (1-\beta) \quad (29)
\]

The left-hand sides of (26) through (29) add to unity, while the right-hand sides add to \( 1/\lambda \); hence

\[
\lambda = 1 \quad (30)
\]

Using (30) in (24),

\[
\Lambda = -W_L / C = -S_L = \text{the share of labour in cost} \quad (31)
\]

Denoting the cost shares of the four inputs by \( S_F, S_D, S_S, S_U \), from (30) and (26) through (29) we see:

\[
S_F = \alpha S_M + h' S_L \quad (32)
\]

\[
S_D = (1-\alpha) S_M - h' S_L \quad (33)
\]

\[
S_S = (H' + \beta) S_L \quad (34)
\]

\[
S_U = (1 - H' - \beta) S_L \quad (35)
\]

The quantity component of the shares is determined [via (5)] by output. That is:

\[
S_L = W \times (bV) / C \quad (36)
\]

\[
W = W_Y / C \quad (37)
\]

The value-added price index \( W \) is
\[
W = \frac{W_S L_S + W_U L_U}{b L_S \beta L_U \gamma}
\]  

(38)

Similarly for materials:

\[
S_M = P_M \times M / C
\]

\[
= P_M Y / C
\]

where composite material prices is given by:

\[
P_M = \frac{P_F M_F + P_D M_D}{M_F \alpha M_D^{1-\alpha}}
\]  

(39)

4. Numerical Illustration

4.1. The Data and Parameter Setting

Our analytical model developed above indicates that several inferences could be drawn from patterns of changes in the system. Thus, we perform some numerical simulation to show the impact of a technology shock (TFP) on the productivity improvement. The problem is approached in a partial equilibrium set up to see what type of changes prevail in the model. We illustrate the mechanism on the basis of a hypothetical data set with admissible values—presented in Tables 1 and 2. We have assigned admissible values to the parameters of the model, \(\alpha\) and \(\beta\). Tables 1 and 2 present the specific initial settings or base-case scenario.

The base-case scenario in Tables 1 and 2 is a solution of the share Equations (32)-(35) above. The impact of TFP improvement on endogenous productivity enhancement is traced via changes in “b” in the wake of several perturbations as specified in the experiments.

4.2. TFP Simulation

We simulate the effect of 5 and 10 percent TFP shock. Following the perturbation, the changed initial configurations of the variables are given in Table 3.

The 10 percent Hicks-Neutral shock is represented by the 10 percent increase in \(b'(2.724/2.4764 = 1.10)\) between Tables 1 and 3. As this shock is factor-neutral by nature, it affects the ‘size’ of the composite value-added whilst the composition of value-added (measured in conventional units) remain unaltered. Thus, because of Hicks-Neutrality skill-unskilled labour ratio between Tables 1 and 3 (4/8 = 0.5 = 3.739/7.478) remains unchanged. With fixed cost and prices kept fixed at the original level, the TFP improvement translates into a fall in the value-added measured in conventional units—compare the values for “V” in Tables 1 and 3—implying each productive factor inputs are required in less amount in physical terms. With cost being held fixed and given no change in the relative prices in the post-shock scenario, as V falls M has to increase to satisfy the constraint for fixed cost. Comparing the last column in these two tables, we infer that in quality-adjusted term, however, real value added increases. This is because the level of productivity bonus \(i.e.,\) value of “b” is augmented from 2.48 to 2.72. This, in turn, increases the effective value-added \(i.e.,\) “bV”. Following the Leontief fixed-coefficient technology at the top-most level, the usage of composite material inputs goes up by the same magnitude as ‘bV’—see third column in Tables 2 and 3. Also, gross output \(Y\) increases by about 2.8 percent—see fourth column in Tables 1 and 3 (15.439/15.014 = 1.028). Results for 5% shock could be explained analogously; however, as

| Table 1. Initial scenario for the representative firm. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|------------------|-----------------|
|               | \(M_F\) | \(M_D\) | \(M\) | \(Y_j\) | \(V\) | \(L_s\) | \(L_U\) | \(b\) | \(b_V\) |
| 10% shock     | 8    | 19.664 | 15.014 | 15.014 | 6.063 | 4    | 8    | 2.476 | 15.014         |
| 5% shock      | 8.116 | 19.952 | 15.234 | 15.439 | 5.858 | 3.865 | 7.730 | 2.600 | 1.50  | 1.65           |

| Table 2. Prices and Parameter setting for the representative firm. |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| \(W_S\) | \(W_U\) | \(P_F\) | \(P_D\) | \(C[exogenous]\) | \(\alpha\) | \(\beta\) |
| 1          | 1             | 1             | 1             | 39.665         | 0.3           | 0.4           |

| Table 3. Post-shock scenario for the representative firm and the impacts of TFP shocks. |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Variables       | \(M_F\) | \(M_D\) | \(M\) | \(Y_j\) | \(V\) | \(L_s\) | \(L_U\) | \(b\) | \(f\) | \(g\) |
| 10% shock       | 8.226 | 20.221 | 15.439 | 15.439 | 5.667 | 3.739 | 7.478 | 2.724 | 1.50 | 1.65 |
| 5% shock        | 8.116 | 19.952 | 15.234 | 15.439 | 5.858 | 3.865 | 7.730 | 2.600 | 1.50 | 1.65 |

