DISCUSSION PAPER SERIES

No. 6419

CONTRACT ENFORCEMENT, COMPARATIVE ADVANTAGE AND LONG-RUN GROWTH

Gianmarco I P Ottaviano

INTERNATIONAL TRADE

Centre for Economic Policy Research

www.cepr.org

Available online at: www.cepr.org/pubs/dps/DP6419.asp

ISSN 0265-8003

CONTRACT ENFORCEMENT, COMPARATIVE ADVANTAGE AND LONG-RUN GROWTH

Gianmarco I P Ottaviano, Università di Bologna and CEPR

Discussion Paper No. 6419
August 2007

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

CEPR Discussion Paper No. 6419

August 2007

ABSTRACT

Contract Enforcement, Comparative Advantage and Long-Run Growth*

The effects of the quality of institutions on economic development and comparative advantage have been so far investigated separately. This paper proposes a theoretical framework in which trade patterns and growth rates are jointly determined by international differences in contract enforcement that affect firms' organizational decisions. In a two-country dynamic Ricardian model with endogenous innovation and hold-up problems, the value chain consists of two activities, innovation and production. Entry in the market happens through R&D and entrants face two decisions. The 'location decision' determines where to place R&D laboratories and production plants. Through the 'ownership decision' firms choose whether to perform innovation and production within the same vertically integrated structure or not. In this framework, the quality of contract enforcement drives the ownership decision, which affects R&D returns, research intensity and growth. Balance of payments adjustments cause movements in relative wages, which affect the location decision and, therefore, the pattern of sectoral specialization and international trade.

JEL Classification: D23, F10, L23, O30 and O40
Keywords: economic growth, incomplete contracts, innovation and theory of the firm

Gianmarco I P Ottaviano
Dip. di Scienze Economiche
Università di Bologna
Piazza Scaravilli 2
40126 Bologna
ITALY
Email: gianmarco.ottaviano@unibo.it

*Paper prepared for the ‘Conference .Globalization and the Organization of Firms and Markets’, Munich, February 10-11, 2007. I am indebted with seminar participants at the University of Oslo and at the Université Libre de Brussels for comments. I am grateful to Pol Antras, Micael Castanheira, Paola Conconi, Jonathan Eaton, Elhanan Helpman, Dalia Marin, Kjetil Storesletten and Thierry Verdier for helpful discussions.

Submitted 28 July 2007

1 Introduction

From an historical perspective there is increasing agreement that institutions (such as contract enforcement, investor protection, constitutions) have played a key role in shaping the international pattern of economic development and still today developed countries typically feature better institutions than developing ones (see, e.g., La Porta, Lopez-de-Silanes, Shleifer and Vishny, 1998; Acemoglu, Johnson and Robinson, 2002). A growing stock of empirical evidence also suggests that institutions (especially, contract enforcement) affect the international pattern of comparative advantage and, thus, sectoral specialization as well as trade flows. For instance, Antras (2003) shows that, when investments related to the labor input are harder to share than investments in physical capital, incomplete contract enforcement can explain why capital-intensive goods are transacted within the boundaries of multinational firms, while labor-intensive goods are traded at arm's length. Levchenko (2004) shows that, when some industries rely on institutions more than others, international differences in institutions act as a source of comparative advantage. Nunn (2007) combines a sectoral measure of intensity in relation-specific investment with data on trade flows and judicial quality. He finds that countries with good contract enforcement specialize in the production of goods for which relationship-specific investments are more important. Costinot (2006) argues that better institutions and more educated workers are complementary sources of comparative advantage in more complex industries.

So far the effects of institutional quality on economic development and comparative advantage have been investigated separately. The aim of the present paper is to propose a theoretical framework in which trade patterns and growth rates are jointly determined by international differences in contract enforcement that affect firms' organizational choices. In a two-country dynamic Ricardian model with endogenous innovation à la Taylor (1993) and hold-up problems à la Grossman and Helpman (2002), the value chain consists of two activities, innovation and production. Entry in the market happens through R&D and firms face two decisions. The 'location decision' concerns where to locate R&D labs and production plants. The 'ownership decision' concerns whether innovation and production should be performed within the same vertically integrated structure or not. While the former decision is driven by comparative advantage and wage differences, the latter is driven by a trade-off between the diseconomies of scope associated with vertical integration and the hold-up frictions associated with outsourcing. These are allowed to vary between countries due to different quality of contract enforcement and across industries depending on their potential for technological improvement. In this framework, the quality of contract enforcement drives the ownership decision between insourcing and outsourcing. The ownership structure then affects the returns to innovation, research intensity and growth. The resulting adjustments in the balance of payments cause movements in relative wages that impact on the location decision and, therefore, on the pattern of sectoral specialization and international trade.

General equilibrium effects due to balance of payments adjustments are the key channel through which the ownership decision influences the location decision. They materialize when innovation and production take place in different countries so that royalty payments from labs to plants cross international borders. In this case, through its impact on royalties, the ownership decision affects wages and location. As a result, when correlated with the sectoral potential for technological improvement, the pattern of comparative advantage determines the relative prevalence of alternative organizational forms in the two countries. The patterns of specialization also depends on the differences across countries in the quality of the contractual environment.

The proposed theoretical framework can be used to investigate several alternative scenarios. For concreteness, the paper focuses on a specific situation in which a developing country ('South') trades with a developed one ('North') that has an advantage in innovation relatively to production, a comparative advantage in industries with higher growth potential and better contract enforcement. In equilibrium industries endogenously sort in five organizational forms depending on comparative advantage: outsourcing from southern innovators to southern producers; outsourcing from northern innovators to southern producers; production in South by vertically integrated northern innovators; outsourcing in North by northern innovators; production in North by vertically integrated northern innovators.

Two shocks are analyzed: an improvement of contract enforcement in South ('institutional convergence') and a generalized increase in the growth potential of all industries ('systemic innovation'). On impact the former leads to an increase in the share of industries that innovate in North but produce in South. As the profits of offshored plants increase, royalty payments from South to North surge. The balance of payments is maintained by a rise in southern net exports and an associated increase in the shares of industries innovating or producing in South as southern wages fall. If the relative advantage of North in innovation is pronounced, the range of industries producing in South increases more than the range of industries innovating there, thus fostering offshoring from North to South. Moreover, if diseconomies of scope are strong, the fraction of offshoring firms that outsource also increases. Turning to systemic innovation, when the potential for technological improvement goes up in all industries, the share of industries that outsource goes down both in North and South. This effect is due to larger hold-up losses for innovators and it is stronger in South due to weaker contract enforcement. If the diseconomies of scope are small and international legal asymmetries large, many industries shift from outsourcing to vertical integration, royalty payments rise and, as before, the balance of payments is maintained through larger net exports from South associated with lower southern wages and a larger share of industries choosing South for innovation or production. Again, more industries offshore if the northern relative advantage in innovation is pronounced. On the contrary, if diseconomies of scope are large and legal asymmetries small, few industries shift to vertical integration, royalty payments fall and the balance of payments is maintained through smaller southern net exports, higher southern wages and smaller shares of industries selecting South for innovation or production. Fewer industries offshore if the northern relative advantage in innovation is pronounced.

