# International Trade, Market Risk, and Multinational Corporations

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Affected by a few years' research and studies, my interests have been gradually formed around theoretical economics and its application to observe international economic phenomena. Herein lies the dissertation on international trade, market risk and multinational corporations, a latest research result along the academic line.

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# Introduction

Literature related with multinational corporations is voluminous. But a perfect cognizance of multinational corporations is far from accomplished. In other words, it is far early to say that it is time to terminate studies with regard to multinational corporations. We still have a lot to do on the way of pursuing a better understanding of their behavior. Based on the objective point, composing this dissertation is in order for paying its own contribution to the ocean of knowledge in multinational corporations theory and related theoretical issues.

In the academia, the widely cited source literature about multinational corporations is countable. Among the most classical, one can find they are Hymer (1976), Buckley and Casson (1976), Dunning (1977, 1980, 1981, 1988) and Rugman (1980). These works intend to explain why a multinational corporation would exist and what drives foreign direct investment (FDI), where Dunning's in particular have done a valuable synthesis, leading to the famous OLI (ownership advantage-location advantage-internalization advantage) paradigm.

On the one hand, these theories are even not enough to throw lucidity upon the most fundamental aspect – why a multinational corporation would exist, for the reasons of FDI are far more than what have been described by them, let alone other relevant ones as a result of existence of FDI[1].

On the other hand, the theories of multinational corporations are, to a large extent, independent of international trade theory (traditional interindustry trade, and the more interesting intraindustry and intrafirm trade is not formally dealt with in these theories), although it is potentially possible that they can be used to explain some trade phenomena. For example, the theory of ownership advantage has essentially the same core compared to the theory of Ricardo's comparative advantage (Ricardo, 1817). Henceforth, traditional trade pattern or specialization of production can be explained by the theory of ownership advantage in principle. Another multinational corporations theory, i.e., the theory of internalization advantage may be used to explain partially intrafirm trade, since the theory tells it can be rational to conduct trade or technological transfer within the interiority of a corporation.

[1]Chung (2001) argues "there has been no complete theory of the multinational firm".

However, the theory can not predict or explain why intrafirm trade also more likely happens between developed countries.

To divide multinational corporations theory and trade theory artificially seems to be unreasonable, since part of trade is conducted by multinational corporations. A theory which only can explain one aspect of a fact is incomplete and always under being challenged. With more and more trade and investment simultaneously happening related with multinational corporations after the Second World War and especially from the 1970s, it appears that a unified theory for accommodating FDI and trade is necessary. Such kind of attempt to reconcile the multinational corporations theory with international trade theory began primarily from Helpman (1984) and Markusen (1984), which have been further developed by the recent endeavour of Markusen (1997, 2000) and Markusen and Maskus (2001a, 2001b). The reconciling coup d'essai tries to find out the reasons for trade and investment through a single framework. Findings of these works are nevertheless not always consistent. For example, Markusen (2000) argues trade and investment is complement when the countries differ in relative endowments and investment is vertical, while trade and investment is substitute when the countries are similar and investment is horizontal when trade costs are lowering. Put it directly, Markusen (2000) argues that trade and investment in developed countries should be substitute. But in Markusen and Maskus (2001a), one of the conclusions is that high-income countries would trade and invest both heavily among one another.

In summary, the theories of FDI and trade, no matter whether they are single pieces or unified ones, have not found out convincingly yet, why on earth trade and investment concentrates in high-income countries, or developed countries.

The above-mentioned issue is one of the most important lingering around the academia. What is more, some other issues related with activities of multinational corporations, such as technological transfer, market risk and factor movement should be studied more thoroughly.

Pertaining to technological transfer, there is a common understanding that developing countries should be helped by technological transfer, regarded as followers in terms of their lower level of technology and science, and of course their lower quality of economic development. Paradoxically, in practice, it is not hard to find

technological transfer from developed countries is always under various restrictions (or not the most advanced). A question mark for this kind of technological transfer rises naturally: whether would it really do good to the international and domestic economic performance of developing corporations or countries? To the best of my knowledge, it is a pity that concern of academia and relevant countries has not been aroused around this topic, at least on a theoretical basis[2]. The gracious effect of technological transfer may be magnified, otherwise, there should have been a sign that technological gap between developing and developed countries is gradually closing up and competitiveness of developing corporations or countries in the world market should have been stronger. There has been empirical literature getting less supportive evidence (e.g., Djankov and Hoekman, 2000), but ground for theoretical attempts still needs to be plowed. The dissertation reconsiders this issue by theoretically examining whether nowadays technological transfer from developed countries is truly beneficial to developing countries.

The world markets are full of uncertainties and risks. But even so, "sales of foreign affiliates are now greater than world total exports of goods, implying that firms use FDI more than they use exports to service foreign markets" (Di Mauro, 2000). It is natural to ask why a corporation is willing to conduct FDI in foreign markets in front of these risks. The question is related with why a corporation would like to become a multinational, which can definitely have a large number of rationales. It may be plausible to infer that FDI in foreign markets by multinational corporations can be a practicable way to evade market risks. Are there any theories supporting this speculation? Not exactly. Theories about multinational corporations and market risk are incomplete. Teaching of prevalent international business and international management theories concludes FDI is an inevitable way of increasing international business of any kind such as trade, licensing, joint venture and the like, but it has been less heedful of the function of risk aversion of FDI. Although literature (especially on financial areas) has extensively studied risk issues faced by a multinational corporation, its focus is however more on the financial side rather than on the real

[2]Krugman (1979a) directly interprets technological transfer as "...the process by which new products are transformed into old products", which de facto takes it for granted that new technology would never be transferred.

one (such as FDI). There is literature indeed about FDI and market risk, most of which only concerns one specific type of risk, such as exchange rate risk or political risk, so a study with more generality is required. As a risk-averse multinational corporation within an environment consisting of various economic and non-economic market risk, how it decides regarding the amount of investment, labor employment, and production in both its home and host markets would be discussed in the paper.

As for factor movement, it is not a new topic and has been touched upon before by traditional international trade theories. These theories simply assume productive factors can not be mobile across borders. Let's take the famous theorem of absolute factor price equalization as an example. The theorem describes that factors prices would be equalized with free trade in goods and on the condition that trading countries do not completely specialize. It is derived from traditional trade theories, which to some extent can be pegged with factor movement because free trade in goods, acceptably recognized in the academia, can be seen as a substitute for free movement of factors. However, the fact that factor movement is more or less neglected is obvious. Wong (1995) argues there are two notable reasons for this, one being "...historically economic relationships between countries have been determined mainly through the movement of goods" and the other "...under certain conditions, the theory of international trade in goods can be extended to cover international factor mobility", and itself is a new theoretical development on the topic. In the available literature, to the question why there would be international factor movement, most explanations have been given from the economic side. But non-economic ones seem to be far less concerned in those literature even including Wong (1995). As we know, to comprehend some phenomena like factor movement, only economic theories may not suffice. For example, happening of labor movement is not just because of a better payment in its immigration countries or areas. Geography and social institution and so forth would have their say in determination too. In addition, previous literature seldom explicitly enquires into three-factors (i.e., labor, capital and technology) in a model; some of their common concern, such as whether labor inflow from another corporation (or country) would do harm to current labor employment in the host corporation (or country), needs further cogitation.

Writing the dissertation is in order to provide deeper understanding and rethink-

ing to these unclosed academic issues, and work for appropriate policy implications. Besides theoretical findings, relevant business and public policies would be presented in this regard.

The dissertation is composed of four chapters. They are respectively chapter one "Why would intraindustry trade or investment more likely happen between developed countries?"; chapter two "Why is it important for a multinational corporation to hold technological leadership? A technological transfer perspective"; chapter three "Multinational corporations and market risk: A real market perspective"; and chapter four "Multinational corporations and factor movement".

Briefly speaking, the theoretical findings and contribution to economics as a philosophy from the four chapters are as follows:

## Theoretical findings:

- Combining human capital theory, the dissertation has shown that intraindustry trade, intraindustry investment, and even interindustry trade and investment would more likely occur between developed countries. It confirms again traditional economic theory (especially from the supply side) can accommodate these new phenomena of trade and investment well with more generality. Some traditional academic issues such as why a corporation would like to be involved in international trade or become a multinational have also been answered.

- Restrained technological transfer from developed corporations or countries is accompanied with reduction of profit from FDI of developing ones in the former's domestic markets and no explicit effect on profit from their home markets. In other words, it would not bring any substantial benefit to developing corporations or countries. To developed ones, they benefit materially a higher level of employment of domestic productive factors and higher total profit level in their home and foreign markets by perpetuating a technological gap with the developing ones. This finding is never meant to accuse of the technological transfer in the real world, but just presents a theoretical reconsideration and seeks for a better route for the future practice of assisting the developing world.

- Being a multinational corporation would be better to avoid market risk from multiple sources, which can be financial, real and so on, and more helpful for making correct decision about investment, labor employment and production in different markets. In the parallel words, a non multinational corporation may uphold unsymmetrical market risk compared to its market share. Hence, the chapter from another (theoretically admissible) angle has reasoned why a corporation would like to become a multinational besides that given in the first chapter.

- Within a framework pulling together economic and non-economic factors, with respect to international movement of labor, capital and technology, only labor inflow from a developed/developing corporation (or country) would be complementary to labor employment of another developing/developed one when the countries involved make progress in the elements like returns to productive factors, social welfare, and property protection and market risk is decreasing continuously; free international factor movement is a key (but not sufficient) to promote production convergence for a multinational corporation and thus economic convergence among countries.

## Theoretical contribution:

The theoretical contribution of the dissertation can be summed up into four laterealities, which are, international trade theory, theory of multinational corporations, growth theory and business and public policy studies.

- To international trade theory, the dissertation is among the first explicitly and analytically in explaining several important trade and investment issues such as why intraindustry and investment dominates in developed countries.

- To theory of multinational corporations, the dissertation raises another two renditions: one is provided in the first chapter and the other is in the third chapter. Concisely, with a perfectly competitive market structure, higher profit in home markets may trigger an incentive to conduct FDI in foreign markets; and being a multinational corporation is a better choice confronting

market risks variously sourced and correlated when the market structure is monopolistic.

- To growth theory[3], the dissertation finds out that even when factor movement is free, production/economic convergence may not happen between developed and developing corporations/countries, non-economic factors like social institution taken into account.

- To business and public policy studies, the dissertation advocates that skill upgrading of available labor force in developing countries is the strategic policy for higher FDI inflow; less affiliated conditions should be bounded with technological transfer from developed corporations/countries to developing counterparts; research and development is crucial to generate higher production, profit, and a long run growth for a developing corporation/country; and argues that a country (an underdeveloped one specially) should strive for a better social environment rather than economic objects only, a direct reason of which is that merits or demerits of social environment can have a vital effect on its economic performance.

[3]Although these four essays are titled related with multinational corporations-a microeconomic topic, they in fact have been involved with another vital theoretic arena, the macro one. Growth theory belongs to the scope of macroeconomics. It is understandable that the microeconomic behavior such as that of a corporation is not an object commonly treated in macroeconomics, but any macroeconomic phenomenon can not be independent of the activities of those microeconomic organs like MNCs. From the account of international trade, investment, factor movement and the like, we hope that the dissertation would be contributive well to understanding of economic growth and development also, since every issue of what we discuss about here has inevitably noticeable effect on economic growth of a country and the world.

# 1 Why would intraindustry trade or investment more likely happen between developed countries?

A typical international economic phenomenon is that intraindustry trade or investment heavily concentrates in developed countries. Traditional trade theory is normally viewed as not being competent in accounting for the issue. Though potentially new development of trade theory has been able to reason why intraindustry trade or investment throngs towards these countries, we would like to show traditional trade theory is not necessary to be invalid.