The discussion and arguments draws partly on the in-house version of the article in Research Institute of Digital Economics, Hanyang University, Ansan. We need to report this to highlight the differences with other counterfactual simulations that we present below in details. However, this reproduction is for facilitating understanding of the theoretical insight via numerical example.
conjectured the lower TFP shock reduces the capture and the output compared to 10%-scenario. The sensitivity analysis with respect to TFP shock does not alter the direction of causality in the results. Keeping the skilled-unskilled factor intensities and the foreign-domestic intermediate input intensities unaltered, we see that the larger is the size of the TFP shock (i.e., 10% as compared to 5%), the larger is the accrual of productivity bonus (BEST). In other words, “b” augments from 2.60 to 2.72 in case of doubling the size of transmitted productivity shock. This motivates us to perform further scenario analysis to examine how variations in the intensities of factor usage in the presence of this TFP-augmentation (5%) could inflate the productivity bonus.

### 4.3. Design of Counterfactuals and Numerical Analysis

We keep the productivity shock at 5% (we call it TFP-base case) and consider the following scenarios:

1) “Ls” remains the same: in this case, we keep it unaltered as in Table 1, Column 6 (that is, it is not reduced as in Table 3, Column 7, TFP-base case). Thus, the constrained cost-minimization by the firm entails reduction in Su, increase in Ss (and hence, in g via Equation (10)). As “f” (via (9)) remains the same, bonus “b” increases to 2.60 (from 2.53) and Y goes up to 15.20 from initial base case value of 15.01 (see Table 4, row 2).

**Inference I:** increase in skill-intensity improves AC and leads to improvement of the productivity bonus despite TFP shock being fixed at 5% level. Skill-intensity is crucial for assimilating productivity benefits.

2) “Ls” is increased: to 10 so that skill intensity of the firm falls. Constrained cost-minimization in the presence of 5% TFP entails reduction of Ls and fall in material input usage (Mf and M3 shrink) compared to both original base-case and TFP-base case (see row 3, Table 4). As expected, “g” and f fall (via Equations (9) and (10)), causing the bonus “b” to dissipate. This leads to fall in “bV” and “Y”.

**Inference II:** decrease in skill-intensity reduces AC and leads to dissipation of the productivity bonus despite the presence of TFP shock being fixed at 5% level. Also, decline in foreign intermediate input intensity leads to shrink in the productivity capture.

3) Foreign intermediate input (Mf) is increased: here traded intermediates is augmented whereas domestically sourced input (M0) input is decreased causing, via the representative firm’s constrained-cost minimization choices of factor inputs, share of materials to increase and share of value-added composite to fall (see row 4, Table 4). This led to increase in “f” substantially whereas “g” remained the same as in both the base-cases. It led to increase in the bonus capture (via (8)) and resultant increase in final output “Y” (row 4, Table 4).

**Inference III:** increase in imported intermediate inputs embodying sophisticated technology increases trade-mediated technology spillover and leads to rise in the productivity bonus even with fixed 5% TFP shock and same skill-intensity levels. Trade intensity is conducive for reaping productivity bonus.

4) “Ls” is increased, while keeping Lu unaltered: in this scenario, the representative firm’s optimization solution leads to increase in skill intensity (hence, in AC) whereas trade-intensity (f) remains almost the same. This led to increase in Ss, bonus (b) and hence, in output “Y” (see row 5, Table 4).

**Inference IV:** increase in skill-intensity enables to reap the productivity bonus via assimilation of imported intermediate inputs embodying sophisticated technology. This leads to rise in the level of final output even with fixed 5% TFP shock and trade intensity.