To summarize, better southern institutions unambiguosly foster outsourcing and a relocation of industries from North to South. Systemic innovation unambiguosly fosters vertical integration. However, it may have different effects on relocation depending on the strength of the diseconomies of scope and the extent of institutional asymmetries as these determine the share of industries that undergo organizational restructuring. As to growth, if relative wages do not change much, the aggregate return to innovation increases whenever royalties increase. This maps into higher research intensity and faster growth rate.

The model combines two well-established approaches. The first is the incomplete contracting approach to the theory of the firm due to Grossman and Hart (1986) as well as Hart and Moore (1990). This approach has been applied to trade theory in the wake of Grossman and Helpman (2002) and has given rise to a thriving literature surveyed by Helpman (2006). The second is Grossman and Helpman's (1991) and Aghion and Howitt's (1998) approach to endogenous growth through rising product quality. This approach has been applied to Ricardian trade by Taylor (1993). In this respect, there are few contributions strictly related to the present paper. Acemoglu and Zilibotti (1999), Martimort and Verdier (2000, 2004) as well as Francois and Roberts (2003) study the qualitative impact of changes in the internal organization of firms on economic growth. Acemoglu and Zilibotti (1999) link the level of economic development to the level of information available in an economy as this determines the importance of agency costs. Martimort and Verdier (2000, 2004) present a Schumpeterian growth model in which firms face agency costs due to the existence of asymmetries of information and discuss the two-ways relationships between the structure of internal transaction costs, organizational technologies and macroeconomic growth focusing on the formation of vertical collusions inside those firms ('bureaucratization'). Francois and Roberts (2003) analyze how growth interacts with the production relationships between firms and workers in an incomplete contracting environment. They show that changes in the technological parameters may have unexpected impacts on growth through their effects on contractual arrangements. In Acemoglu, Aghion and Zilibotti (2005) firms closer to the technology frontier have a stronger incentive to outsource production in order to concentrate on more valuable R&D. Finally, Naghavi and Ottaviano (2006) study the effects of outsourced production on growth in a closed-economy model of incomplete contracts and increasing product diversity when R&D and production are performed by independent firms. The closest contribution to the present paper is Acemoglu, Antras and Helpman (2006) who investigate the channels through which institutional parameters determine countries' comparative advantages by affecting firms' decisions on technology adoption and organizational forms. They find that weaker contract enforcement leads to the adoption of less advanced technologies. Their model of technology adoption is, however, essentially static. Moreover, the ownership and location decisions are treated separately. In short, none of the foregoing models deals with Ricardian trade and simultaneously with both the ownership and the location decisions in an general equilibrium endogenous growth framework.

The rest of the paper is organized in four sections. Section 2 presents the model. Section 3 characterizes its general equilibrium. Section 4 deals with comparative statics. Section 5 concludes.

2 The model

Consider a given set of industries indexed $z \in [0,1]$ that employ labor as their only primary factor. The industries operate in two countries, 'South' and 'North'. Variables pertaining to the former bear no label while those pertaining to the latter are labeled by an asterisk. In the two countries there are given measures ('numbers') of workers, L and L^*, each supplying one unit of labor inelastically. All income belongs to workers, so L and L^* also represent the numbers of consumers in the two countries. The presentation will focus on South with analoguous expressions holding for North.

2.1 Consumption

All consumers share the same preferences and within countries also the same income. The preferences of the representative southern consumer are captured by the following utility function:

$$U = \int_0^\infty e^{-\rho t} \ln D(t) dt \tag{1}$$

where $\rho > 0$ is the rate of time preference. Instantaneous consumption $\ln D(t)$ consists of a CES basket comprising the outputs ('products') of all industries $z \in [0,1]$:

$$\ln D(t) = \int_0^1 \ln\left[x(z,t)\right] dz \tag{2}$$

where $x(z,t)$ is the consumption of the product of industry z and all industries absorb the same expenditure share.

Borrowing and lending is free in a perfectly integrated international capital market where a riskless bond exists bearing interest rate $r(t)$. Intertemporal utility maximization then yields the standard consumption smoothing result:

$$\frac{\dot{E}(t)}{E(t)} = r(t) - \rho \tag{3}$$

where $E(t)$ is expenditures and $\dot{E}(t) \equiv dE(t)/dt$. Moreover, instantaneous utility maximization also implies that consumption is allocated across industries depending on their prices:

$$x(z,t) = \frac{E(t)}{p(z,t)} \tag{4}$$

2.2 Production

In any industry z the value chain consists of two activities, 'innovation' and 'production', with the former inventing new vintage technologies for the latter. As a result of repeated innovations, in a generic instant t there are several vintages available for production whose efficiency is a decreasing function of their age with the same efficiency gap between any pair of contiguous vintages. This allows one to rank all vintages in increasing order of efficiency along a 'technology ladder' from the oldest to the youngest. Specifically, let $a(z,j) = a(z)\phi(j,z)$ be the unit input requirement of the vintage that occupies the generic position j along the technology ladder of industry z. Then, the productivity ratio of vintage $j+1$ to vintage j, namely $\phi(j,z)/\phi(j+1,z) > 1$, identifies the constant 'step' of the industry technology ladder ('potential for technological improvement'). At $t = 0$ the same vintage $j = 0$ is available in both countries with unit input requirements $a(z,0) = a(z)\phi(0,z)$ in South and $a^*(z,0) = a(z)^*\phi(0,z)$ in North.

After invention the properties of the latest and thus most efficient vintage remain known only to its inventor ('leader') until the next vintage is discovered. When this happens, the properties of the formerly leading vintage become common knowledge. This knowledge spillovers will sustain technological progress in the long run. Market structure is modelled as oligopolistic Bertrand competition so that the incumbent 'leader' maximizes its profit by quoting a price that is just low enough to prevent anybody else from selling at all ('limit pricing'). As a result, the leader is the only supplier in the industry. It faces two choices. First, it may supply the product on its own ('vertical integration') or it may contract the use of its vintage to an independent producer ('outsourcing'). This is the 'ownership decision'. Second, no matter whether the leader selects integration or outsourcing, it may choose whether production should take place in the same country as innovation or in the other country ('offshoring'). This is the 'location decision'. As in Antras and Helpman (2004), the combination of the ownership and the location decisions determines the overall 'organizational form' of the industry.

