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Abstract

In this paper, we construct a model to study the technology transfer decision of a monopolist, with access to a finite number of technologies, under taxation. It is shown that a policy maker in a low-wage developing country cannot always increase the number of technologies transferred from a developed country through a tax on wages-and-invest scheme. We provide conditions for such an intervention to be successful and show that there is no unique choice of tax for doing so.

Keywords: technology transfer, multinational, tax, model

JEL Classification: D42; H21; O33

1 Introduction

In recent years international technology transfer has been a prominent topic in the literature on international trade and economic development. It is widely recognised that technology is traditionally created in developed countries only to be gradually transferred to less developed countries as it becomes obsolete. These considerations lead to the "product cycles" introduced by Vernon, [Vernon 1966], and further studied by Krugman, [Krugman 1979].

Dynamic models of technology diffusion, see for example [Findlay 1978], have also been used to explain the transfer of technology from a developed country (DC) to a less developed country (LDC) and to understand the role played by foreign direct investment in fostering these transfers. Related to this is the quest for the "right" policy measures to encourage multinational corporations to transfer more technology to affiliates in less developed countries increasing the potential for spillovers. A

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complementary line of research has focused on how government taxation of royalties paid by the affiliates to parent companies influences local R&D and the transfer of technology, [Hines 1995].

In this paper, we attempt to address the question of whether a tax on wages-and-invest scheme can affect the process of technology transfer from the so called developed North to the developing South. We construct a simple partial equilibrium model where a monopolist, namely a multinational firm, has access to a finite number of different technologies for producing a specific good. A simpler form of the model, has appeared in [Marjit 1988]. It is initially shown that the implementation of such a scheme in a closed economy affects the magnitude, not the order, of the costs associated with each technology employed in the production of the good. In particular, the application of a tax on wages-and-invest scheme splits the technologies into two groups, one of which may perfectly be empty. The first group is composed of those technologies that draw benefit from the applied scheme becoming more efficient while the second is composed of those technologies that, following a state intervention, are left worse off, i.e. with production costs revised upwards, Theorem 2.5. Further analysis of our model adjusted for the case of the DC-LDC bipolar yields results that accept a dual interpretation. Read from the point of view of the developing South, they may spell out a policy to promote the technology transfer from the North. Read from the point of view of the developed North, they may dictate a protectionist policy against technology transfers. The allocation of technologies across the world is motivated by profit maximization and it is shown that the less advanced technologies are more likely to get transferred first. It is also shown that often a tax on wages-and-invest policy cannot by itself tilt the allocation of technologies across the world. Conditions are given on when this may happen, Theorem 2.11.

The remaining of the paper is organized as follows. In Section 2 we introduce the model and derive all the results. In Section 3, we explain further the results of Section 2 through a comparative statics discussion. In Section 4, we conclude.

2 The model

A monopolist in a developed country (DC) has access to n different technologies ordered by their efficiency coefficient a_i as follows

$$0 < a_1 < a_2 < \cdots < a_n \,.$$

The labour requirement $a_i(x)$ to produce x units of the product using i technology is therefore proportional to a_i while the respective cost of production $C_i(x)$ is given by

$$C_i(x) = W a_i(x) x = W a_i x^2 \quad \text{with} \quad a_i(x) = a_i x \,, \quad i \in \{1, \ldots, n\} \,,$$

where $W > 0$ is the wage rate of DC, assumed uniform for all technologies i. It follows immediately from our assumptions that

$$a_1(x) < a_2(x) < \cdots < a_n(x)$$

and

$$C_1(x) < C_2(x) < \cdots < C_n(x)\,.$$

Let us, now, introduce a uniform tax T levied exclusively on the wage rate W to be used by the state as a public policy instrument via an investment function $f : \mathbf{R}_+ \to [0, a_1)$, again uniform for all technologies. It is understood that this function is an inherent characteristic of the administration of DC. Following the introduction of the tax T and the implementation of the return benefit $f(T)$, the rank of the technologies remain unchanged

$$0 < a_1 - f(T) < a_2 - f(T) < \cdots < a_n - f(T)\,,$$

while the new production cost is set to

$$C(T,f)_i(x) = (W+T)\,(a_i - f(T))\,x^2 = Wa_ix^2 + (Ta_i - Wf(T) - Tf(T))\,x^2\,,\ \forall i\,.$$