Applying human capital theory and under a framework of perfect competition, the chapter finds out the causes for the vista as follows: to corporations from developing countries, investing directly in developed countries would be more attractive than trading with them; to corporations from developed countries, they would like more to conduct trade and direct investment between themselves and just export to the developing counterparts. Other related theoretical issues like why a corporation would like to participate in international trade or become a multinational, and why even interindustry trade or investment concentrates in developed countries have been dealt with alongside.

## 1.1 Introduction

Intraindustry trade (IIT) has become an important academic interest since the Second World War and especially 1970s. The commonly recognized earliest analysis about IIT can be dated back to Linder (1961). Based on the definition of Södersten and Reed (1994), IIT refers to "...the situation where countries simultaneously import and export what are essentially the same products". In the past several decades, volume of IIT occupied a substantial proportion of the world trade. Theoretical development seems to be led behind the changes of economic development. Traditional trade theories, such as Ricardo's comparative advantage theory and Heckscher-Ohlin's factor endowment theory, have been announced by many (new trade) theorists that they can not explain IIT, still less why IIT thrives between developed countries. In our point of view, traditional trade theory is not necessary to be thus discarded. It has continued to be utilized in many contexts. For example, among others, Young (1991) introduces learning by doing into the theory, but it predicts "...developed countries would most like to trade with their less developed counterparts..." (see Aghion and Howitt, 1998), which is obviously against the typical fact we can notice from today's world economy.

Some international economists have had relevant, but not perfectly consistent research results. Markusen (2000) argues trade and investment is complement when the countries differ in relative endowments and investment is vertical, while trade and investment is substitute when the countries are similar and investment is horizontal when trade costs are lowering. Markusen (2000) is equivalent to say that trade and investment in developed countries is thought to be substitute. But in Markusen and Maskus (2001a), one of its conclusions is that high-income countries would trade and invest both heavily among one another. Both these two papers are involved with characteristics of new trade theory.

The aim of the chapter is not to justify whether trade and investment in developed countries is substitute or not. We are only interested why IIT or investment are biased to developed countries. Observing that a large volume of trade (see Bhagwati and Davis, 1999) and investment (see Brainard, 1997[4]) actually happens

[4]According to Sauvant (2001), there is 74%, 14%, 11%, 3% and 1% FDI allocated in developed areas, Asia, Latin America and Caribbean, Central and Eastern Europe and Africa respectively.

between developed countries, the chapter has furthermore enlarged its explanatory capability in the stylized trade and investment phenomena of our times which is not just limited to IIT and intraindustry investment. Through the study, we can see not only IIT, but also its gravity in developed world can be accommodated within a framework of traditional trade theory.

There is no specially new methodology applied in the chapter. Inspired from the theoretical practice that the human capital theory has ever been used to explain the Leontief Paradox of international economics, we judge it may be helpful in explaining some other international economic issues. Our judgement is correct and the key findings of the chapter include: when there is difference in labor capability due to existence of human capital, corporations from developed countries will more likely not choose to invest in developing countries, since trading or investing between themselves would be more profitable; to corporations from developing countries, investment in developed countries would be more attractive than trading with them.

The following text is organized as follows: section 2 is theoretical foundation; section 3 is the model; section 4 is discussion and section 5 concludes.

## 1.2 Theoretical foundation

Effort to elucidate IIT is tremendous. Imbrued from those valuable works by many authors, we would have a terse review of the quintessence of their works. It should be said the IIT most scholars concern refers to the traded goods which are made with similar factors and highly substitutable. Grubel and Lloyd (1975) ever discerned three groups of IIT differentiated goods. The first group are those made with similar factor requirements but are less substitutable; the second group are those made with different factor requirement but are highly substitutable; and the third group are those made with similar factor requirements and highly substitutable, in which it is the third group that calls forth much attention. That is because the former two groups can be explained respectively by Ricardo model with comparative advantage argument and Heckscher-Ohlin model [HO, Heckscher (1919), Ohlin (1933)] with factors endowment argument[5]. The opinions about whether the third group can be

[5]Not all IIT phenomena necessitate extra explanations beyond traditional trade models. A part of IIT happens because of seasonal, geographical, transport costs, entrepot trade, or government

handled with traditional trade theory are still diverse. New trade theorists argue traditional trade theory should be abandoned, whose constant return to scale and perfect competition framework is not suited to account for IIT. They saddle with increasing return to scale and imperfect competition instead (e.g., Krugman, 1979b, 1980, 1995). There are mainly two branches of models brought up accordingly, which are neo-Chamberlinian (NC) and neo-Hotelling models (NH).

NC and NH models are used to explain IIT of horizontally differentiated goods. The major difference between NC and NH models lies in their assumption about consumers' preference. Krugman (1979b), with the assumption of increasing returns to scale, is among the earliest on NC models. NH models are sourced from Lancaster (1980). In Krugman (1979b), introduction of every new variety of a product in the utility function is symmetric, which implies consumers would consume as many varieties of a product as possible, known as that consumers demand for varieties. In Lancaster (1980), consumers would prefer to consume the most ideal variety of a product. The appearance of every new variety of a product would lead to the fact that a consumer is closer to consume his or her most ideal variety of the product. In short, consumers demand for characteristics.

The preference mode Krugman (1979b) applies is developed from Dixit and Stiglitz (1977) and Spence (1976), which assumes each consumer would demand all available varieties of a differentiated good. Krugman (1979b, 1980), and Helpman and Krugman (1985) study IIT mainly from the perspective of heterogeneous goods. Markusen (1981), Brander (1981), and Brander and Krugman (1983) explain IIT of homogeneous goods in the framework of imperfectly competitive market structure. The extensive literature forms later well-known "new trade theory" characterized with introduction of increasing return to scale and imperfect competition into trade models.

Though new trade theory based on NC and NH models gives a reasonable narration of IIT, it can be noted that traditional trade models are still utilized and further improved by scholars. Development of neo-Heckscher-Ohlin models (NHO) or Heckscher-Ohlin-Ricardo models (HOR) by Davis (1995) is an example.

intervention reasons. Statistical classification can also play a role in apparent increase or decrease of IIT.

NHO models [see Falvey (1981), Falvey and Kierzkowski (1987)] are factually extended versions of the HO model. Linking product specifications with factor endowments, NHO models are used to explain IIT of vertical differentiated goods. Vertical differentiation refers to quality differentiation of the products made in different countries. Products of higher quality are preferred to those of lower one, but the consumption should be subject to income constraint. Products of lower quality would be demanded more by consumers with lower income in less richer countries (e.g., labor relatively intensive, but capital scarce), while those of higher quality would be demanded more by consumers with higher income in richer countries (e.g., labor relatively scarce, but capital abundant). NHO models have not essentially surpassed the arena of theory of factor endowments even though they stress the supply side (factor endowments) as well as the demand side.

Davis (1995) is possibly the first pointing out increasing return is not a necessary condition for IIT. By introducing element of technological difference into a HO model (forming the so-called Heckscher-Ohlin-Ricardo model which is intrinsically equivalent to NHO models), it provides a contrasting result with the standard HO models. As the paper mentions, "a striking contrast between the predictions of the standard analysis and that in the Heckscher-Ohlin-Ricardo model is that the standard model predicts that countries with identical factor ratios do not trade. In the present model, such countries have no interindustry trade...there may yet be intraindustry trade. "

Despite the whatsoever difference, all of these models, no matter what type they are, NC, NH, or NHO, tell a same story that it is IIT that helps realize the maximum of consumers' utility by providing the condition that consumers can have more access to varieties of a product. Consumers are modelled to prefer consuming as many varieties of a product as possible. Since a country can hardly produce all the varieties of a product, IIT would hence take place between countries[6].

With regard to the issue why IIT would more likely happen between developed countries, literature with NC, NH, NHO or HOR models have not given an direct analysis before, though NC and NH models can potentially be developed to accommodate it. We are more interested in whether traditional trade models can be

[6]More detailed illustration regarding to consumers' taste can be referred to Barker (1977).

employed in the chapter. From NHO or HOR models, one may get a theoretical impression that IIT would also symmetrically happen between developing countries as it would between developed ones. For example, much NHO or HOR literature does not distinguish developed countries and developing ones explicitly. The most noticeable conclusion is that there can be equivalent amount of IIT between countries with identical factor ratios and lower technology level. Therefore one may misconceive that a sizeable amount of IIT would happen between developing countries and confuse predictions of the models with real economic phenomenon.

Additionally, a common shortcoming of aforementioned models is that they are not general enough to cover multiple issues of IIT. Though they explain why there is IIT from a certain perspective, comparatively speaking, they have more or less ignored the fact why IIT seems to more likely take place between developed countries.

A more general theoretical model is built in this regard within the chapter, which can answer these issues simultaneously. Interestingly, besides the key two issues discussed, the model also can answer why a corporation would like to become a multinational corporation (MNC), why intraindustry investment would be more likely happen between developed countries emphasized by Markusen (1997)[7], and why even interindustry trade or investment concentrates in developed countries.

## 1.3 The model

The section provides a theoretical clue to why IIT would more likely happen between developed countries. As mentioned above, the analysis would answer some other concomitant questions such as why a corporation would like to participate international trade or become a multinational, and why intraindustry investment

[7]According to Markusen (1997), "...there has been a substantial rise in both trade and direct investment since the early 1970's, with direct investment growing substantially faster than trade.... direct investment has been concentrated among the high-income countries, even more so than trade, with some moderation of this effect in the 1990's (almost 40% of the direct investment to developing countries went to China alone however). These stylized facts suggest that (a) direct investment is not motivated primarily by trade-barrier-avoidance, and (b) not motivated primarily by factor-endowment/price differences. Both results cast significantly doubt on any treatment which sees direct investment as more or less the same thing as portfolio/physical factor flows. "

would more likely happen between developed countries.

A model makes use of human capital theory and optimal control approach for this purpose. The issues would be dealt with from the supply side, which is different from the main-stream analysis mainly from the demand side.

Assuming there are three countries, each one having two kinds of productive factors, i.e., labor and capital (which is fully used to invest in production by assumption), and many different industries, each industry having numerous corporations producing homogenous goods of the industry-specific type. The products produced by different industries are heterogeneous. Some industries are foreign-oriented, but some are not. Goods produced by foreign-oriented firms are demanded by foreign markets. Non-foreign-oriented firms have no demand from foreign countries on the contrary. Market prices for goods and productive factors are exogenous and every firm in these three countries is a price taker.

Within the three countries, there can be two symmetric developing countries and the rest one is developed; or two symmetric developed countries and the other one is developing. Industries and corporations from a developed country have higher technology level than those from a developing one. Investment and trade within these three countries is assumed to be free to all corporations. There is no such transaction cost as transport cost, trade and investment barrier, and sunk cost. Production of a corporation in a foreign country would employ local labor and capital.