Both ownership structures have pros and cons. Vertical integration incurs diseconomies of scope as the combination of innovation and R&D within the boundaries of the same firm foregoes the efficiency gains of specialized production. Outsourcing faces instead hold-up problems due to incomplete contracts. In particular, in each period the inventor has to find a producer to contract. It is assumed that producers can enter and exit the market freely and there is a large number of them potentially active. While the inventor is thus surely matched, all matches are destroyed every period. Production takes place only after the matched parties have signed a contract and the leader has revealed the properties of its vintage to the producer. The contract is incomplete because those properties are unobservable to third parties, which makes it possible for the producer to renege on the contract and exploit the leader's vintage without being prosecuted. Crucially, if that happens, it is too late for the leader to find a substitute for the producer or to produce on its own. On the other hand, reneging bears some costs for the producer too as the vintage technology can not be exploited to its full potential without the support of its inventor. These circumstances affect the outside options of the two parties at the ex-post bargaining stage, which takes place after the innovator reveals the properties of the vintage to the producer but before the latter actually produces.

Formally, diseconomies of scope are captured by assuming that, under vertical integration, the technological step equals $\lambda(z)$ whereas under outsourcing it equals $\alpha\lambda(z)$ with $\alpha \in (1, \infty)$. The hold-up problem is modeled through ex-post instantaneous Nash bargaining assuming that, when used outside the contractual relation, the technological step is reduced to $\beta\lambda(z)$ with $\beta \in (1/\lambda(z), 1)$. Accordingly, β can be interpreted as an inverse measure of the quality of the contractual environment. For simplicity, the ex-post bargaining weight of the producer is set to zero. Under limit pricing, different technological steps imply different mark-ups over marginal cost and therefore different profits. In the case of vertical integration, the mark-up equals $\lambda(z)$, which yields profits:

$$\Pi_V(z) = \left[1 - \frac{1}{\lambda(z)}\right] [E(t) + E^*(t)] \tag{5}$$

When production is outsourced, there are two possible outcomes. In the first, the producer reneges and uses the leading vintage to supply the market on its own. This reduces the efficiency of the vintage and therefore the price the producer can command. In this case, the mark-up becomes $\beta\lambda(z)$ with profits

$$\Pi_R(z) = \left[1 - \frac{1}{\beta\lambda(z)}\right] [E(t) + E^*(t)] \tag{6}$$

In the second outcome, the producer keeps its contractual commitment with the innovator and, thanks to its support, productivity is higher than under vertical integration by a factor $\alpha \in (1, \infty)$. This implies that the mark-up equals $\alpha\lambda(z)$ with profits

$$\Pi_M(z) = \left[1 - \frac{1}{\alpha\lambda(z)}\right] [E(t) + E^*(t)] \tag{7}$$

This expression identifies the joint surplus from the outsourcing contract that has to be shared between the innovator and the producer through ex-post Nash bargaining. Since its bargaining weight is zero, the producer is left as well off as if it had reneged while the residual surplus is appropriated by the innovator. Hence, the former gets $\Pi_R(z)$ whereas the latter gets $\Pi_O(z) \equiv \Pi_M(z) - \Pi_R(z)$. Results (6) and (7) then imply:

$$\Pi_O(z) = \left(\frac{1}{\beta} - \frac{1}{\alpha}\right) \frac{E(t) + E^*(t)}{\lambda(z)} \tag{8}$$

Anticipating this, the leader chooses to outsource whenever $\Pi_O(z) - \Pi_V(z) > 0$ or equivalently, by (5) and (8), whenever

$$\lambda(z) < 1 + \frac{1}{\beta} - \frac{1}{\alpha} \tag{9}$$

In words, outsourcing is preferred when the tecnological step is small (small $\lambda(z)$), the diseconomies of scope are strong (large α) and the quality of the contractual environment is good (small β). The reason is that, while under vertical integration profits (5) are an increasing function of the technological step, under outsourcing they are a decreasing function of $\lambda(z)$. This is due to the fact that a larger step raises the outside option of the producer (6) more than the joint surplus from the outsourcing contract (7). The more so, the worse the quality of the contractual environment and the weaker the gains from specialized production.

2.3 Innovation

The innovation technology is Poisson with an arrival rate that varies proportionately with R&D efforts. Specifically, in industry z the southern innovation technology is such that an R&D effort of intensity $i(z)$ exerted for a time interval dt faces a probability $i(z)dt$ of moving the state-of-the-art technology one step forward. This research effort is financed by issuing equity claims that give right to the flow profit associated with market leadership in case of success, and nothing otherwise. Well-diversified equity holders finance the R&D effort as long as the expected benefits equal the associated costs. The former are given by the expected stock value of industry leadership $v(z)i(z)dt$, the latter by the wage w multiplied by unit labor requirement $a_I(z)$ and R&D intensity $i(z)dt$. Positive and finite R&D intensity $i(z) \in (0, \infty)$ therefore requires

$$v(z) = wa_I(z) \tag{10}$$

where time dependence is left implicit. To alleviate notation, this will be the convention henceforth.

Due to financial arbitrage equities have to grant the same rate of return as the riskless bond. For industries with R&D in South, that happens whenever

$$r = \frac{R(z)}{v(z)} + \frac{\dot{v}(z)}{v(z)} - i(z) \tag{11}$$

where $R(z)$ is the dividend of leadership for (i.e. the profit accruing to) the innovator, $\dot{v}(z)$ the associated capital gain and $i(z)$ is the probability leadership is lost to the next innovator. The dividend $R(z)$ depends on both the ownership and the location decisions.

Mutadis mutandis, analoguous results apply to North. The following analysis will focus on three types of international asymmetries in terms of: the production technological parameters $a^*(z)$ vs. $a(z)$; the R&D technological parameters $a_I^*(z)$ vs. $a_I(z)$; the contractual parameters β^* vs. β.

2.4 Comparative advantage

To simplify notation define

$$n_V(z) \equiv 1 - \frac{1}{\lambda(z)},\ n_M(z) \equiv 1 - \frac{1}{\alpha\lambda(z)} \tag{12}$$

where $n_V(z)$ and $n_M(z)$ are the operating margins under integration and outsourcing respectively. Then define

$$\begin{aligned} \theta(z) &\equiv 1 - \left[1 - \frac{1}{\beta\lambda(z)}\right] \Big/ \left[1 - \frac{1}{\alpha\lambda(z)}\right] \\ \theta^*(z) &\equiv 1 - \left[1 - \frac{1}{\beta^*\lambda(z)}\right] \Big/ \left[1 - \frac{1}{\alpha\lambda(z)}\right] \end{aligned} \tag{13}$$

These capture the weakness of the outside options of the producers in the two countries and are therefore measures of the quality of national contractual environments. They range from 0 to 1 being both decreasing in $\lambda(z)$ since the producer's outside option is stronger when the technology step is larger. Note that $dn_V(z)/d\lambda(z) > 0$, $dn_M(z)/d\lambda(z) > 0$, $d\theta(z)/d\lambda(z) < 0$ and $d\left[n_M(z)\theta(z)\right]/d\lambda(z) < 0$. Accordingly, the ownership decision rule (9) leading to outsourcing becomes

$$n_V(z) < n_M(z)\theta(z) \text{ and } n_V(z) < n_M(z)\theta^*(z) \tag{14}$$

for production in South and North respectively. Finally, define the relative input requirements in production and innovation as

$$A(z) \equiv \frac{a^*(z)\phi(0,z)}{a(z)\phi(0,z)},\ RD(z) \equiv \frac{a_I^*(z)}{a_I(z)} \tag{15}$$