5) “Mf” is increased and “M3” is fixed at the original base-value: in this case, we see that “f” increases (as trade intensity goes up), but skill-intensity remains the same (g is unaltered). This leads to rise in the productivity spillover “b” causing output “Y” to grow (see row 6, Table 4).

| Scenario | Mf | M0 | M | Y | V | Ls | Lu | b | f | g |
|----------|----|----|---|---|---|----|----|---|---|---|
| Scenario 1) | 8.09 | 19.91 | 15.20 | 15.20 | 5.91 | 4 | 7.66 | 2.60 | 1.50 | 1.69 |
| Scenario 2) | 7.56 | 18.42 | 14.10 | 14.10 | 6.71 | 3.68 | 10 | 2.32 | 1.43 | 1.40 |
| Scenario 3) | 13.91 | 17.39 | 16.30 | 16.30 | 4.22 | 2.80 | 5.60 | 3.85 | 2.23 | 1.65 |
| Scenario 4) | 9.16 | 22.50 | 17.18 | 17.18 | 4.02 | 4.01 | 4 | 4.09 | 1.50 | 2.72 |
| Scenario 5) | 8.69 | 19.66 | 15.39 | 15.39 | 5.72 | 3.77 | 7.54 | 2.70 | 1.56 | 1.65 |
| Scenario 6) | 8.07 | 19.83 | 15.14 | 15.14 | 5.92 | 3.76 | 8 | 2.56 | 1.50 | 1.61 |
| Original base-case | 8 | 19.66 | 15.01 | 15.01 | 6.06 | 4 | 8 | 2.47 | 1.50 | 1.65 |
| TFP-base case | 8.12 | 19.95 | 15.23 | 15.23 | 5.86 | 3.86 | 7.73 | 2.60 | 1.50 | 1.65 |

Original base case scenario is the one without any TFP shock. TFP-base case is the one with only 5% TFP shock. Since 5% and 10% TFP shock generates the same direction of causality of results, only size or the magnitude of impacts differ, in the context of these series of counterfactuals this does not undermine our purpose. It is obvious that the higher doses of TFP coupled with those simulations would change the magnitude of accrual of bonus.
Inference V: increase in trade-intensity enables to reap the productivity bonus embedded in the imported intermediate inputs containing sophisticated technology. This leads to rise in the level of final output even with fixed 5% TFP shock and similar skill-unskilled labor shares.

6) “L_s” decreases, but “L_u” remains at the original base-case value: in this counterfactual case, L_s decreases so that S_t falls and hence, skill intensity declines. As M_s and M_u do not alter much, following the firm’s constrained cost-minimization exercise, “f” remains unaltered while “g” is reduced. Thus, the bonus magnitude “b” shrinks compared to TFP-base case. But as there is initial 5% TFP improvement, this causes output “Y” to register marginally higher level than the original base-case value (compare row 7, Table 4 with row 8). This is lower than TFP-base case as there is a fall in “g” following decline of skill-unskilled ratio.

Inference VI: decrease in skill-intensity in the presence of unchanged trade-intensity causes less chance to reap the productivity bonus embedded in the imported intermediate inputs. In this case, rise in the level of final output is induced by 5% TFP shock despite declining skill composition and similar level of trade intensity.

All these inferences are instrumental in understanding the working of the theoretical model developed in this paper. The numerical illustration of the model confirms our conjecture that trade, indigenous skill-induced adaptivity capabilities as well as technological sophistication are important forces for sustained growth and development. All these three channels facilitate learning of technologies of recent vintage. They mutually reinforce each other to translate into higher growth of output.

5. Conclusions

This paper presents and numerically implements a theoretical model of endogenous capture of technical change originating in the source of knowledge-creation (assumed exogenous). Numerical simulation confirms that: increases in the intensity of skilled labor in the input mix improves the absorptive capacity of the work force; the amount of technology captured increases with the import intensity of the material inputs while technological change is vehicle by foreign intermediates; increase in both types of intensities complements each other to augment the bonus capture; only technological change cannot deliver the potential benefits unless the input mixes are optimally chosen by the firm while making cost-minimization decision. We have explored their effects in harnessing the trade-induced technology flows. We show that capture-parameter is the propellant force for assimilation of transmitted technology. Further work along these lines will involve mounting the full scale simulations in a higher dimensional model and integrating a dynamic aspect of R&D-creation and its propagation. This work has important implications for technology policy and planning as well as for trade or regional integration, for example, in the context of European Union’s accession program under Europe 2020 aimed at social cohesion, competitiveness, skill formation, and R&D (Shankar and Shah [28]). Often, the necessity of political and social integration as precursor of successful monetary union is stressed. A systemic view is warranted for pursuing this objective. The model elicits heuristically that technology policy, trade policy and macroeconomic management needs a synergistic planning to achieve sustained growth. Trade, per se, is insufficient for achieving the growth dividends. Trade creates the opportunities for sustained development via industrialization and technology transfer; however, developing adequate socio-institutional framework, educational attainment and skill formations, inter alia, are necessary for seizing plethora of opportunities.

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