A technology, i, benefits from the introduction of the levy T and the subsequent state intervention if and only if

$$C(T,f)_i(x) < C_i(x)\,,$$

i.e. if and only if

$$Wa_ix^2 + (Ta_i - Wf(T) - Tf(T))\,x^2 < Wa_ix^2 \;\Leftrightarrow$$

$$Ta_i - Wf(T) - Tf(T) < 0\,. \tag{2.0.0}$$

Let us call the implementation of the levy T on the wage rate along with a uniform benefit on the labour requirement $f(T)$ a (T,f) state intervention. Rearranging (2.0.0) and taking into account the definition of f, we get

Lemma 2.1 *In a closed economy, the technologies, i, that benefit from a (T,f) state intervention are precisely those for which*

$$\frac{Ta_i}{W+T} < f(T) < a_1\,. \tag{2.1.0}$$

Given a state intervention (T,f), the monopolist's profit function is given by

$$P(T,f)(x_1,\ldots,x_n) = p(x_1+\cdots+x_n) - \sum_{i=1}^{n} C(T,f)_i(x_i)\,,$$

where p is the price of the product. One deduces that in the extrapolated case of a single technology, $a_i = a$ for all i, the introduction of a small tax T of order $0 < T < {}^{W}\!/_{a-1}$ increases the profit of the monopolist provided f is such that ${}^{Ta}\!/_{W+T} < f(T) < a$. Generally,

Proposition 2.2 *In a closed economy with $n \geq 2$, for*

$$0 < T < \frac{W}{\frac{a_n}{a_1} - 1} \quad \textit{and} \quad \frac{Ta_n}{W+T} < f(T) < a_1 \,,$$

a (T,f) state intervention lowers the production cost of all technologies increasing the profit of the monopolist.

PROOF. The first double inequality is necessary for the second to be true because

$$T < \frac{W}{\frac{a_n}{a_1} - 1} = \frac{Wa_1}{a_n - a_1} \;\Leftrightarrow\; Ta_n - Ta_1 < Wa_1 \;\Leftrightarrow\; \frac{Ta_n}{T+W} < a_1 \,.$$

Notice that

$$a_1 < a_2 < \cdots < a_n \;\Leftrightarrow\; \frac{Ta_1}{T+W} < \frac{Ta_2}{T+W} < \cdots < \frac{Ta_n}{T+W} \,,$$

therefore

$$\frac{Ta_n}{W+T} < f(T) \;\Rightarrow\; \frac{Ta_i}{W+T} < f(T) \;\Leftrightarrow\; Ta_i - Wf(T) - Tf(T) < 0$$

for all i and the result follows from (2.0.0).

Remark 2.3 *We observe that the result in Proposition 2.2 was proved under no assumptions on f other than it be a function.*

From now on, we require that the investment function f be twice differentiable on $[0, \infty)$, strictly increasing, strictly concave, i.e. $f'' < 0$, and such that $f(0) = 0$.

Definition 2.4 *We define $i_f \in \{0, 1, \ldots, n\}$ to be the biggest index such that $a_{i_f} \leq f'(0)W$. We let $i_f \equiv 0$ if and only if $f'(0)W < a_i$ for all $i \in \{1, \ldots, n\}$.*

Theorem 2.5 *Let i_f be as in Definition 2.4 with $i_f \neq 0$. Then, there is a $\mathcal{T}_{i_f} > 0$, such that for all $T \in (0, \mathcal{T}_{i_f})$ the implementation of a (T, f) state intervention lowers the production cost for all technologies i, with $1 \leq i \leq i_f$.*
Conversely, if there is a $\mathcal{T} > 0$, such that for all $T \in (0, \mathcal{T})$ the implementation of a (T, f) state intervention lowers the production cost of all technologies i, with $1 \leq i \leq i_f$ then, $a_i < f'(0)W, 1 \leq i < i_f$.