To study the trade pattern of these three countries, we only need to study that of three representative foreign-oriented corporations from these countries respectively based on the assumptions. We call them corporation $d$, $f1$,and $f2$. The corporations would choose to maximize their own discounted sum of long run profit, which is given as follows:

For the corporation $d$ of the country $d$

$$\max \int_{t_0}^{\infty} e^{-r(t-t_0)} f(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) dt \quad (1)$$
$$\text{subject to } d\Pi_{d_d},\ d\Pi_{d_{f1}},\ d\Pi_{d_{f2}}$$
$$\Pi_{d_d}(t_0) = \Pi_{d_{d0}}$$
$$\Pi_{d_{f1}}(t_0) = \Pi_{d_{f10}} \text{ and } \Pi_{d_{f2}}(t_0) = \Pi_{d_{f20}}$$

For the corporation $f1$ of the country $f1$

$$\max \int_{t_0}^{\infty} e^{-r(t-t_0)} f(\Pi_{f1_d}, \Pi_{f1_{f1}}, \Pi_{f1_{f2}}) dt \quad (2)$$
$$\text{subject to } d\Pi_{f1_d},\ d\Pi_{f1_{f1}},\ d\Pi_{f1_{f2}}$$
$$\Pi_{f1_d}(t_0) = \Pi_{f1_{d0}}$$
$$\Pi_{f1_{f1}}(t_0) = \Pi_{f1_{f10}} \text{ and } \Pi_{f1_{f2}}(t_0) = \Pi_{f1_{f20}}$$

For the corporation $f2$ of the country $f2$

$$\max \int_{t_0}^{\infty} e^{-r(t-t_0)} f(\Pi_{f2_d}, \Pi_{f2_{f1}}, \Pi_{f2_{f2}}) dt \quad (3)^{8}$$
$$\text{subject to } d\Pi_{f2_d},\ d\Pi_{f2_{f1}},\ d\Pi_{f2_{f2}}$$
$$\Pi_{f2_d}(t_0) = \Pi_{d0}$$
$$\Pi_{f2_{f1}}(t_0) = \Pi_{f2_{f10}} \text{ and } \Pi_{f2_{f2}}(t_0) = \Pi_{f2_{f20}}$$

where $t_0$ denotes the base period. The total profit functions of the three corporations are assumed to have a Cobb-Douglas-production-function-like form:

$$\Pi_d = f(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) = \alpha_d \Pi_{d_d}^{\beta_d} \Pi_{d_{f1}}^{\phi_d} \Pi_{d_{f2}}^{1-\beta_d-\phi_d} \quad (4)$$
$$\Pi_{f1} = f(\Pi_{f1_d}, \Pi_{f1_{f1}}, \Pi_{f1_{f2}}) = \alpha_{f1} \Pi_{f1_d}^{\beta_{f1}} \Pi_{f1_{f1}}^{\phi_{f1}} \Pi_{f1_{f2}}^{1-\beta_{f1}-\phi_{f1}} \quad (5)$$
$$\Pi_{f2} = f(\Pi_{f2_d}, \Pi_{f2_{f1}}, \Pi_{f2_{f2}}) = \alpha_{f2} \Pi_{f2_d}^{\beta_{f2}} \Pi_{f2_{f1}}^{\phi_{f2}} \Pi_{f2_{f2}}^{1-\beta_{f2}-\phi_{f2}} \quad (6)$$

$\Pi_d$, $\Pi_{f1}$ and $\Pi_{f2}$ denote total profit of the corporations $d$, $f1$ and $f2$ respectively. From (4), (5) and (6), total profit of each corporation is a multiplication of profits from its domestic market and the other two foreign ones, i.e., $\Pi_{d_d}$, $\Pi_{d_{f1}}$, and $\Pi_{d_{f2}}$, $\Pi_{f1_d}$, $\Pi_{f1_{f1}}$ and $\Pi_{f1_{f2}}$, or $\Pi_{f2_d}$, $\Pi_{f2_{f1}}$, and $\Pi_{f2_{f2}}$. $\Pi_{d_d}$ stands for the profit of the corporation $d$ in its home market in the circumstance where it accrues independently without any direct connection with profits from the other two markets. Similarly, $\Pi_{d_{f1}}$ is the profit of the corporation $d$ in the foreign market $f1$ which is also directly uncorrelated with profits from the other two markets. The same explanation applies to $\Pi_{d_{f2}}$, ..., and $\Pi_{f2_{f2}}$. Product of profits from home and foreign markets here has twofold intentions. One is to capture the fact that the corporations $d$, $f1$ and $f2$ strategically operate in the three markets by, say, profit transfer, aiming to maximize profit comprehensively within all the three markets rather than separately in every single one. The other is purely for computational feasibility.

[8]The continuous form of the profit functions (1), (2) and (3) not only mimics more precisely economic behavior in reality, but also renders easier calcualtion convenience in the following text.

There are two productive factors, i.e., labor and capital. They can be denoted according to their sites of employment and proprietors as $L_d$, $L_{d_{f1}}$, and $L_{d_{f2}}$, $I_d$, $I_{d_{f1}}$, and $I_{d_{f2}}$, $L_{f1}$, $L_{f1_d}$, and $L_{f1_{f2}}$, $I_{f1}$, $I_{f1_d}$, and $I_{f1_{f2}}$, $L_{f2}$, $L_{f2_d}$, and $L_{f2_{f1}}$, and $I_{f2}$, $I_{f2_d}$, and $I_{f2_{f1}}$. $L_d$ means the amount of labor employed in the country $d$ by the corporation $d$. $L_{d_{f1}}$ means the amount of labor employed in the country $f1$ by the corporation $d$. The explanation applies to $L_{d_{f2}}$, ..., and $L_{f2_{f2}}$.

The production functions of the three corporations are Cobb-Douglas, with constant return to scale and given by (7), (8) and (9):

$$Q_d = M_d I_d^{\chi_d} L_d^{1-\chi_d} \quad (7)$$
$$Q_{f1} = M_{f1} I_{f1}^{\chi_{f1}} L_{f1}^{1-\chi_{f1}} \quad (8)$$
$$Q_{f2} = M_{f2} I_{f2}^{\chi_{f2}} L_{f2}^{1-\chi_{f2}} \quad (9)$$

where $M_d$, $M_{f1}$, and $M_{f2}$ are total factor productivity (TFP) of the corporations $d$, $f1$ and $f2$ respectively. The TFP in corporations originally from developed countries should be higher than or equal to those originally from developing ones.

The profit function of each corporation in an individual market, which is equal to income from that market deducting the corresponding production cost and is assumed to be larger than zero. (10) denotes the profit of the corporation $d$ in its domestic market; (11) and (12) tell there are two ways of profit realization for the corporation $d$ in $f1$ and $f2$ markets: one is through FDI and the other is through export.

$$\Pi_{d_d} = p_{Q_d} Q_d - p_{I_d} I_d - p_{L_d} L_d \quad (10)$$

$$\Pi_{d_{f1}} = \begin{cases} p_{Q_{d_{f1}}} Q_{d_{f1}} - p_{I_{d_{f1}}} I_{d_{f1}} - p_{L_{d_{f1}}} L_{d_{f1}} & \text{(FDI)} \\ p_{E_{d_{f1}}} E_{d_{f1}} - p_{I_{E_{d_{f1}}}} I_{E_{d_{f1}}} - p_{L_{E_{d_{f1}}}} L_{E_{d_{f1}}} & \text{(Export)} \end{cases} \quad (11)$$

$$\Pi_{d_{f2}} = \begin{cases} p_{Q_{d_{f2}}} Q_{d_{f2}} - p_{I_{d_{f2}}} I_{d_{f2}} - p_{L_{d_{f2}}} L_{d_{f2}} & \text{(FDI)} \\ p_{E_{d_{f2}}} E_{d_{f2}} - p_{I_{E_{d_{f2}}}} I_{E_{d_{f2}}} - p_{L_{E_{d_{f2}}}} L_{E_{d_{f2}}} & \text{(Export)} \end{cases} \quad (12)$$

Similarly, we can have the profit functions of the corporation $f1$ in the markets $f1$, $d$, and $f2$ shown in (13), (14) and (15).

$$\Pi_{f1_{f1}} = p_{Q_{f1}} Q_{f1} - p_{I_{f1}} I_{f1} - p_{L_{f1}} L_{f1} \quad (13)$$

$$\Pi_{f1_d} = \begin{cases} p_{Q_{f1_d}} Q_{f1_d} - p_{I_{f1_d}} I_{f1_d} - p_{L_{f1_d}} L_{f1_d} \quad \text{(FDI)} \\ p_{E_{f1_d}} E_{f1_d} - p_{I_{E_{f1_d}}} I_{E_{f1_d}} - p_{L_{E_{f1_d}}} L_{E_{f1_d}} \quad \text{(Export)} \end{cases} \tag{14}$$

$$\Pi_{f1_{f2}} = \begin{cases} p_{Q_{f1_{f2}}} Q_{f1_{f2}} - p_{I_{f1_{f2}}} I_{f1_{f2}} - p_{L_{f1_{f2}}} L_{f1_{f2}} \quad \text{(FDI)} \\ p_{E_{f1_{f2}}} E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}} I_{E_{f1_{f2}}} - p_{L_{E_{f1_{f2}}}} L_{E_{f1_{f2}}} \quad \text{(Export)} \end{cases} \tag{15}$$

And the profit functions for the corporation $f2$ in the markets $f2$, $d$, and $f1$ are given by:

$$\Pi_{f2_{f2}} = p_{Q_{f2}} Q_{f2} - p_{I_{f2}} I_{f2} - p_{L_{f2}} L_{f2} \tag{16}$$

$$\Pi_{f2_d} = \begin{cases} p_{Q_{f2_d}} Q_{f2_d} - p_{I_{f2_d}} I_{f2_d} - p_{L_{f2_d}} L_{f2_d} \quad \text{(FDI)} \\ p_{E_{f2_d}} E_{f2_d} - p_{I_{E_{f2_d}}} I_{E_{f2_d}} - p_{L_{E_{f2_d}}} L_{E_{f2_d}} \quad \text{(Export)} \end{cases} \tag{17}$$

$$\Pi_{f2_{f1}} = \begin{cases} p_{Q_{f2_{f1}}} Q_{f2_{f1}} - p_{I_{f2_{f1}}} I_{f2_{f1}} - p_{L_{f2_{f1}}} L_{f2_{f1}} \quad \text{(FDI)} \\ p_{E_{f2_{f1}}} E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}} I_{E_{f2_{f1}}} - p_{L_{E_{f2_{f1}}}} L_{E_{f2_{f1}}} \quad \text{(Export)} \end{cases} \tag{18}$$

Hence, making use of the expressions from (10) to (18), we can have the total profit dynamics of the corporation $d$ which is denoted by the four forms of stochastic differential equations:

$$\begin{aligned} (19)\ d\Pi_d = \quad & (1)\ \beta_d(p_{Q_d} Q_d - p_{I_d} I_d - p_{L_d} L_d)dt + \phi_d(p_{Q_{d_{f1}}} Q_{d_{f1}} - p_{I_{d_{f1}}} I_{d_{f1}} \\ & - p_{L_{d_{f1}}} L_{d_{f1}})dz_1 + (1 - \beta_d - \phi_d)(p_{Q_{d_{f2}}} Q_{d_{f2}} - p_{I_{d_{f2}}} I_{d_{f2}} \\ & - p_{L_{d_{f2}}} L_{d_{f2}})dz_2 \quad \text{(FDI)} \end{aligned}$$

$$\begin{aligned} & (2)\ \beta_d(p_{Q_d} Q_d - p_{I_d} I_d - p_{L_d} L_d)dt + \phi_d(p_{E_{d_{f1}}} E_{d_{f1}} - p_{I_{E_{d_{f1}}}} I_{E_{d_{f1}}} \\ & - p_{L_{E_{d_{f1}}}} L_{E_{d_{f1}}})dz_1 + (1 - \beta_d - \phi_d)(p_{E_{d_{f2}}} E_{d_{f2}} - p_{I_{E_{d_{f2}}}} I_{E_{d_{f2}}} \\ & - p_{L_{E_{d_{f2}}}} L_{E_{d_{f2}}})dz_2 \quad \text{(Export)} \end{aligned}$$

$$\begin{aligned} & (3)\ \beta_d(p_{Q_d} Q_d - p_{I_d} I_d - p_{L_d} L_d)dt + \phi_d(p_{Q_{d_{f1}}} Q_{d_{f1}} - p_{I_{d_{f1}}} I_{d_{f1}} \\ & - p_{L_{d_{f1}}} L_{d_{f1}})dz_1 + \ (1 - \beta_d - \phi_d)(p_{E_{d_{f2}}} E_{d_{f2}} - p_{I_{E_{d_{f2}}}} I_{E_{d_{f2}}} \\ & - p_{L_{E_{d_{f2}}}} L_{E_{d_{f2}}})dz_2 \quad \text{(Mixed I)} \end{aligned}$$

$$\begin{aligned} & (4)\ \beta_d(p_{Q_d} Q_d - p_{I_d} I_d - p_{L_d} L_d)dt + \phi_d(p_{E_{d_{f1}}} E_{d_{f1}} - p_{I_{E_{d_{f1}}}} I_{E_{d_{f1}}} \\ & - p_{L_{E_{d_{f1}}}} L_{E_{d_{f1}}})dz_1 + (1 - \beta_d - \phi_d)(p_{Q_{d_{f2}}} Q_{d_{f2}} - p_{I_{d_{f2}}} I_{d_{f2}} \\ & - p_{L_{d_{f2}}} L_{d_{f2}})dz_2 \quad \text{(Mixed II)} \end{aligned}$$

The first case specifies that profit change of the corporation $d$ is composed of three parts: one is from profit change in its domestic market and the other two from conducting FDI in the other two markets; the second case denotes its profit change when the firm exports to the other two markets; the third and forth cases (i.e., Mixed I and II) illustrate its profit change when the corporation $d$ invests in one of the two markets while exporting to the other one. In the dynamics of change of $\Pi_d$, the share of profit gained from the domestic market is deterministic, and the other two shares from the foreign markets are stochastic ($dz_1$ and $dz_2$ obey a Wiener process).