In principle, the functions $A(z)$ and $RD(z)$ may take any shape. The same is true for $\lambda(z)$ and thus for $\theta(z)$ and $\theta^*(z)$. Moreover, β may be larger or smaller than β^*. To avoid a proliferation of subcases that would make the analysis taxonomic without adding much insight, the following assumptions are made: (i) $RD(z) < A(z)$ so that North has an advantage in innovation relatively to production; (ii) $RD'(z) < 0$ and $A'(z) < 0$ so that in terms of both innovation and production North has a comparative advantage in high z industries; (iii) $RD'(z) < A'(z)$ so that northern comparative advantage in high z industries is stronger for innovation than for production; (iv) $\lambda'(z) > 0$ so that northern comparative advantage is positively correlated with industries technological steps; (v) $\beta > \beta^*$ and hence $\theta(z) < \theta^*(z)$ so that North offers a better contractual environment. Taken together, all these assumptions depict a situation in which North is more developed than South as it exhibits better legal institutions, a relative advantage in innovation and a comparative advantage in industries with more room for technological improvement.

3 General equilibrium

The general equilibrium of the model is represented in Figure 1 under the above assumptions (i)-(v).[1] The top panel, where the $BP(z)$ curve represents the balance of payments (see Section 3.3 for its derivation), is the same as Fig. 1 p.

[1] The equilibrium analysis focuses on the steady state of the model. Grossman and Helpman (1991) prove that a model like the present one reaches its steady state instantaneously.

234 in Taylor (1993) with the industry index z and relative southern wage w/w^* on the horizontal and the vertical axes respectively. This panel shows that the *location decision* generates a Ricardian pattern of specialization according to which South performs innovation in industries $z \in [0, Z_I]$ and production in industries $z \in [0, Z_P]$ whereas North performs innovation in industries $z \in [Z_I, 1]$ and production in industries $z \in [Z_P, 1]$ with $Z_I < Z_P$. Industries $z \in [Z_I, Z_P]$ are caracterized by 'offshoring' since innovation takes place in North and production in South. The solid $A(z)$ curve corresponds to the situation at time 0 and shows that initially South features front line technologies in innovation and production up to industries Z_I and Z_P respectively. For industries above these thresholds front line technologies belong to North. Free entry in R&D implies that only innovators in the country where the innovation tecnology is front line are able to raise funds in the capital market. Accordingly, innovation is only implemented on southern products for $z \in [0, Z_P]$ and northern products for $z \in [Z_P, 1]$. Thus, as time passes, Z_P does not change and $A(z)$ rotates clockwise around it, as exemplified by the dash-dotted curve.

The bottom panel of Figure 1 shows the outcome of the *ownership decision* as determined by the quality of the contractual environment in the two countries. It shows that, when production is located in South, outsourcing is selected for industries $z \in [0, Z_O]$ and vertical integration for industries $z \in [Z_O, 1]$. Analoguously, when production takes place in North, outsourcing is selected for industries $z \in [0, Z_O^*]$ and vertical integration for industries $z \in [Z_O^*, 1]$. The ranking $Z_O < Z_O^*$ reflects the fact that the hold-up problem associated with outsourcing is more severe in South as this has poorer contract enforcement.

Crossing the location and the ownership decisions gives the equilibrium organizational forms and the associated relative wage ω. While the location and the ownership thresholds are ranked $Z_I < Z_P$ and $Z_O < Z_O^*$ respectively, there is no unambiguous ordering of the former with respect to the latter. Figure 1 is drawn under the additional assumption that $Z_I < Z_O < Z_P < Z_O^*$ and this ranking will be used from now on. The specific results derived will naturally follow from this specific ranking. However, nothing in the analysis in general relies on them as other cases are relatively straighforward to examine once the selected case is understood. For parsimony, this is left to the interested reader.

Considering the two panels together allows one to partition the industries in five groups depending on their organizational forms: outsourcing from southern innovators to southern producers for $z \in [0, Z_I]$; outsourcing from northern innovators to southern producers for $z \in [Z_I, Z_O]$; production in South by vertically integrated northern innovators for $z \in [Z_O, Z_P]$; outsourcing in North by northern innovators $z \in [Z_P, Z_O^*]$; production in North by vertically integrated northern innovators for $z \in [Z_O^*, 1]$. Since $\lambda'(z) > 0$ by assumption, the industries are allocated from the first to the fifth groups in increasing order of magnitude of their technological steps. Finally, the dashed areas T_O and T_V in Figure 1 represent royalty payments from southern producers to northern innovators when these decide to offshore production. The former area concerns transations between independent firms, the latter concerns transactions between divisions of the same vertical integrated firm.

3.1 Piecewise notation

With industries sorted in five organizational forms, a compact description of the equilibrium can be achieved by turning to piecewise notation. In particular, define the two following piecewise functions that are relevant for production

$$\eta(z) = \left\{ \begin{array}{c} \theta(z) \\ 1 \\ \theta^*(z) \\ 1 \end{array} \right. , \; n(z) = \left\{ \begin{array}{c} n_M(z) \\ n_V(z) \\ n_M(z) \\ n_V(z) \end{array} \right. \quad \text{for} \quad z \in \left\{ \begin{array}{c} [0, Z_O] \\ [Z_O, Z_P] \\ [Z_P, Z_O^*] \\ [Z_O^*, 1] \end{array} \right. \tag{16}$$

Hence, profits accruing to innovators can be written as $R(z) = \eta(z)n(z)(E+E^*)$. Define also a third piecewise function that is relevant for innovation

$$\delta(z) = \left\{ \begin{array}{c} wa_I(z) \\ w^* a_I^*(z) \end{array} \right. \quad \text{for} \quad z \in \left\{ \begin{array}{c} [0, Z_I] \\ [Z_I, 1] \end{array} \right. \tag{17}$$

3.2 Research intensity and expenditures

Let us pick labor in South as numeraire ($w = 1$) so that southern wage is constant ($\dot{w} = 0$). In steady state also expenditures and northern wage have to be constant: $\dot{E} = \dot{E}^* = \dot{w}^* = 0$. The consumption smoothing result (3) then implies $r = \rho$ and the arbitrage condition (11) can be rewritten as

$$i(z) = \frac{\eta(z)n(z)(E+E^*)}{\delta(z)} - \rho \tag{18}$$

which reveals that reseach intensity varies across industries depending on their organizational forms as captured by $\eta(z)n(z)$ and $\delta(z)$. Research intensity (18) is increasing in world expenditures, which can be evaluated by equating world labor income $wL + w^*L^*$ to the sum of the wage bills paid for production and innovation:

$$wL + w^*L^* = (E+E^*) \int_0^1 [1 - n(z)]\, dz + (E+E^*) \int_0^1 \eta(z)n(z)dz - \rho \int_0^1 \delta(z)dz$$