PROOF. Applying De l'Hôpital's theorem, we get

$$\lim_{T \to 0^+} \frac{f(T)}{\frac{Ta_{i_f}}{W+T}} = \lim_{T \to 0^+} \frac{f'(T)}{\frac{a_{i_f}(W+T) - Ta_{i_f}}{(W+T)^2}} = \lim_{T \to 0^+} \frac{f'(T)}{Wa_{i_f}}(W+T)^2 = \frac{f'(0)}{a_{i_f}} W > 1 \,.$$

This means that there is an open interval, $(0, \mathcal{T}_{i_f})$, such that

$$\frac{f(T)}{\frac{Ta_{i_f}}{W+T}} > 1 \;\Leftrightarrow\; \frac{Ta_{i_f}}{W+T} < f(T)\,, \forall T \in (0, \mathcal{T}_{i_f})\,.$$

Lemma 2.1 completes the proof.
To prove the converse, the fact that a state intervention (T, f) lowers the unit production cost of technology i_f means that

$$Wa_{i_f} > (W+T)(a_{i_f} - f(T)) \;\Leftrightarrow\; (W+T)f(T) > Ta_{i_f} \;\Leftrightarrow\; \frac{f(T)}{\frac{Ta_{i_f}}{T+W}} > 1,\; \forall T \in (0, \mathcal{T})\,.$$

Therefore,

$$\frac{f'(0)}{a_{i_f}}W = \lim_{T\to 0^+} \frac{f'(T)}{\frac{a_{i_f}(W+T) - Ta_{i_f}}{(W+T)^2}} = \lim_{T\to 0^+} \frac{f(T)}{\frac{Ta_{i_f}}{W+T}} \geq 1\,.$$

To complete the proof we observe that

$$a_i < a_{i_f} \leq f'(0)W\,,\; \forall 1 \leq i < i_f\,.$$

Proposition 2.6 *Let i_f be as in Definition 2.4 with $i_f \neq 0$. Then, there is an open interval $(0, \mathcal{T})$, such that for all $i, 1 \leq i < i_f$, the benefit*

$$b_i(T) := Wa_i - (W+T)(a_i - f(T)) = Wf(T) - Ta_i + Tf(T)$$

obtained by a state intervention (T, f) is an increasing function of the levy $T \in (0, \mathcal{T})$. Similarly, the increase of the production cost for all $i_f < i \leq n$ is again an increasing function of the levy $T \in (0, \mathcal{T})$ for the same $\mathcal{T}$.

PROOF. Let $1 \leq i \leq i_f$. Taking the derivative of $b_i(T)$, we observe that

$$b_i'(T) = Wf'(T) - a_i + f(T) + Tf'(T) > 0$$

provided

$$Wf'(T) - a_i > 0$$

which holds true in $(0, \mathcal{T}_i)$, for some $\mathcal{T}_i > 0$, since f' is continuous by assumption and $a_i < Wf'(0)$. For each $i > i_f$ the result follows by a similar to the above argument together with the fact that from the definition of i_f

$$Wf'(T) - a_i < 0\,, \forall i > i_f\,.$$

To complete the proof, we take $\mathcal{T} = \min\{\mathcal{T}_i\}_{1\leq i\leq n}$.