Similarly, we can have the corresponding dynamics of change of total profit for the corporations $f1$ and $f2$.

$$
\begin{aligned}
(20)\ d\Pi_{f1} = \quad & (1)\ \beta_{f1}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_{f1} - p_{L_{f1}}L_{f1})dt + \phi_{f1}(p_{Q_{f1_d}}Q_{f1_d} - p_{I_{f1_d}}I_{f1_d} \\
& -p_{L_{f1_d}}L_{f1_d})dz_1 + (1-\beta_{f1}-\phi_{f1})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} - p_{I_{f1_{f2}}}I_{f1_{f2}} \\
& -p_{L_{f1_{f2}}}L_{f1_{f2}})dz_2 \quad \text{(FDI)}
\end{aligned}
$$

$$
\begin{aligned}
& (2)\ \beta_{f1}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_{f1} - p_{L_{f1}}L_{f1})dt + \phi_{f1}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}I_{E_{f1_d}} \\
& -p_{L_{E_{f1_d}}}L_{E_{f1_d}})dz_1 + (1-\beta_{f1}-\phi_{f1})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}I_{E_{f1_{f2}}} \\
& -p_{L_{E_{f1_{f2}}}}L_{E_{f1_{f2}}})dz_2 \quad \text{(Export)}
\end{aligned}
$$

$$
\begin{aligned}
& (3)\ \beta_{f1}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_{f1} - p_{L_{f1}}L_{f1})dt + \phi_{f1}(p_{Q_{f1_d}}Q_{f1_d} - p_{I_{f1_d}}I_{f1_d} \\
& -p_{L_{f1_d}}L_{f1_d})dz_1 + \ (1-\beta_{f1}-\phi_{f1})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}I_{E_{f1_{f2}}} \\
& -p_{L_{E_{f1_{f2}}}}L_{E_{f1_{f2}}})dz_2 \quad \text{(Mixed I)}
\end{aligned}
$$

$$
\begin{aligned}
& (4)\ \beta_{f1}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_{f1} - p_{L_{f1}}L_{f1})dt + \phi_{f1}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}I_{E_{f1_d}} \\
& -p_{L_{E_{f1_d}}}L_{E_{f1_d}})dz_1 + (1-\beta_{f1}-\phi_{f1})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} - p_{I_{f1_{f2}}}I_{f1_{f2}} \\
& -p_{L_{f1_{f2}}}L_{f1_{f2}})dz_2 \quad \text{(Mixed II)}
\end{aligned}
$$

$$
\begin{aligned}
(21)^{9}\ d\Pi_{f2} = \quad & (1)\ \beta_{f2}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_{f2} - p_{L_{f2}}L_{f2})dt + \phi_{f2}(p_{Q_{f2_d}}Q_{f2_d} \\
& -p_{I_{f2_d}}I_{f2_d} - p_{L_{f2_d}}L_{f2_d})dz_1 + (1-\beta_{f2}-\phi_{f2})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} \\
& -p_{I_{f2_{f1}}}I_{f2_{f1}} - p_{L_{f2_{f1}}}L_{f2_{f1}})dz_2 \quad \text{(FDI)}
\end{aligned}
$$

[9] Values of $dZ_1$ and $dZ_2$ are different in (19), (20), (21) and their extension forms (22)-(30) given in the Appendix A.

$$(2)\ \beta_{f2}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_{f2} - p_{L_{f2}}L_{f2})dt + \phi_{f2}(p_{E_{f2_d}}E_{f2_d} - p_{I_{E_{f2_d}}}I_{E_{f2_d}} - p_{L_{E_{f2_d}}}L_{E_{f2_d}})dz_1 + (1-\beta_{f2}-\phi_{f2})(p_{E_{f2_{f1}}}E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}}I_{E_{f2_{f1}}} - p_{L_{E_{f2_{f1}}}}L_{E_{f2_{f1}}})dz_2 \quad \text{(Export)}$$

$$(3)\ \beta_{f2}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_{f2} - p_{L_{f2}}L_{f2})dt + \phi_{f2}(p_{Q_{f2_d}}Q_{f2_d} - p_{I_{f2_d}}I_{f2_d} - p_{L_{f2_d}}L_{f2_d})dz_1 + \ (1-\beta_{f2}-\phi_{f2})(p_{E_{f2_{f1}}}E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}}I_{E_{f2_{f1}}} - p_{L_{E_{f2_{f1}}}}L_{E_{f2_{f1}}})dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \beta_{f2}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_{f2} - p_{L_{f2}}L_{f2})dt + \phi_{f2}(p_{E_{f2_d}}E_{f2_d} - p_{I_{E_{f2_d}}}I_{E_{f2_d}} - p_{L_{E_{f2_d}}}L_{E_{f2_d}})dz_1 + (1-\beta_{f2}-\phi_{f2})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} - p_{I_{f2_{f1}}}I_{f2_{f1}} - p_{L_{f2_{f1}}}L_{f2_{f1}})dz_2 \quad \text{(Mixed II)}$$

The dynamics of profit in individual markets of the three corporations would be further figured out in details in the following text where human capital theory is employed.

### 1.3.1 When the home country is developing

The reason that we would use the theory of human capital is that we have noticed, unlike pursuing the cause of Leontief Paradox with human capital theory[10], it is surprising that there are few attempts using this argument to interpret IIT between developed countries. We would combine the theory sourced from Schultz (1961) explicitly with the model. And we will consider two situations, one is that when the home country $d$ is a developing country and when it is a developed country.

When the country $d$ is developing, its one unit of labor and capital can be viewed as a proportion of one unit of labor and capital of the developed country $f1$. That is to say, there is difference in labor capability between developing and developed countries whereas the latter is dominated by human capital. And for simplicity, we assume it is the same as that of the other developing country $f2$. The idea can be indicated as follows:

[10]The so-called Leontief Paradox (Leontief, 1953) found that the export of United States was labor intensive, while import is capital intensive, which is against the HO theory. Kenen (1965) argues if human capital is considered, export of the United States is capital intensive and Paradox disappears. That is to say, countries that are well endowed with human capital will export goods intensive in human capital.

$$L_d = L_{f2},\ I_d = I_{f2}$$
$$L_{f1} = \gamma L_d,\ I_{f1} = \eta I_d$$
$$\gamma,\ \eta \succ 1$$

Therefore, we will have the profit dynamics considering the factor of human capital of the three corporations in individual markets with the form as $d\Pi_{d_d}$, $d\Pi_{d_{f1}}$, $d\Pi_{d_{f2}}$, ..., and $d\Pi_{f2_{f2}}$ [see (22) to (30) in the Appendix A], each of which is composed of part of profit from the other two markets and has thus mimicked (at least partially) transfer of profits conducted by the corporations.

With the profit dynamics, we can now enquire into the trade pattern of the corporations. We first investigate the situations when the corporation $d$ exports to and invests in the two foreign markets.

**When the corporation $d$ chooses to export to the developing market and the developed market** Since time $t$ only enters through the discount term without appearing in the profit functions [see (1) to (18)], we study an infinite horizon autonomous problem in fact. Therefore, with applying Talor expansion series, Itô's theorem and expectation operator, a corresponding value function which is independent of time $t$ can be written down in (31), where the corporations $f1$ and $f2$ can invest in or export to each other's market and invest in or export to the third market.

$$rV_d(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) =$$
$$\begin{aligned}
&\max_{Q_{d_d}, I_{d_{f1}}, L_{d_{f2}}} [f(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) + V'_{d_d}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}})\beta_{d3}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d) + \\
&\tfrac{1}{2}\beta_{d4}^2(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d - p_{L_{E_{d_{f1}}}}L_d)^2 V''_{d_d}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) + \\
&\tfrac{1}{2}(\beta_d - \beta_{d3} - \beta_{d4})^2(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d - p_{L_{E_{d_{f2}}}}L_d)^2 V''_{d_d}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) + \\
&V'_{d_{f1}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}})\phi_{d3}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d) + \\
&\tfrac{1}{2}\phi_{d4}^2(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d - p_{L_{E_{d_{f1}}}}L_d)^2 V''_{d_{f1}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) \\
&+\tfrac{1}{2}(\phi_d - \phi_{d3} - \phi_{d4})^2(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d - p_{L_{E_{d_{f2}}}}L_d)^2 V''_{d_{f1}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) \\
&+V'_{d_{f2}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}})\ \theta_{d3}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d) + \\
&\tfrac{1}{2}\theta_{d4}^2(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d - p_{L_{E_{d_{f1}}}}L_d)^2 V''_{d_{f2}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) \\
&+\tfrac{1}{2}(1 - \beta_d - \phi_d - \theta_{d3} - \theta_{d4})^2(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d - p_{L_{E_{d_{f2}}}}L_d)^2 V''_{d_{f2}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}})
\end{aligned} \tag{31}$$

To solve the value function, assume

$$V_d(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) = A_d f(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) \tag{32}$$

Differentiate the both sides with respect to $Q_{d_d}$ (which is a control variable for the corporation $d$), and after simplification, we will have

$$0 = \beta_{d4}^2 \Pi_{d_{f1}}^2 \beta_d (1-\beta_d) + (\beta_d - \beta_{d3} - \beta_{d4})^2 \Pi_{d_{f2}}^2 \beta_d (1-\beta_d) + [\phi_d \Pi_{d_{f1}}^{-1} \phi_{d3} + (1-\beta_d-\phi_d)\Pi_{d_{f2}}^{-1} \theta_{d3}] \Pi_{d_d}^3 \quad (33)$$

Solving the equation, we can have three results for $\tilde{Q}_{d_d}$, one real and two complex, given by (34) and (35):

$$\tilde{Q}_{d_d} = \frac{\sqrt[3]{-\frac{(\beta_{d4}^2 \Pi_{d_{f1}}^2 \beta_d(1-\beta_d) + (\beta_d - \beta_{d3} - \beta_{d4})^2 \Pi_{d_{f2}}^2 \beta_d (1-\beta_d))}{\phi_d \Pi_{d_{f1}}^{-1} \phi_{d3} + (1-\beta_d-\phi_d)\Pi_{d_{f2}}^{-1}\theta_{d3}}} + p_{I_d} I_d + p_{L_d} L_d}{P_{Q_d}} \quad (34)$$

and

$$\tilde{Q}_{d_d} = -\frac{1}{2}\sqrt[3]{\frac{-a}{b}} \pm \frac{1}{2} i \frac{\sqrt{3}}{b} \sqrt[3]{(-ab^2)} \quad (35)^{11}$$