This yields steady state expenditures as labor income plus dividend payments from leading vintages:

$$E + E^* = \Lambda^{-1} \left[wL + w^*L^* + \rho \int_0^1 \delta(z)dz \right] \tag{19}$$

where $\Lambda \equiv \int_0^1 \{1 - [1 - \eta(z)]\, n(z)\}\, dz < 1$ measures world innovators' profit loss due to the limited contract enforcement. This loss has a positive impact on expenditures (19) as it diverts resources away from R&D investment. When the quality of the contractual environment is at its best (i.e. $\eta(z) = 1$), $\Lambda = 1$ and expenditures are independent from ownership decisions.

3.3 Balance of payments

In the top panel of Figure 1 a key role is played by the upward sloping curve representing the balance of payments. This is found by imposing the current account balance:

$$\begin{aligned} \left[Z_P E^* - (1 - Z_P)\, E\right] &= -\Lambda^{-1}\rho \left[s \int_{Z_I}^{1} \delta(z)dz - (1-s) \int_{0}^{Z_I} \delta(z)dz \right] \\ &\quad + (E + E^*) \int_{Z_I}^{Z_P} \eta(z) n(z) dz \end{aligned} \quad (20)$$

where s is the southern share of world assets.

To understand the derivation of (20), one has to keep in mind that Z_P and $(1 - Z_P)$ are the shares of products supplied by South and North respectively. Then, on the left hand side of (20), given northern expenditures E^* and southern expenditures E, $Z_P E^*$ is northern demand for southern products whereas $(1 - Z_P)\, E$ is southern demand for northern products. Hence, the left hand side is South's trade balance. When negative, this must be exactly matched by net service payments from South to North. These appear on the right hand side. Since industries $z \in [0, Z_I]$ innovate in South and $(1 - s)$ is the northern share of world assets, the term $\Lambda^{-1}\rho(1 - s) \int_0^{Z_I} \delta(z)dz$ represents dividend payments from southern labs to northern investors. Viceversa, $\Lambda^{-1}\rho s \int_{Z_I}^{1} \delta(z)dz$ represents dividend payments from northern labs to southern investors. Lastly, as industries $z \in [Z_I, Z_p]$ innovate in North but produce in South, the second terms on the right represents royalty payments from southern plants to northern labs that arise due to offshoring.

Using $E = \Lambda^{-1} \left[wL + \rho\, s \int_0^1 \delta(z)dz \right]$ and $E^* = \Lambda^{-1} \left[w^* L^* + \rho\, (1 - s) \int_0^1 \delta(z)dz \right]$, the balance of payments (20) condition can be rewritten as:

$$\frac{w}{w^*} = \frac{Z_P - \int_{Z_I}^{Z_P} \eta(z)n(z)dz}{1 - Z_P + \int_{Z_I}^{Z_P} \eta(z)n(z)dz} \frac{L^* + \rho A_I^*(Z_I)}{L + \rho A_I(Z_I)} \quad (21)$$

with $wA_I(Z_I) \equiv \int_0^{Z_I} \delta(z)dz$ and $w^* A_I^*(Z_I) \equiv \int_{Z_I}^{1} \delta(z)dz$. Expression (21) defines the balance of payments schedule $BP(z)$ depicted in Figure 1.

3.4 Location and ownership

The equilibrium conditions of the model represented in Figure 1 can be summarized as follows. First, given the relative wage w/w^*, the industry in which it is indifferent where to innovate determines the innovation location threshold Z_I such that

$$\frac{w}{w^*} = RD(Z_I) \quad (22)$$

Second, given the relative wage, the industry in which it is indifferent where to produce determines the production location threshold Z_P such that

$$\frac{w}{w^*} = A(Z_P) \quad (23)$$

Third, the industry in which it is indifferent whether to outsource production or not in South determines the southern ownership threshold Z_O such that

$$n_V(Z_O) = n_M(Z_O)\theta(Z_O) \tag{24}$$

Fourth, the industry in which it is indifferent whether to outsource production or not in North determines the northern ownership threshold Z_O^* such that

$$n_V(Z_O^*) = n_M(Z_O^*)\theta^*(Z_O^*) \tag{25}$$

Finally, given the four thresholds, the balance of payments (21) determines the relative wage. Accordingly, expressions (21) to (25) generate a system of five equations in the five unknowns Z_I, Z_P, Z_O, Z_O^* and w/w^*. Recalling that $w = 1$ by choice of numeraire, the solutions for those variables can be used in (19) and (18) to obtain the equilibrium values of expenditures and research intensities.

3.5 Growth rate

The equilibrium research intensities determine the overall growth rate of the world economy. To see this, recall that the innovation technology is such that each industry experiences occasional innovations whose arrivals are governed by independent Poisson processes. The technological evolution of each industry is therefore both choppy and random with an expected number of discoveries in a time interval of length t equal to $i(z)t$. At the aggregate level, however, the law of large numbers kicks in and technological progress is both smooth and nonrandom with a constant fraction of industries upgrading their vintages each period by their respective steps $1/[1-n(z)]$. As a result, the average price of products falls steadily and, as equilibrium expenditures are constant, such price reduction maps into increasing consumption. In particular, the consumption index (2) grows at the constant growth rate

$$g = -\int_0^1 \ln[1-n(z)]\, i(z)dz \tag{26}$$

where $1/[1-n(z)]$ is the technological step in industry z, $-\ln[1-n(z)]$ is the utility value of the associated reduction in price and $i(z)$ is the industry's research intensity.

Hence, the technological step $1/[1-n(z)]$ has both an indirect and a direct effects on growth. On the one hand, a larger step raises R&D intensity and thus the probability of technological breakthroughs in each period. On the other hand, a larger step increases the contribution of each breakthrough to aggregate productivity.

4 Technology and institutions

General equilibrium effects due to balance of payments adjustments are the key channel through which the ownership decision affects the location decision. They materialize only when innovation and production take place in different countries so that royalty payments from plants to labs cross international borders. In this case, through its impact on royalties, the ownership decision affects wages and location. As a result, the pattern of comparative advantage determines the relative prevalence of alternative organizational forms in the two countries and their patterns of specialization depend on the differences across countries in terms of contractual enforcement. To see this, consider again Figure 1 and assume that $RD(Z) = A(Z)$ so that $Z_I = Z_P$ and $\int_{Z_I}^{Z_P} \eta(z)n(z)dz = 0$. In this case no industry innovates in North and produces in South, so royalty payments do not cross international borders. As (21) is independent from Z_O, the location and the ownership decisions are unrelated.