Up until this point we have been discussing the situation of a closed economy. We, now, assume that the monopolist can transfer part of his production abroad, usually to a less developed country (LDC) so that he can profit from the lower wage rate that comes along. In consistency with [Marjit 1988], we denote all indeces characterizing the economy of the LDC by an upper left star (*). Thus, in general, we expect the wage rate $W^* < W$ while we assume the corresponding labour requirement, a_i^*, uniformly increased throughout the technology spectrum, i.e. $a_i^* = a_i + t, t > 0$. We, further, look at the natural question a policy maker in the LDC is faced with whether a state intervention (T^*, f^*) could prove helpful in promoting a technology transfer from the DC to the LDC. The LDC investment function $f^* : [0, \infty) \to [0, t)$ is again twice differentiable, strictly increasing, strictly concave, i.e.$(f^*)'' < 0$, and $f^*(0) = 0$.

Proposition 2.7 *The i-th technology will be transferred following a state intervention (T^*, f^*) with $T^* > 0$, if and only if*

$$(2.7.0) \qquad \mathcal{D}_i(T^*) := f^*(T^*) - \frac{T^*(a_i + t)}{W^* + T^*} > \frac{W^*(a_i + t) - W a_i}{W^* + T^*} =: \mathcal{Q}_i(T^*) .$$

Proof. By the hypothesis of the theorem we get

$$\mathcal{D}_i(T^*) := f^*(T^*) - \frac{T^*(a_i + t)}{W^* + T^*} > \frac{W^*(a_i + t) - W a_i}{W^* + T^*} .$$

Equivalently

$$f^*(T^*) > \frac{W^*(a_i + t) - W a_i}{W^* + T^*} + \frac{T^*(a_i + t)}{W^* + T^*} ,$$

i.e.,

$$\begin{aligned} f^*(T^*)(W^* + T^*) &> W^*(a_i + t) - W a_i + T^*(a_i + t) \\ f^*(T^*)(W^* + T^*) &> (W^* + T^*)(a_i + t) - W a_i \\ W a_i &> (W^* + T^*)(a_i + t) - f^*(T^*)(W^* + T^*) \\ W a_i &> (W^* + T^*)(a_i + t - f^*(T^*)) , \end{aligned}$$

which completes the proof.

Lemma 2.8 *If the i-th technology is transferred under a (T^*, f^*) state intervention then so do all less efficient technologies.*

Proof. The fact that the i-th technology is transfered is equivalent to

$$W a_i > (W^* + T^*)(a_i + t - f^*(T^*)) \;\Leftrightarrow\; \frac{W}{W^* + T^*} > \frac{a_i + t - f^*(T^*)}{a_i} .$$

By assumption $f^*(T^*) < t$, so for $j > i$,

$$(a_j - a_i)(t - f^*(T^*)) > 0 \;\Leftrightarrow\; \frac{a_i + t - f^*(T^*)}{a_i} > \frac{a_j + t - f^*(T^*)}{a_j}$$

thus,

$$\frac{W}{W^*+T^*} > \frac{a_i+t-f^*(T^*)}{a_i} > \frac{a_j+t-f^*(T^*)}{a_j} \;\Rightarrow\; Wa_j > (W^*+T^*)(a_j+t-f^*(T^*))$$

and the j-th technology is transferred as well.

Definition 2.9 *Let $s \in \{0,1,\ldots,n\}$ denote the smallest index such that*

$$\frac{W}{W^*} > \frac{a_s+t}{a_s}\,.$$

We set $s \equiv n+1$ if and only if $s \notin \{1,\ldots,n\}$.

Corollary 2.10 (Marjit 1988) *Let s be as in Definition 2.9. Without state intervention, all technologies i with $s \leq i \leq n$ will be transferred abroad.*

PROOF. If there is no state intervention, i.e. if $T^* = 0$, then, $\mathcal{D}_i(T^*) = 0$ for all i, in particular, $\mathcal{D}_s(T^*) = 0$ and

$$\frac{W}{W^*} > \frac{a_s+t}{a_s} \;\Leftrightarrow\; \mathcal{D}_s(T^*) = 0 > \frac{W^*(a_s+t)-Wa_s}{W^*}\,.$$

The result follows from a combination of Proposition 2.7 and Lemma 2.8.