We are only interested in the real number solution. Therefore, (35) can be ignored. Similarly, we can also have the solutions for the amount of the corporation $d$'s export to the markets $f1$ and $f2$, denoted by $\tilde{E}_{d_{f1}}$ and $\tilde{E}_{d_{f2}}$.

$$\tilde{E}_{d_{f1}} = \frac{\Pi_{d_{f1}} + p_{I_{E_{d_{f1}}}} I_d + p_{L_{E_{d_{f1}}}} L_d}{p_{E_{d_{f1}}}} \quad (36)$$

In (36), we will have four solutions for $\Pi_{d_{f1}}$:

$$\Pi_{d_{f1}}^1 = \frac{1}{12}\sqrt{6}\sqrt{M_{d_{f1}}} + \frac{1}{12}\sqrt{6}\sqrt{M_{d_{f1}}} + \sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9n_{d_{f1}}^2 + \sqrt{\left(-768 v_{d_{f1}}^3 m_{d_{f1}} + 81 n_{d_{f1}}^4\right)}\right) m_{d_{f1}}\right)}}{m_{d_{f1}}} - \frac{24\left(\sqrt[3]{12}\right)^2 v_{d_{f1}}}{\sqrt[3]{\left(\left(9n_{d_{f1}}^2 + \sqrt{\left(-768 v^3 m_{d_{f1}} + 81 n_{d_{f1}}^4\right)}\right) m_{d_{f1}}\right)}} - \frac{72 n_{d_{f1}}\sqrt{6}}{\sqrt{M_{d_{f1}}} m_{d_{f1}}}} \quad (37)^{12}$$

[11] In (34) and (35), $a = \beta_{d4}^2 \Pi_{d_{f1}}^2 \beta_d(1-\beta_d) + (\beta_d - \beta_{d3} - \beta_{d4})^2 \Pi_{d_{f2}}^2 \beta_d (1-\beta_d)$ and $b = \phi_d \Pi_{d_{f1}}^{-1} \phi_{d3} + (1-\beta_d-\phi_d)\Pi_{d_{f2}}^{-1}\theta_{d3}$.

[12] In (37), $M_{d_{f1}} = \sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9n_{d_{f1}}^2 + \sqrt{\left(-768 v_{d_{f1}}^3 m + 81 n_{d_{f1}}^4\right)}\right) m_{d_{f1}}\right)}\right)^2 + 4 v_{d_{f1}} \sqrt[3]{12} m_{d_{f1}}}{m_{d_{f1}} \sqrt[3]{\left(\left(9n_{d_{f1}}^2 + \sqrt{\left(-768 v_{d_{f1}}^3 m_{d_{f1}} + 81 n_{d_{f1}}^4\right)}\right) m_{d_{f1}}\right)}}$, $m_{d_{f1}} = -\beta_{d4}^2 \beta_d (1-\beta_d)\Pi_{d_d}^{-2} - \theta_{d4}^2 (1-\beta_d-\phi_d)(\beta_d+\phi_d)\Pi_{d_{f2}}^{-2}$, $n_{d_{f1}} = -\phi_d \phi_{d3} \Pi_{d_d}$, and $v_{d_{f1}} = (\phi_d - \phi_{d3} - \phi_{d4})^2 \Pi_{d_{f2}}^2 \phi_d (1-\phi_d)$.

From the four solutions of $\Pi_{d_{f1}}$[13] (the other three, i.e., $\Pi^2_{d_{f1}}$, $\Pi^3_{d_{f1}}$ and $\Pi^4_{d_{f1}}$ are given in the Appendix A), the $\Pi^1_{d_{f1}}$ shown in (37) is the largest profit the corporation $d$ can make in the market $f1$. In the following text, we will just provide the largest solution for similar issues.

$$\tilde{E}_{d_{f2}} = \frac{\Pi_{d_{f2}} + p_{I_{E_{d_{f2}}}} I_d + p_{L_{E_{d_{f2}}}} L_d}{p_{E_{d_{f2}}}} \quad (38)$$

where

$$\Pi_{d_{f2}} = \frac{1}{12}\sqrt{6}\sqrt{M_{d_{f2}}} + \frac{1}{12}\sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n_{d_{f2}})^2+\sqrt{\left(-768(v_{d_{f2}})^3 m_{d_{f2}}+81(n_{d_{f2}})^4\right)}\right)m_{d_{f2}}\right)}}{m_{d_{f2}}} - \frac{24\left(\sqrt[3]{12}\right)^2 v_{d_{f2}}}{\sqrt[3]{\left(\left(9(n_{d_{f2}})^2+\sqrt{\left(-768(v_{d_{f2}})^3 m_{d_{f2}}+81(n_{d_{f2}})^4\right)}\right)m_{d_{f2}}\right)}} - \frac{72 n_{d_{f2}}\sqrt{6}}{\sqrt{M_{d_{f2}}}\, m_{d_{f2}}}} \quad (39)[14]$$

In the above solutions, it can be seen that $m_{d_{f1}}$, $n_{d_{f1}}$, $m_{d_{f2}}$, $n_{d_{f2}} \prec 0$ and $v_{d_{f1}}$, $v_{d_{f2}} \succ 0$. We can know from the formula of $\Pi^1_{d_{f1}}$, when $\Pi_{d_d}$ tends to be infinitely large, $\Pi_{d_{f1}}$ would tend to be infinitely large. The intuition is that the higher profit a corporation makes in its home market, the higher profit it can make in a foreign market ($f1$ in this case). Because $\Pi_{d_{f1}}$ is obtained from export of the corporation $d$ to the market $f1$, from this point, that is why a corporation would like to participate in international trade. The same conclusion and intuition can also be obtained by looking at $\tilde{E}_{d_{f2}}$. Of course, we can find out higher $\Pi_{d_{f2}}$ would also lead to higher $\Pi_{d_{f1}}$, which implies that a corporation would have stronger wish to expand the scale of its involvement in international trade if it can make higher profit in one of the foreign markets.

[13] We can note that $\Pi_{d_{f1}}$ and the following relevant functions of profit are different from (10) to (18).

[14] In (39), $M_{d_{f2}} = \frac{\sqrt[3]{12}\left(\sqrt[3]{\left(\left(9(n_{d_{f2}})^2+\sqrt{\left(-768(v_{d_{f2}})^3 m_{d_{f2}}+81(n_{d_{f2}})^4\right)}\right)m_{d_{f2}}\right)}\right)^2 + 4 v_{d_{f2}}\sqrt[3]{12} m_{d_{f2}}}{m_{d_{f2}}\sqrt[3]{\left(\left(9(n_{d_{f2}})^2+\sqrt{\left(-768(v_{d_{f2}})^3 m_{d_{f2}}+81(n_{d_{f2}})^4\right)}\right)m_{d_{f2}}\right)}}$, $m_{d_{f2}} = -(\beta_d - \beta_{d3} - \beta_{d4})^2\beta_d(1-\beta_d)\Pi_{d_d}^{-2} - (\beta_d - \beta_{d3} - \beta_{d4})^2\phi_d(1-\phi_d)\Pi_{d_{f1}}^{-2}$, $n_{d_{f2}} = -(1 - \beta_d - \phi_d)\theta_{d3}^2\Pi_{d_d}$, and $v_{d_{f2}} = \theta_{d4}^2\Pi_{d_{f1}}^2(1-\beta_d-\phi_d)(\beta_d+\phi_d)$.

**When the corporation $d$ chooses to invest in the developing market and the developed market** When the corporation $d$ chooses to invest in the other two markets, we rewrite the value function in (40), where the corporations $f1$ and $f2$ can invest in or export to each other's market and invest in or export to the third market.

$$rV_d(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) =$$

$$\begin{aligned}\max_{Q_{d_d}, I_{d_{f1}}, L_{d_{f2}}} & [f(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) + V'_{d_d}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}})\beta_{d1}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d) + \\ & \tfrac{1}{2}\beta_{d2}^2(p_{Q_{d_{f1}}}Q_{d_{f1}} - p_{I_{d_{f1}}}\eta I_d - p_{L_{d_{f1}}}\gamma L_d)^2 V''_{d_d}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) + \\ & \tfrac{1}{2}(\phi_d - \phi_{d1} - \phi_{d2})^2(p_{Q_{d_{f2}}}Q_{d_{f2}} - p_{I_{d_{f2}}}I_d - p_{L_{d_{f2}}}L_d)^2 V''_{d_d}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) + \\ & V'_{d_{f1}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}})\phi_{d1}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d) + \tfrac{1}{2}\phi_{d2}^2(p_{Q_{d_{f1}}}Q_{d_{f1}} - p_{I_{d_{f1}}}\eta I_d - p_{L_{d_{f1}}}\gamma L_d)^2 V''_{d_{f1}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) \\ & + \tfrac{1}{2}(\phi_d - \phi_{d1} - \phi_{d2})^2(p_{Q_{d_{f2}}}Q_{d_{f2}} - p_{I_{d_{f2}}}I_d - p_{L_{d_{f2}}}L_d)^2 V''_{d_{f1}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) \\ & + V'_{d_{f2}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}})\ \theta_{d1}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d) + \\ & \tfrac{1}{2}\theta_{d2}^2(p_{Q_{d_{f1}}}Q_{d_{f1}} - p_{I_{d_{f1}}}\eta I_d - p_{L_{d_{f1}}}\gamma L_d)^2 V''_{d_{f2}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) \\ & + \tfrac{1}{2}(1 - \beta_d - \phi_d - \theta_{d1} - \theta_{d2})^2(p_{Q_{d_{f2}}}Q_{d_{f2}} - p_{I_{d_{f2}}}I_d - p_{L_{d_{f2}}}L_d)^2 V''_{d_{f2}}(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}})\end{aligned} \tag{40}$$

Combining (29), and differentiate the both sides with respect to $Q_{d_d}$, $Q_{d_{f1}}$ and $Q_{d_{f2}}$, we can solve

$$\begin{aligned}0 = \beta_{d2}^2\Pi_{d_{f1}}^2\beta_d(1-\beta_d) + (\phi_d - \phi_{d1} - \phi_2)^2\Pi_{d_{f2}}^2\beta_d(1-\beta_d) + \\ [\phi_d\Pi_{d_{f1}}^{-1}\phi_{d1} + (1 - \beta_d - \phi_d)\Pi_{d_{f2}}^{-1}\theta_{d1}]\Pi_{d_d}^3\end{aligned}$$

for the production of the corporation $d$ in all the three markets denoted by (41), (42) and (43):

$$\tilde{Q}_{d_d} = \frac{\sqrt[3]{\frac{-(\beta_{d2}^2\Pi_{d_{f1}}^2\beta_d(1-\beta_d) + (\phi_d - \phi_{d1} - \phi_{d2})^2\Pi_{d_{f2}}^2\beta_d(1-\beta_d))}{\phi_d\Pi_{d_{f1}}^{-1}\phi_{d1} + (1-\beta_d-\phi_d)\Pi_{d_{f2}}^{-1}\theta_{d1}}} + p_{I_d}I_d + p_{L_d}L_d}{P_{Q_d}} \tag{41}$$

$$\tilde{Q}_{d_{f1}} = \frac{\Pi_{d_{f1}} + p_{I_{d_{f1}}}\eta I_d + p_{L_{d_{f1}}}\gamma L_d}{p_{Q_{d_{f1}}}} \tag{42}$$

where

$$\Pi_{d_{f1}} = \tfrac{1}{12}\sqrt{6}\sqrt{M_{d_{f1}}} +$$

$$\frac{1}{12}\sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9n_{d_{f1}}^2+\sqrt{\left(-768v_{d_{f1}}^3m_{d_{f1}}+81n_{d_{f1}}^4\right)}\right)m_{d_{f1}}\right)}}{m_{d_{f1}}}-\frac{24\left(\sqrt[3]{12}\right)^2v_{d_{f1}}}{\sqrt[3]{\left(\left(9n_{d_{f1}}^2+\sqrt{\left(-768v^3m_{d_{f1}}+81n_{d_{f1}}^4\right)}\right)m_{d_{f1}}\right)}}-\frac{72n_{d_{f1}}\sqrt{6}}{\sqrt{M_{d_{f1}}}m_{d_{f1}}}} \quad (42')^{15}$$

$$\tilde{Q}_{d_{f2}}=\frac{\Pi_{d_{f2}}+p_{I_{d_{f2}}}I_d+p_{L_{d_{f2}}}L_d}{p_{Q_{d_{f2}}}} \quad (43)$$

where

$$\Pi_{d_{f2}}=\frac{1}{12}\sqrt{6}\sqrt{M_{d_{f2}}}+$$
$$\frac{1}{12}\sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n_{d_{f2}})^2+\sqrt{\left(-768(v_{d_{f2}})^3m_{d_{f2}}+81(n_{d_{f2}})^4\right)}\right)m_{d_{f2}}\right)}}{m_{d_{f2}}}-\frac{24\left(\sqrt[3]{12}\right)^2v_{d_{f2}}}{\sqrt[3]{\left(\left(9(n_{d_{f2}})^2+\sqrt{\left(-768(v_{d_{f2}})^3m_{d_{f2}}+81(n_{d_{f2}})^4\right)}\right)m_{d_{f2}}\right)}}-\frac{72n_{d_{f2}}\sqrt{6}}{\sqrt{M_{d_{f2}}}m_{d_{f2}}}} \quad (43')^{16}$$