Several comparative statics experiments can be investigated starting from an initial situation like the one depicted in Figure 1. The present section focuses on two scenarios: an increase in the technological step parameter $\lambda(z)$ across all industries ('systemic innovation') and an improvement in the quality of the contractual environment in South ('institutional convergence'). The first scenario shows what changes when industries can react to a technological shock not only in terms of location as in Taylor (1993) but also in terms of ownership structure. The second scenario shows how the model can be used to study the general equilibrium effects of institutional changes when these affect industrial organization.

4.1 Systemic innovation

When $\lambda(z)$ increases uniformly across all industries, both curves $n_M(z)\theta(z)$ and $n_M(z)\theta^*(z)$ shift toward the horizontal axis as producers' outside options strengthen. These shifts are larger the larger the differences $(1/\beta - 1/\alpha)$ and $(1/\beta^* - 1/\alpha)$ respectively, so $n_M(z)\theta(z)$ shifts more than $n_M(z)\theta^*(z)$. On the other hand, as $\lambda(z)$ increases, $n_V(z)$ moves away from the horizontal axis as innovators see their competitive lead increase. These movements are depicted in the bottom panel of Figure 2, which shows Z_O and Z_O^* falling as some industries turn from outsourcing to vertical integration. The figure also shows that, if α is small and β is much smaller than β^*, smaller Z_O raises the royalty payments T_O and T_V on impact as many offshored industries restructure from outsourcing to vertical integration. Given (21), larger royalties shift the balance of payments schedule $BP(z)$ downwards in the top panel, thus causing a fall in southern relative wage as well as a rise in both Z_I and Z_P. This is due to the fact that higher royalties yield an incipient external deficit for South, which is compensated by import substitution in both innovation and production. Hence, a generalized increase in the potential for technological improvement affects both the ownership and the location decisions by expanding the ranges of industries that innovate and produce in South.

If $RD(z)$ is much steeper than $A(z)$, an increase in $\lambda(z)$ also implies that the range of southern producing industries rises more than the range of southern innovating industries, thus fostering offshoring. Moreover, the fraction of offshored industries that outsource shrinks. This is the case when the relative advantage of North in innovation is very pronounced.

On the other hand, if α is large and β is close to β^*, few industries shift from outsourcing to vertical integration, royalty payments go down and the $BP(z)$ curve shifts upwards. As before, fewer industries outsource but an incipient southern external surplus leads to export substitution in both innovation and production with rising southern relative wages. In this case, if $RD(z)$ is much steeper than $A(z)$, the number of offshoring industries falls.

4.2 Institutional convergence

Turning to institutional change, Figure 3 depicts the effects of improved contractual enforcement in South as captured by weaker outside options for local producers (smaller β). In the bottom panel, this shifts $n_M(z)\theta(z)$ away from the horizontal axis, which on impact increases royalty payments T_O and T_V from South to North. The reason is the reduction in the ex-post bargaining power of southern producers, which generates a transfer from them to northern innovators. Accordingly, the southern ownership threshold Z_O increases and some offshoring industries restructure from vertical integration to outsourcing. The northern ownership threshold Z_O^* is, instead, unaffected. General equilibrium effects materialize through the movement of the balance of payments schedule $BP(z)$. As in the case of systemic innovation, richer royalties shift $BP(z)$ downwards, which reduces the southern relative wage and raises both the innovation location threshold Z_I and the production location threshold Z_P.

Hence, better southern contract enforcement expands the shares of industries that innovate and produce in South. If $RD(z)$ is much steeper than $A(z)$, the range of southern producing industries increases more than the range of southern innovating ones, thus fostering offshoring. Moreover, if the gains from specialized production are large (large α), the fraction of offshoring firms that outsource increases.

As to growth, if relative wages do not change much, the aggregate return to innovation increases whenever royalties increase. This maps into higher research intensity and faster growth rate.

5 Conclusion

This paper has modeled the organizational choices of firms in dynamic industries characterized by 'creative destruction' due to ongoing technology improvement. In the proposed model, the value chain of each industry consists of two tasks, innovation and production. In a two-country world the organizational form is the result of two types of decisions. The location decision determines where innovation and production take place. This decision is driven by relative and comparative advantages. Offshoring arises when the two tasks are separated in different countries within the same industry. The ownership decision determines whether the two tasks are performed within the boundaries of the same firm ('vertical integration') or by independent firms ('outsourcing'). This decision is driven by a trade-off between efficiency gains from specialization and hold-up problems from limited contract enforcement. The two decisions interact in the aggregate through the balance of payments jointly affecting the wages in the two countries, their expenditure levels and overall research intensity.

The model is able to generate several comparative statics results. The analysis has focused on two scenarios based on the assumption that one of the two countries is more developed than the other in that it has a relative advantage in innovation with respect to production, a comparative advantage in production in industries characterized by a larger potential for technological improvement and better contract enforcement. The first scenario has studied a generalized increase in the technological improvement potential across all industries ('systemic innovation'). The second experiment has considered an increase in the quality of the contractual environment in the less developed country ('institutional convergence').

Additional assumptions are needed to pin down how aggregate research intensity and, thus, the aggregate growth rate respond to such changes in technology and institutions. Further work along these lines is a first direction of future research. Also, for simplicity the industries' potentials for technological improvement have been kept exogenously given. Another direction of future research is to endogenize it, possibly exploiting the formal connections between the adopted growth model and the static model with heterogeneous firms by Bernard, Eaton, Jensen and Kortum (2003).

References

[1] Acemoglu, Daron and Fabrizio Zilibotti (1999) Information Accumulation in Development, *Journal of Economic Growth* 4, 5-38.

[2] Acemoglu, Daron, Philippe Aghion and Fabrizio Zilibotti (2006) Distance to Frontier, Selection, and Economic Growth, *Journal of European Economic Association* 4, 37-74.

[3] Acemoglu, Daron, Pol Antras and Elhanan Helpman (2006) Contracts and Technology Adoption, *American Economic Review*, forthcoming.

[4] Acemoglu, Daron, Simon Johnson and James Robinson (2002) Reversal of Fortune: Geography and Institutions in the Making of the ModernWorld Income Distribution, *Quarterly Journal of Economics* 117, 1231-1294.

[5] Aghion, Philippe and Peter Howitt (1998) *Endogenous Economic Growth*, Cambridge: MIT Press.

[6] Antras, Pol (2003) Firms, Contracts, and Market Structure, *Quarterly Journal of Economics* 118, 1375-1418.

[7] Bernard, Andrew, Jonathan Eaton, Bradford Jensen, and Samuel Kortum (2003) Plants and Productivity in International Trade, *American Economic Review* 93, 1268-1290.

[8] Costinot, Arnaud (2006) On the Origins of Comparative Advantage, UC San Diego, mimeo.