Let i_{f^*} as in Definition 2.4 for the LDC and s as in Definition 2.9. Define

$$\mathcal{R}_i(T^*) := \mathcal{D}_i(T^*) - \mathcal{Q}_i(T^*)\,, \quad i \in \{1,\ldots,n\}\,.$$

Because of Theorem 2.5, applied on the LDC, there is a $\mathcal{T}^* > 0$ so that $\mathcal{D}_i(T^*) > 0$ for all $T^* \in (0,\mathcal{T}^*)$ and all $i \in \{1,\ldots,i_{f^*}\}$. The continuity of $\mathcal{R}_i : (0,\mathcal{T}^*) \to \mathbf{R}$ implies that $\mathcal{R}_i^{-1}[(0,\infty)]$ is an open subinterval of $(0,\mathcal{T}^*)$. Define $r \in \{0,1,\ldots,n\}$ by

$$(0,\mathcal{T}^*) \cap \mathcal{R}_r^{-1}[(0,\infty)] \neq \emptyset \quad \text{while} \quad (0,\mathcal{T}^*) \cap \mathcal{R}_i^{-1}[(0,\infty)] = \emptyset \; i \in \{1,\ldots,r-1\}\,.$$

If $i_{f^*} = 0$, or if $\mathcal{R}_i$ takes non-positive values for all $i \in \{1,\ldots,n\}$ then, we define $r \equiv n+1$.

Theorem 2.11 *Given f^* let s, i_{f^*} and r be defined as above.*

(i) If $i_{f^*}+1 < s$ then, no tax can increase the number of technologies to be transferred.

(ii) If $s < i_{f^*}+1$ then, $r \leq s$ and there is an open subinterval $U \subseteq (0,\mathcal{T}^*)$ such that the implementation of any intervention $(T^*, f^*), T^* \in U$ results in the transfer of all technologies with $i \geq r$.

(iii) If $s = i_{f^*}+1$ then, either there exists $r < s$ and (ii) holds true or else (i) holds true.

PROOF. For the first part of the theorem, notice that by the definition of i_{f^*} and Theorem 2.5 applied on the LDC we get $\mathcal{D}_{s-1}(T^*) < 0$ for all $T^* > 0$. On the other hand, the definition of s ensures that $W^*(a_{s-1}+t) - Wa_{s-1} > 0$ rendering impossible inequality (2.7.0) and therefore, by Proposition 2.7, the $(s-1)$-technology does not get transferred, nor does any more efficient technology because of Lemma 2.8.
To prove (ii), notice that for $s \leq i < i_{f^*}+1$ there is a $T^* > 0$ so that $\mathcal{D}_i(T^*) > 0 > \mathcal{Q}_i(T^*)$, i.e. $\mathcal{R}_i(T^*) > 0$ and therefore $r \leq s$. We may take $U = (0, \mathcal{T}^*) \cap \mathcal{R}_r^{-1}[(0,\infty)]$ and the result follows from the definition of r, the continuity of $\mathcal{R}_r$, Proposition 2.7 and Lemma 2.8.
For the third part of the theorem, if $r \leq s$ the proof follows the lines of part (ii). Otherwise, Corollary 2.10 applies completing the proof.

Corollary 2.12 *Let $s \leq i_{f^*}+1$. If there is $k < s$ such that*

$$\mathcal{D}_{i_{f^*}}(T^*) > \frac{W^*(a_k+t) - Wa_k}{W^*}. \tag{2.12.0}$$

for some T^*, all less efficient technologies, including k, get transferred.

PROOF. Inequality (2.12.0) implies

$$\mathcal{D}_{i_{f^*}}(T^*) = f^*(T^*) - \frac{T^*(a_{i_{f^*}}+t)}{W^*+T^*} > \frac{W^*(a_k+t) - Wa_k}{W^*} > \frac{W^*(a_k+t) - Wa_k}{W^*+T^*}$$

which together with $k \leq i_{f^*}$ implies that

$$f^*(T^*) > \frac{W^*(a_k+t) - Wa_k}{W^*+T^*} + \frac{T^*(a_{i_{f^*}}+t)}{W^*+T^*} \geq \frac{W^*(a_k+t) - Wa_k}{W^*+T^*} + \frac{T^*(a_k+t)}{W^*+T^*}.$$

and the result follows from Proposition 2.7 and Lemma 2.8.