It is significant to notice that $\Pi_{d_{f1}}$ in (42) is not necessarily the same as that of $\Pi_{d_{f1}}$ in (36). Direct investment in the $f1$ market makes the corporation $d$ employ local labor and capital which has higher skill than that in the $d$ market. Even though TFP of the corporation $d$ remains the same in the market $f1$, its production in that market still can increase. The corporation $d$ can pay higher or equally for the service of (the same amount of) local labor and investment in the market $f1$ as it does in its home market, i.e.,

$$p_{I_{d_{f1}}}I_{f1}+p_{L_{d_{f1}}}L_{f1}=\eta(p_{I_{d_{f1}}}I_d)+\gamma(p_{L_{d_{f1}}}L_d)\succeq p_{I_{E_{d_{f1}}}}I_d+p_{L_{E_{d_{f1}}}}L_d.$$

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[15] In (42'), $M_{d_{f1}}=\sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9n_{d_{f1}}^2+\sqrt{\left(-768v_{d_{f1}}^3m+81n_{d_{f1}}^4\right)}\right)m_{d_{f1}}\right)}\right)^2+4v_{d_{f1}}\sqrt[3]{12}m_{d_{f1}}}{m_{d_{f1}}\sqrt[3]{\left(\left(9n_{d_{f1}}^2+\sqrt{\left(-768v_{d_{f1}}^3m_{d_{f1}}+81n_{d_{f1}}^4\right)}\right)m_{d_{f1}}\right)}}$, $m_{d_{f1}}=-\beta_{d2}^2\beta_d(1-\beta_d)\Pi_{d_d}^{-2}-\theta_{d2}^2(1-\beta_d-\phi_d)(\beta_d+\phi_d)\Pi_{d_{f2}}^{-2}$, $n_{d_{f1}}=-\phi_d\phi_{d1}\Pi_{d_d}$, and $v_{d_{f1}}=(\phi_d-\phi_{d1}-\phi_{d2})^2\Pi_{d_{f2}}^2\phi_d(1-\phi_d)$.

[16] In (43'), $M_{d_{f2}}=\sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9(n_{d_{f2}})^2+\sqrt{\left(-768(v_{d_{f2}})^3m_{d_{f2}}+81(n_{d_{f2}})^4\right)}\right)m_{d_{f2}}\right)}\right)^2+4v_{d_{f2}}\sqrt[3]{12}m_{d_{f2}}}{m_{d_{f2}}\sqrt[3]{\left(\left(9(n_{d_{f2}})^2+\sqrt{\left(-768(v_{d_{f2}})^3m_{d_{f2}}+81(n_{d_{f2}})^4\right)}\right)m_{d_{f2}}\right)}}$, $m_{d_{f2}}=-(\beta_d-\beta_{d1}-\beta_{d2})^2\beta_d(1-\beta_d)\Pi_{d_d}^{-2}-(\beta_d-\beta_{d1}-\beta_{d2})^2\phi_d(1-\phi_d)\Pi_{d_{f1}}^{-2}$, $n_{d_{f2}}=-(1-\beta_d-\phi_d)\theta_{d1}^2\Pi_{d_d}$, and $v_{d_{f2}}=\theta_{d2}^2\Pi_{d_{f1}}^2(1-\beta_d-\phi_d)(\beta_d+\phi_d)$.

The ratiocination is that market prices for productive factors (including higher-skilled and lower-skilled ones) employed by different industries are exogenously setting, and working in a lower technology industry would get lower remuneration (see Mehta, 1998) [$\eta(p_{I_{d_{f1}}} I_d) + \gamma(p_{L_{d_{f1}}} L_d)$ is less than $\eta(p_{I_{f1_{f1}}} I_d) + \gamma(p_{L_{f1_{f1}}} L_d)$ owing to the fact]. Of course, employers can pay productive factors more according to their production performance than the market level in this perfect competition market system, but they will never automatically pay in totality the excess profit back to the employed factors.

So, when $\tilde{Q}_{d_{f1}}$ [equal to $M_{d_{f1}}(\eta I_d)^{\chi_{d_{f1}}}(\gamma L_d)^{1-\chi_{d_{f1}}}$] is larger than $\tilde{E}_{d_{f1}}$ (equal to $M_{d_{f1}} {I_{d1}}^{\chi_{d_{f1}}} {L_d}^{1-\chi_{d_{f1}}}$), $p_{Q_{d_{f1}}} = p_{E_{d_{f1}}}$, and $\eta(p_{I_{d_{f1}}} I_d) + \gamma(p_{L_{d_{f1}}} L_d)$ is equal to $p_{I_{E_{d_{f1}}}} I_d + p_{L_{E_{d_{f1}}}} L_d$, $\Pi_{d_{f1}}$ in (42) would be larger than $\Pi_{d_{f1}}$ in (36).

Besides the reason mentioned above, the institutional guarantee is, before international economic exchange reaching a steady state, the prevalent rate of increase of cost[17] of employing labor and conducting investment in the market is less than that of production in the framework of constant return to scale. To a corporation, more output with identical or less production cost means that it can make higher profit. Therefore, before reaching that steady state, FDI instead of export would be a more favorable choice to the corporation $d$ [18].

The fact illustrates that direct investment of developing corporations in developed markets would have more production than pure export from the former ones due to higher profitability of the former. Along with the above logic, it can be inferred that trade with or direct investment in the developing country $f2$ makes no difference regarding to its net income.

Because direct investment in the country $f1$ can make more profit, the corporation $d$ would less likely export to $f1$ ceteris paribus. The conclusion is also applied to the corporation $f2$. That is the reason why it is more likely that the corporations $d$ and $f2$ would be more possible to invest in the country $f1$ and do not produce at

[17]The production cost in the chapter obviously refers to wages for employing labour and cost of conducting investment.

[18]From $\eta(p_{I_{d_{f1}}} I_d) + \gamma(p_{L_{d_{f1}}} L_d) \succ p_{I_{E_{d_{f1}}}} I_d + p_{L_{E_{d_{f1}}}} L_d$, though the nominal wage to the physical capital and labor is higher when the corporation $d$ produces in the $f1$ market, the payment to the abstract value in terms of content of $I_d$ and $L_d$ per unit of physical capital and labor factually can be equal to or less than that paid in its home marekt.

their home markets. It is also easy to know that the corporation $f1$ would be more likely to choose to export to both the countries $d$ and $f2$ rather than directly invest in their markets, which would be confirmed by the subsequent text.

### 1.3.2 When the home country is developed

We have studied the case when the home country is a developing state. Following the reasoning given above, now we would look at the case when it is a developed one. The relationships of productive factors of the three countries are redefined as follows:

$$L_d = L_{f1} = \gamma' L_{f2}$$
$$I_d = I_{f1} = \eta' I_{f2}$$
$$\gamma' > 1, \eta' > 1$$

(22)-(30) are correspondingly rewritten in (44) to (52) which are also given in the Appendix A. We study the pattern of FDI and trade, i.e., the corporation $d$ invests in the country $f1$ and exports to the country $f2$ first. The value function for this situation is therefore:

$$rV_d(\Pi_{d_d}, \Pi_{d_{f1}}, \Pi_{d_{f2}}) =$$
$$\begin{array}{c}\max_{Q_{d_d}, I_{d_{f1}}, L_{d_{f2}}}[f(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}})+V'_{d_d}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}})\ \beta'_{d5}(p_{Q_d}Q_d-p_{I_d}I_d-p_{L_d}L_d)+ \\ \frac{1}{2}\beta'^2_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}}-p_{I_{d_{f1}}}I_d-p_{L_{d_{f1}}}L_d)^2V''_{d_d}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}})+ \\ \frac{1}{2}(\beta_d-\beta'_{d5}-\beta'_{d6})^2(p_{E_{d_{f2}}}E_{d_{f2}}-p_{I_{E_{d_{f2}}}}I_d-p_{L_{E_{d_{f2}}}}L_d)^2V''_{d_d}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}})+ \\ V'_{d_{f1}}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}})\ \phi'_{d5}(p_{Q_d}Q_d-p_{I_d}I_d-p_{L_d}L_d)+ \\ \frac{1}{2}\phi'^2_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}}-p_{I_{d_{f1}}}I_d-p_{L_{d_{f1}}}L_d)^2V''_{d_{f1}}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}}) \\ +\frac{1}{2}(\phi_d-\phi'_{d5}-\phi'_{d6})^2(p_{E_{d_{f2}}}E_{d_{f2}}-p_{I_{E_{d_{f2}}}}I_d-p_{L_{E_{d_{f2}}}}L_d)^2V''_{d_{f1}}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}}) \\ +V'_{d_{f2}}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}})\ \theta'_{d5}(p_{Q_d}Q_d-p_{I_d}I_d-p_{L_d}L_d)+ \\ \frac{1}{2}\theta'^2_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}}-p_{I_{d_{f1}}}I_d-p_{L_{d_{f1}}}L_d)^2V''_{d_{f2}}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}}) \\ +\frac{1}{2}(1-\beta_d-\phi_d-\phi'_{d5}-\phi'_{d6})^2(p_{E_{d_{f2}}}E_{d_{f2}}-p_{I_{E_{d_{f2}}}}I_d-p_{L_{E_{d_{f2}}}}L_d)^2V''_{d_{f2}}(\Pi_{d_d},\Pi_{d_{f1}},\Pi_{d_{f2}})\end{array} \quad (53)$$