[9] Francois, Patrick and Joanne Roberts (2003) Contracting Productivity Growth, *Review of Economic Studies* 70, 59-85.

[10] Grossman, Sanford and Oliver Hart (1986) The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration, *Journal of Political Economy* 94, 691-719.

[11] Grossman, Gene and Elhanan Helpman (1991) *Innovation and Growth in the Global Economy*, Cambridge: MIT Press.

[12] Grossman, Gene and Elhanan Helpman (2002) Integration vs. Outsourcing in Industry Equilibrium, *Quarterly Journal of Economics* 117, 85–120.

[13] Hart, Oliver and John Moore (1990) Property Rights and the Nature of the Firm, *Journal of Political Economy* 98, 1119-1158.

[14] Helpman, Elhanan (2006) Trade, FDI, and the Organization of Firms, *Journal of Economic Literature* 44, 589-630.

[15] La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert Vishny (1998) Law and Finance, *Journal of Political Economy* 106, 1113-1155.

[16] Levchenko, Andrei (2004) Institutional Quality and International Trade, *Review of Economic Studies*, forthcoming.

[17] Martimort, David and Thierry Verdier (2000) The Internal Organization of the Firm, Transaction Costs and Macroeconomic Growth, *Journal of Economic Growth* 5, 315-340.

[18] Martimort, David and Thierry Verdier (2004) The Agency Cost of Internal Collusion and Schumpeterian Growth, *Review of Economic Studies* 71, pp. 1119-1141.

[19] Naghavi, Alireza and Gianmarco I.P. Ottaviano (2006) Outsourcing, Complementary Innovations and Growth, CEPR Discussion Paper No. 5925.

[20] Nunn, Nathan (2007) Relationship-Specificity, Incomplete Contracts and the Pattern of Trade, *Quarterly Journal of Economics* 122, 569-600.

[21] Taylor, M. Scott (1993) 'Quality Ladders' and Ricardian Trade, *Journal of International Economics* 34, 225-243.