3 Discussion

In this section, we shall analyse further the results in Section 2 in order to reveal the economic meaning hidden under the mathematical guise of Proposition 2.2, Theorem 2.5, Proposition 2.6 and Theorem 2.11.

First, we make some comments on the public investment function $f : \mathbf{R}_+ \to [0, a_1)$. It is natural to assume that without taxation there is nothing the state can invest, i.e. $f(0) = 0$. Moreover, f has to be an increasing function, albeit at a decreasing rate, in a fashion similar to a utility function. The assumption on the range of f is a direct outcome of the fact that whatever gain a state intervention can offer to the production of a product this cannot exceed the labour requirement of the most efficient technology. It implies though that the asymptotic behaviour of f as well as its curvature, in fact f itself is product-specific. This is, however, not a surprise as the impact of state intervention is not the same for all products.

Proposition 2.2 says that, under conditions, in a closed economy, a monopolist may actually increase his profit through a public investment scheme. The technologies benefited from the implementation of such a scheme are those that are more efficient. According to Lemma 2.1, for a specific product, if all parameters of the economy including the state intervention (T, f) are kept fixed benefit will result for those technologies for which the labour requirement is sufficiently small so that (2.1.0) holds true. On the other hand, given the efficiency coefficients a_i's of the different technologies, the lower the monopolist's contribution as a percentage of total wage is the greater the number of technologies benefited by a fixed state intervention (T, f). This happens more frequently in developed countries as it is traditionally these countries that exhibit higher wage rates. Theorem 2.5 provides a necessary and sufficient condition for such taxes to exist in a convex neighbourhood of 0. The technologies benefited do not depend on the magnitude of the tax T. They only depend on the order relation of the wage rate and the marginal public investment at 0, i.e. on the wage rate and the geometry of f at 0. However, if a state intervention has resulted in benefit for a specific technology, the actual benefit is an increasing function of $T \in (0, \mathcal{T})$, for some $\mathcal{T} > 0$ common for all benefited technologies, Proposition 2.6.

Theorem 2.11 can have both a forward and a backward reading. As it stands, it provides a sufficient condition for a technology to be transferred under a state intervention (T^*, f^*). Without a state intervention the technologies are split into two groups according to the sign of the difference $W^*(a_i + t) - Wa_i$, Corollary 2.10. If the characteristics of the economy in the LDC are such that a public investment scheme can improve the production cost of the first i_{f^*} technologies with $i_{f^*} < s - 1$ then, no state intervention can alter the balance of the technologies transferred. If, however, $s - 1 \leq i_{f^*}$ then, public investment could be beneficial for the less developed country in the sense that it could increase the number of technologies transferred from a DC. Corollary 2.12 offers a sufficient target for a policy maker should he wish to intervene since the right-hand side of inequality (2.12.0) is independent of T^*.

4 Concluding remarks

In this paper, we have constructed a rather simple model to address the production decision of a monopolist under taxation. We have knowingly put aside a number of factors such as asymmetry of demand between north and south, transfer costs etc. to better focus on the main question which is whether and how a state intervention by means of taxation can affect the decision process of a multinational.

Theorem 2.5 measures the effectiveness of a state intervention through a tax on wages on the production of a specific good. The main Theorem 2.11 says that such an intervention is in many cases fruitless, Theorem 2.11 (i), lending support to those who fervently oppose all taxes. Theorem 2.11 (ii) provides conditions for a successful intervention to exist. It, further, says that if a single tax value can tilt the equilibrium then so do all values of T^* in a bounded, open interval of $\mathbf{R}_+$.

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