Applying the same procedure, we would have $\tilde{Q}_{d_d}$, $\tilde{Q}_{d_{f1}}$, and $\tilde{E}_{d_{f2}}$ given by (54), (55) and (56):

$$\tilde{Q}_{d_d} = \frac{\sqrt[3]{\frac{-(\beta'^2_{d6}\Pi^2_{d_{f1}}\beta_d(1-\beta_d)+(\beta_d-\beta'_{d5}-\beta'_{d6})^2\Pi^2_{d_{f2}}\beta_d(1-\beta_d))}{\phi_d\Pi^{-1}_{d_{f1}}\phi'_{d5}+(1-\beta_d-\phi_d)\Pi^{-1}_{d_{f2}}\phi'_{d5}}}+p_{I_d}I_d+p_{L_d}L_d}{P_{Q_d}} \quad (54)$$

$$\tilde{Q}_{d_{f1}} = \frac{\Pi_{d_{f1}}+p_{I_{d_{f1}}}\eta I_d+p_{L_{d_{f1}}}\gamma L_d}{p_{Q_{d_{f1}}}} \quad (55)$$

where

$$\Pi_{d_{f1}} = \tfrac{1}{12}\sqrt{6}\sqrt{M'_{d_{f1}}} + \sqrt{\frac{1}{12}\sqrt{\frac{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{d_{f1}})^2+\sqrt{\left(-768(v'_{d_{f1}})^3m'_{d_{f1}}+81(n'_{d_{f1}})^4\right)}\right)m'_{d_{f1}}\right)}}{m'_{d_{f1}}} - \frac{24\left(\sqrt[3]{12}\right)^2 v'_{d_{f1}}}{\sqrt[3]{\left(\left(9(n'_{d_{f1}})^2+\sqrt{\left(-768(v'_{d_{f1}})^3m'_{d_{f1}}+81(n'_{d_{f1}})^4\right)}\right)m'_{d_{f1}}\right)}} - \frac{72n'_{d_{f1}}\sqrt{6}}{\sqrt{M'_{d_{f1}}}m'_{d_{f1}}}}} \quad (55')[19]$$

$$\tilde{E}_{d_{f2}} = \frac{\Pi_{d_{f2}} + p_{I_{E_{d_{f2}}}} I_d + p_{L_{E_{d_{f2}}}} L_d}{p_{E_{d_{f2}}}} \quad (56)$$

where

$$\Pi_{d_{f2}} = \tfrac{1}{12}\sqrt{6}\sqrt{M'_{d_{f2}}} + \sqrt{\frac{1}{12}\sqrt{\frac{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}}{m'_{d_{f2}}} - \frac{24\left(\sqrt[3]{12}\right)^2 v'_{d_{f2}}}{\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}} - \frac{72n'_{d_{f2}}\sqrt{6}}{\sqrt{M'_{d_{f2}}}m'_{d_{f2}}}}} \quad (56')[20]$$

If the corporation $d$ invests in the country $f2$ rather than exporting to it, (56) will become

$$\tilde{E}_{d_{f2}} = \frac{\Pi_{d_{f2}} + p_{I_{d_{f2}}} I_d \frac{1}{\eta'} + p_{L_{d_{f2}}} L_d \frac{1}{\gamma'}}{p_{d_{f2}}} \quad (57)$$

where

[19] In (55'), $M'_{d_{f1}} = \sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9(n'_{d_{f1}})^2+\sqrt{\left(-768(v'_{d_{f1}})^3m'_{d_{f1}}+81(n'_{d_{f1}})^4\right)}\right)m'_{d_{f1}}\right)}\right)^2 + 4v'_{d_{f1}}\sqrt[3]{12}m'_{d_{f1}}}{m'_{d_{f1}}\sqrt[3]{\left(\left(9(n'_{d_{f1}})^2+\sqrt{\left(-768(v'_{d_{f1}})^3m'_{d_{f1}}+81(n'_{d_{f1}})^4\right)}\right)m'_{d_{f1}}\right)}}$, $m'_{d_{f1}} = -\beta'^2_{d6}\beta_d(1-\beta_d)\Pi_{d_d}^{-2} - \theta'^2_{d6}(1-\beta_d-\phi_d)(\beta_d+\phi_d)\Pi_{d_{f2}}^{-2}$, $n'_{d_{f1}} = -\phi_d\phi'_{d5}\Pi_{d_d}$, and $v'_{d_{f1}} = (\phi_d-\phi'_{d5}-\phi'_{d6})^2\Pi^2_{d_{f2}}\phi_d(1-\phi_d)$.

[20] In (56'), $M'_{d_{f2}} = \sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}\right)^2 + 4v'_{d_{f2}}\sqrt[3]{12}m'_{d_{f2}}}{m'_{d_{f2}}\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}}$, $m'_{d_{f2}} = -(\beta_d-\beta'_{d5}-\beta'_{d6})^2\beta_d(1-\beta_d)\Pi_{d_d}^{-2} - (\beta_d-\beta'_{d5}-\beta'_{d6})^2\phi_d(1-\phi_d)\Pi_{d_{f1}}^{-2}$, $n'_{d_{f2}} = -(1-\beta_d-\phi_d)\theta'^2_{d5}\Pi_d$, and $v'_{d_{f2}} = \theta'^2_{d6}\Pi^2_{d_{f1}}(1-\beta_d-\phi_d)(\beta_d+\phi_d)$.

$$\Pi_{d_{f2}} = \frac{1}{12}\sqrt{6}\sqrt{M'_{d_{f2}}} + \frac{1}{12}\sqrt{6}\sqrt{M'_{d_{f2}}} + \sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3 m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}}{m'_{d_{f2}}} - \frac{24\left(\sqrt[3]{12}\right)^2 v'_{d_{f2}}}{\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3 m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}} - \frac{72 n'_{d_{f2}}\sqrt{6}}{\sqrt{M'_{d_{f2}}}m'_{d_{f2}}}} \quad (57')^{21}$$

With the similar induction, $\Pi_{d_{f2}}$ in (57) tends to be smaller than that in (56) where

$$p_{I_{d_d}} I_d + p_{L_{d_d}} L_d \succ p_{I_{E_{d_{f2}}}} I_d + p_{L_{E_{d_{f2}}}} L_d \succeq p_{I_{d_{f2}}} I_d \tfrac{1}{\eta'} + p_{L_{d_{f2}}} L_d \tfrac{1}{\gamma'},$$

since the corporation $d$ would choose to export to rather than invest in the country $f2$ in order for maximizing its profit. Similarly, $m'_{d_{f1}}$, $n'_{d_{f1}}$, $m'_{d_{f2}}$, $n'_{d_{f2}} \prec 0$ and $v'_{d_{f1}}$, $v'_{d_{f2}} \succ 0$. Judged from $\Pi_{d_{f1}}$ in (55), when $\Pi_{d_d}$ tends to be infinitely large, $\Pi_{d_{f1}}$ would also tend to be infinitely large. Because $\Pi_{d_{f1}}$ is obtained from FDI of the corporation $d$ in the $f1$ market, from this point, it can be understood why a corporation would like to become a multinational. That is, higher profit in its home market may trigger the corporation to invest in another country. When there is higher profit in the market $f2$, the corporation $d$ would much more likely strengthen its FDI in the market $f1$.

The analysis in both sections 1.3.1 and 1.3.2 has shown that corporations from developed countries would be more likely to conduct trade or direct investment between each other, but biased to export to developing countries, while corporations from developing countries would be more likely to invest directly in developed ones. It makes no difference that a corporation from a developing country trades with or invests directly in the other.

[21] In (57'), $M'_{d_{f2}} = \sqrt[3]{12}\dfrac{\left(\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3 m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}\right)^2 + 4v'_{d_{f2}}\sqrt[3]{12}m'_{d_{f2}}}{m'_{d_{f2}}\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3 m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}}$,

$m'_{d_{f2}} = -(\beta_d - \beta'_{d7} - \beta'_{d8})^2\beta_d(1-\beta_d)\Pi_{d_d}^{-2} - (\beta_d - \beta'_{d7} - \beta'_{d8})^2\phi_d(1-\phi_d)\Pi_{d_{f1}}^{-2}$, $n'_{d_{f2}} = -(1-\beta_d-\phi_d)\theta'^2_{d7}\Pi_d$, and $v'_{d_{f2}} = \theta'^2_{d8}\Pi^2_{d_{f1}}(1-\beta_d-\phi_d)(\beta_d+\phi_d)$.

## 1.4 Further discussion

The above text only considers individual behavior of a corporation without taking into account the other two corporations' reaction. It can be more interesting to look into the case where the three representative firms interact with one another. For more direct insight, we study the situation where the home country is developed.

To the two corporations $d$ and $f1$, since there is no clear-cut quantitative difference with regard to their profit from trade or FDI, we simply assume they trade with each other and export to the country $f2$. And the corporation $f2$ invests in the two developed countries as predicted from above. The interaction obeys the procedure once and for ever: the two developed corporations choose their own optimal quantity of export simultaneously after their observing the action of the corporation $f2$.

We complement another three assumptions in order to find out the relationships among the relevant quantity of export and FDI:

$q_d$ is assumed to be the aggregate demand for products of the corporations $d$, $f1$ and $f2$ of the home market of the corporation $d$, which is the addition of $Q_d$, $E_{f1_d}$ and $Q_{f2_d}$.

$$E_{d_{f1}} = q_{f1} - Q_{f2_{f1}} - Q_{f1_{f1}};\ E_{d_{f2}} = q_{f2} - E_{f1_{f2}} - Q_{f2_{f2}}$$

$q_{f1}$ is assumed to be aggregate demand for the products of the corporations $d$, $f1$ and $f2$ of the home market of $f1$, which is the addition of $E_{d_{f1}}$, $Q_{f1_{f1}}$ and $Q_{f2_{f1}}$.

$$E_{f1_d} = q_d - Q_{f2_d} - Q_{d_d};\ E_{f1_{f2}} = q_{f2} - E_{d_{f2}} - Q_{f2_{f2}}$$

$q_{f2}$ is assumed to be aggregate demand for the products of the corporations $d$, $f1$ and $f2$ of the home market of $f2$, which is the addition of $E_{d_{f2}}$, $E_{f1_{f2}}$ and $Q_{f2_{f2}}$.

$$Q_{f2_d} = q_d - Q_{d_d} - E_{f1_d};\ Q_{f2_{f1}} = q_{f1} - E_{d_{f1}} - Q_{f1_{f1}}$$

$q_d$, $q_{f1}$, and $q_{f2}$ are three constants. Making use of the same algebra, we have (58) to (66) immediately as follows:

$$\tilde{Q}_{d_d} = \frac{\sqrt[3]{\begin{array}{c} -(\beta'^2_{d4}(p_{E_{d_{f1}}}(q_{f1} - Q_{f2_{f1}} - Q_{f1_{f1}}) - p_{I_{E_{d_{f1}}}} I_d - \\ p_{L_{E_{d_{f1}}}} L_d)^2 \beta_d (1-\beta_d) + \\ (\beta_d - \beta'_{d3} - \beta'_{d4})^2 (p_{E_{d_{f2}}}(q_{f2} - E_{f1_{f2}} - Q_{f2_{f2}}) \\ -p_{I_{E_{d_{f2}}}} I_d - p_{L_{E_{d_{f2}}}} L_d)^2 \beta_d (1-\beta_d)) \end{array}}}{\begin{array}{c} \phi_d (p_{E_{d_{f1}}}(q_{f1} - Q_{f2_{f1}} - Q_{f1_{f1}}) - p_{I_{E_{d_{f1}}}} I_d - p_{L_{E_{d_{f1}}}} L_d)^{-1} \phi'_{d3} + \\ (1 - \beta_d - \phi_d)(p_{E_{d_{f2}}}(q_{f2} - E_{f1_{f2}} - Q_{f2_{f2}}) \\ -p_{I_{E_{d_{f2}}}} I_d - p_{L_{E_{d_{f2}}}} L_d)^{-1} \phi'_{d3} \\ +p_{I_d} I_d + p_{L_d} L_d \end{array}}{P_{Q_d}} \quad (58)$$

$$\tilde{E}_{d_{f1}} = \frac{\Pi_{d_{f1}} + p_{I_{E_{d_{f1}}}} I_d + p_{L_{E_{d_{f1}}}} L_d}{p_{E_{d_{f1}}}} \quad (59)$$