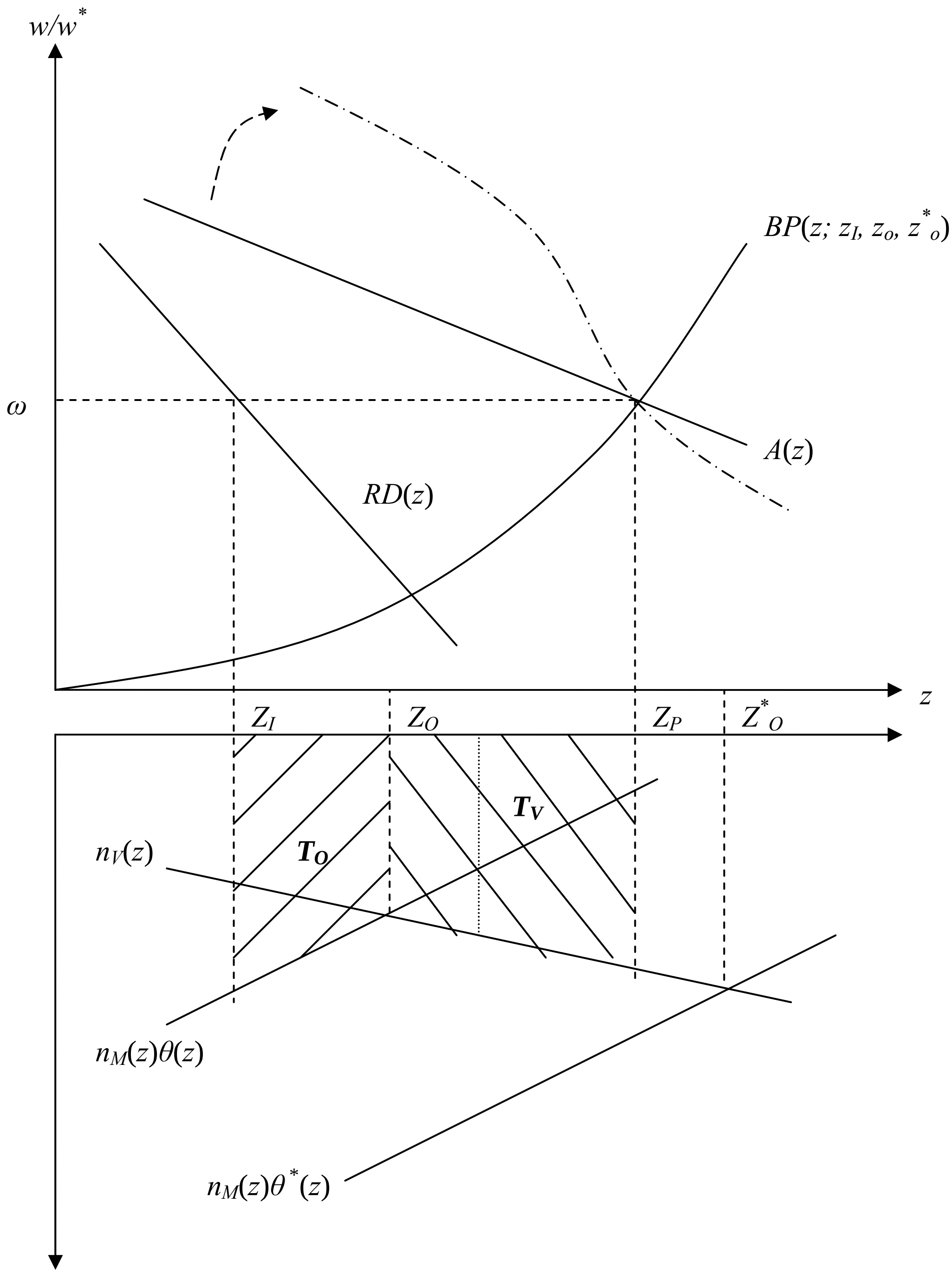

Figure 1 – General equilibrium

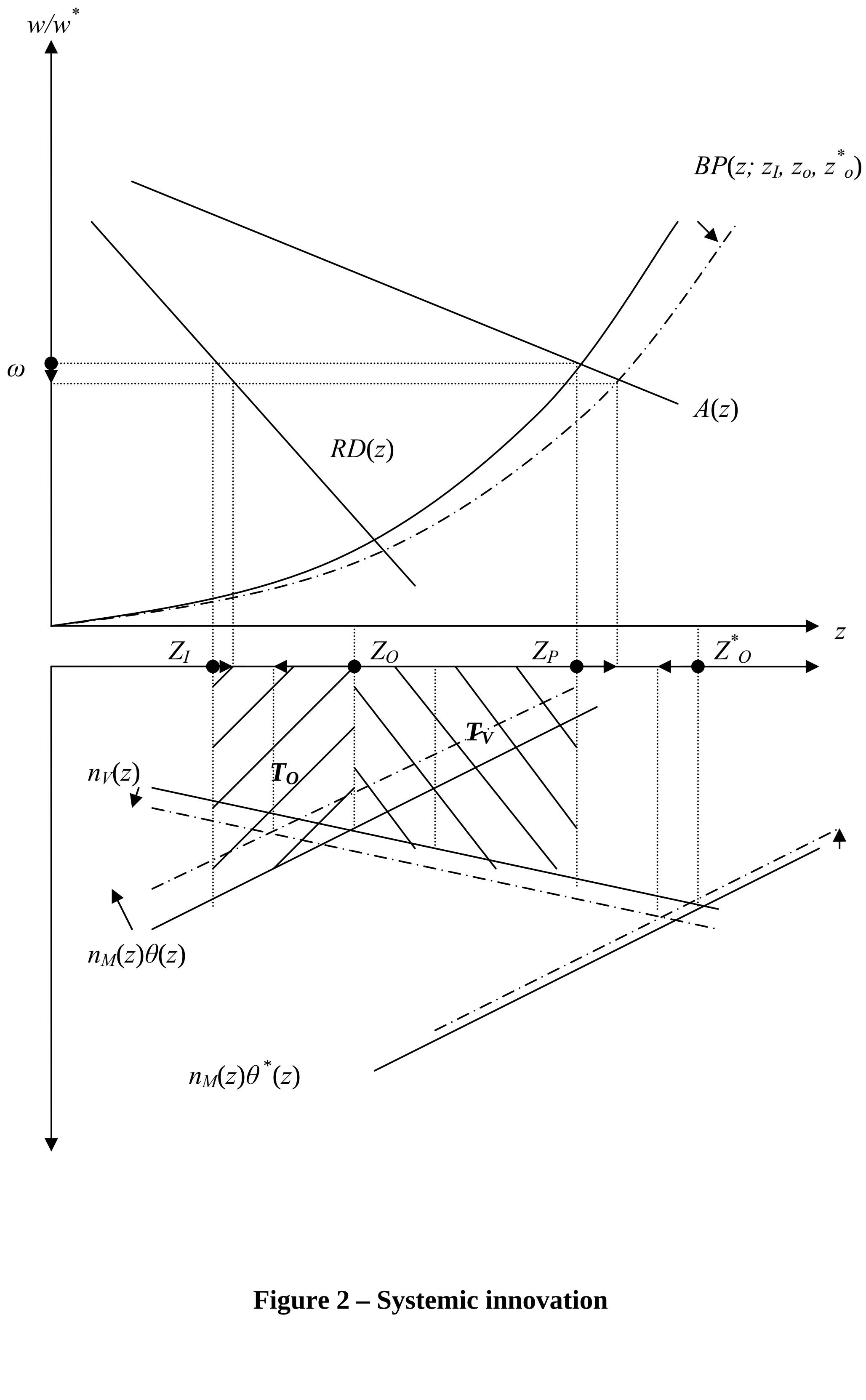

Figure 2 – Systemic innovation

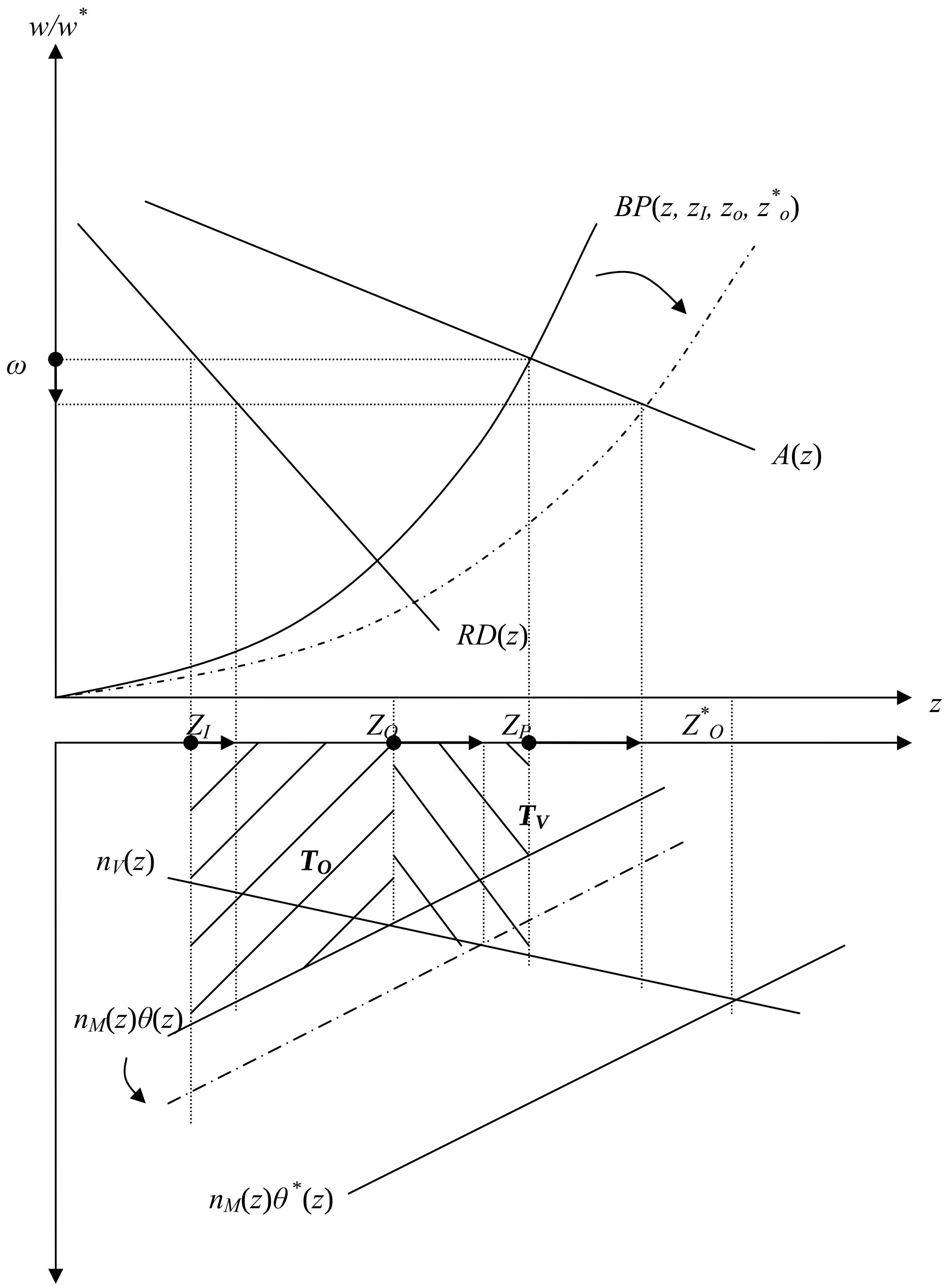

Figure 3 – Institutional convergence