where

$$\Pi_{d_{f1}} = \tfrac{1}{12}\sqrt{6}\sqrt{M'_{d_{f1}}} + \sqrt{\frac{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{d_{f1}})^2 + \sqrt{\left(-768(v'_{d_{f1}})^3 m'_{d_{f1}} + 81(n'_{d_{f1}})^4\right)}\right) m'_{d_{f1}}\right)}}{m'_{d_{f1}}} - \frac{24\left(\sqrt[3]{12}\right)^2 v'_{d_{f1}}}{\sqrt[3]{\left(\left(9(n'_{d_{f1}})^2 + \sqrt{\left(-768(v'_{d_{f1}})^3 m'_{d_{f1}} + 81(n'_{d_{f1}})^4\right)}\right) m'_{d_{f1}}\right)}} - \frac{72 n'_{d_{f1}}\sqrt{6}}{\sqrt{M'_{d_{f1}}} m'_{d_{f1}}}}{12}} \quad (59')^{22}$$

$$\tilde{E}_{d_{f2}} = \frac{\Pi_{d_{f2}} + p_{I_{E_{d_{f2}}}} I_d + p_{L_{E_{d_{f2}}}} L_d}{p_{E_{d_{f2}}}} \quad (60)$$

where

$$\Pi_{d_{f2}} = \tfrac{1}{12}\sqrt{6}\sqrt{M'_{d_{f2}}} +$$

[22] In (59'), $M'_{d_{f1}} = \frac{\sqrt[3]{12}\left(\sqrt[3]{\left(\left(9(n'_{d_{f1}})^2 + \sqrt{\left(-768(v'_{d_{f1}})^3 m'_{d_{f1}} + 81(n'_{d_{f1}})^4\right)}\right) m'_{d_{f1}}\right)}\right)^2 + 4 v'_{d_{f1}} \sqrt[3]{12} m'_{d_{f1}}}{m'_{d_{f1}} \sqrt[3]{\left(\left(9(n'_{d_{f1}})^2 + \sqrt{\left(-768(v'_{d_{f1}})^3 m'_{d_{f1}} + 81(n'_{d_{f1}})^4\right)}\right) m'_{d_{f1}}\right)}}$, $m'_{d_{f1}} = -\beta'^2_{d4}\beta_d(1-\beta_d)(p_{Q_d}(q_d - E_{f1_d} - Q_{f2_d}) - p_{I_d} I_d - p_{L_d} L_d)^{-2} - \theta'^2_{d4}(1-\beta_d-\phi_d)(\beta_d + \phi_d)(p_{E_{d_{f2}}}(q_{f2} - E_{f1_{f2}} - Q_{f2_{f2}}) - p_{I_{E_{d_{f2}}}} I_d - p_{L_{E_{d_{f2}}}} L_d)^{-2}$, $n'_{d_{f1}} = -\phi_d \phi'_{d3}(p_{Q_d}(q_d - E_{f1_d} - Q_{f2_d}) - p_{I_d} I_d - p_{L_d} L_d)$, and $v'_{d_{f1}} = (\phi_d - \phi'_{d3} - \phi'_{d4})^2 (p_{E_{d_{f2}}}(q_{f2} - E_{f1_{f2}} - Q_{f2_{f2}}) - p_{I_{E_{d_{f2}}}} I_d - p_{L_{E_{d_{f2}}}} L_d)^2 \phi_d (1 - \phi_d)$.

$$\frac{1}{12}\sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}}{m'_{d_{f2}}}-\frac{24\left(\sqrt[3]{12}\right)^2v'_{d_{f2}}}{\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}}-\frac{72n'_{d_{f2}}\sqrt{6}}{\sqrt{M'_{d_{f2}}}m'_{d_{f2}}}} \quad (60')^{23}$$

$$\tilde{E}_{f1_d}=\frac{\Pi_{f1_d}+p_{I_{E_{f1_d}}}I_d+p_{L_{E_{f1_d}}}L_d}{p_{E_{f1_d}}} \quad (61)$$

where

$$\Pi_{f1_d}=\tfrac{1}{12}\sqrt{6}\sqrt{M'_{f1_d}}+$$

$$\frac{1}{12}\sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{f1_d})^2+\sqrt{\left(-768(v'_{f1_d})^3m'_{f1_d}+81(n'_{f1_d})^4\right)}\right)m'_{f1_d}\right)}}{m'_{f1_d}}-\frac{24\left(\sqrt[3]{12}\right)^2v'_{f1_d}}{\sqrt[3]{\left(\left(9(n'_{f1_d})^2+\sqrt{\left(-768(v'_{f1_d})^3m'_{f1_d}+81(n'_{f1_d})^4\right)}\right)m'_{f1_d}\right)}}-\frac{72n'_{f1_d}\sqrt{6}}{\sqrt{M'_{f1_d}}m'_{f1_d}}} \quad (61')^{24}$$

$$\tilde{Q}_{f1_{f1}}=$$

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[23] In (60'), $M'_{d_{f2}}=\sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}\right)^2+4v'_{d_{f2}}\sqrt[3]{12}m'_{d_{f2}}}{m'_{d_{f2}}\sqrt[3]{\left(\left(9(n'_{d_{f2}})^2+\sqrt{\left(-768(v'_{d_{f2}})^3m'_{d_{f2}}+81(n'_{d_{f2}})^4\right)}\right)m'_{d_{f2}}\right)}}$, $m'_{d_{f2}}=-(\beta_d-\beta'_{d3}-\beta'_{d4})^2\beta_d(1-\beta_d)(p_{Q_d}(q_d-E_{f1_d}-Q_{f2_d})-p_{I_d}I_d-p_{L_d}L_d)^2-(\beta_d-\beta'_{d3}-\beta'_{d4})^2\phi_d(1-\phi_d)(p_{E_{d_{f1}}}(q_{f1}-Q_{f2_{f1}}-Q_{f1_{f1}})-p_{I_{E_{d_{f1}}}}I_d-p_{L_{E_{d_{f1}}}}L_d)^{-2}$, $n'_{d_{f2}}=-(1-\beta_d-\phi_d)\theta'^2_{d3}(p_{Q_d}(q_d-E_{f1_d}-Q_{f2_d})-p_{I_d}I_d-p_{L_d}L_d)$, and $v'_{d_{f2}}=\theta'^2_{d4}(p_{E_{d_{f1}}}(q_{f1}-Q_{f2_{f1}}-Q_{f1_{f1}})-p_{I_{E_{d_{f1}}}}I_d-p_{L_{E_{d_{f1}}}}L_d)^2(1-\beta_d-\phi_d)(\beta_d+\phi_d)$.

[24] In (61'), $M'_{f1_d}=\sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9(n'_{f1_d})^2+\sqrt{\left(-768(v'_{f1_d})^3m'_{f1_d}+81(n'_{f1_d})^4\right)}\right)m'_{f1_d}\right)}\right)^2+4v'_{f1_d}\sqrt[3]{12}m'_{f1_d}}{m'_{f1_d}\sqrt[3]{\left(\left(9(n'_{f1_d})^2+\sqrt{\left(-768(v'_{f1_d})^3m'_{f1_d}+81(n'_{f1_d})^4\right)}\right)m'_{f1_d}\right)}}$, $m'_{f1_d}=-\theta'^2_{f14}(1-\beta_{f1}-\phi_{f1})(\beta_{f1}+\phi_{f1})(p_{E_{f1_{f2}}}(q_{f2}-E_{d_{f2}}-Q_{f2_{f2}})-p_{I_{E_{f1_{f2}}}}I_d-p_{L_{E_{f1_{f2}}}}L_d)^{-2}-\phi'^2_{f14}\phi_{f1}(1-\phi_{f1})(p_{Q_{f1}}(q_{f1}-E_{d_{f1}}-Q_{f2_{f1}})-p_{I_{f1}}I_d-p_{L_{f1}}L_d)^{-2}$, $n'_{f1_d}=-\beta_{f1}\beta'_{f13}(p_{Q_{f1}}(q_{f1}-E_{d_{f1}}-Q_{f2_{f1}})-p_{I_{f1}}I_d-p_{L_{f1}}L_d)$, and $v'_{f1_d}=(\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2(p_{E_{f1_{f2}}}(q_{f2}-E_{d_{f2}}-Q_{f2_{f2}})-p_{I_{E_{f1_{f2}}}}I_d-p_{L_{E_{f1_{f2}}}}L_d)^2\beta_{f1}(1-\beta_{f1})$.

$$\frac{\sqrt[3]{\begin{array}{c}-(\phi'^2_{f14}(p_{E_{f1_d}}(q_d-Q_{f2_d}-Q_{d_d})-p_{I_{E_{f1_d}}}I_d-p_{L_{E_{f1_d}}}L_d)^2\phi_{f1}(1-\phi_{f1})+\\(\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2(p_{E_{f1_{f2}}}(q_{f2}-E_{d_{f2}}-Q_{f2_{f2}})\\-p_{I_{E_{f1_{f2}}}}I_d-p_{L_{E_{f1_{f2}}}}L_d)^2\phi_{f1}(1-\phi_{f1}))\end{array}}}{\sqrt{\begin{array}{c}\beta_{f1}(q_d-Q_{f2_d}-Q_{d_d})-p_{I_{E_{f1_d}}}I_d-p_{L_{E_{f1_d}}}L_d)^{-1}\beta'_{f13}+\\(1-\beta_{f1}-\phi_{f1})(p_{E_{f1_{f2}}}(q_{f2}-E_{d_{f2}}-Q_{f2_{f2}})-p_{I_{E_{f1_{f2}}}}I_d-p_{L_{E_{f1_{f2}}}}L_d)^{-1}\theta'_{f13}\\+p_{I_{f1}}I_d+p_{L_{f1}}L_d\end{array}}}}{P_{Q_{f1}}} \quad (62)$$

$$\tilde{E}_{f1_{f2}}=\frac{\Pi_{f1_{f2}}+p_{I_{E_{f1_{f2}}}}I_d+p_{L_{E_{f1_{f2}}}}L_d}{p_{E_{f1_{f2}}}} \quad (63)$$

where

$$\Pi_{f1_{f2}}=\tfrac{1}{12}\sqrt{6}\sqrt{M'_{f1_{f2}}}+$$

$$\frac{1}{12}\sqrt{\begin{array}{c}-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{f1_{f2}})^2+\sqrt{\left(-768(v'_{f1_{f2}})^3m'_{f1_{f2}}+81(n'_{f1_{f2}})^4\right)}\right)m'_{f1_{f2}}\right)}}{m'_{f1_{f2}}}-\\\frac{24\left(\sqrt[3]{12}\right)^2v'_{f1_{f2}}}{\sqrt[3]{\left(\left(9(n'_{f1_{f2}})^2+\sqrt{\left(-768(v'_{f1_{f2}})^3m'_{f1_{f2}}+81(n'_{f1_{f2}})^4\right)}\right)m'_{f1_{f2}}\right)}}-\frac{72n'_{f1_{f2}}\sqrt{6}}{\sqrt{M'_{f1_{f2}}}m'_{f1_{f2}}}\end{array}} \quad (63')^{25}$$

$$\tilde{Q}_{f2_d}=\frac{\Pi_{f2_d}+p_{I_{f2_d}}I_d+p_{L_{f2_d}}L_d}{p_{Q_{f2_d}}} \quad (64)$$

where

$$\Pi_{f2_d}=\tfrac{1}{12}\sqrt{6}\sqrt{M'_{f2_d}}+$$

[25] In (63'), $M'_{f1_{f2}}=\sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9(n'_{f1_{f2}})^2+\sqrt{\left(-768(v'_{f1_{f2}})^3m'_{f1_{f2}}+81(n'_{f1_{f2}})^4\right)}\right)m'_{f1_{f2}}\right)}\right)^2+4v'_{f1_{f2}}\sqrt[3]{12}m'_{f1_{f2}}}{m'_{f1_{f2}}\sqrt[3]{\left(\left(9(n'_{f1_{f2}})^2+\sqrt{\left(-768(v'_{f1_{f2}})^3m'_{f1_{f2}}+81(n'_{f1_{f2}})^4\right)}\right)m'_{f1_{f2}}\right)}}$, $m'_{f1_{f2}}=-(\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2\beta_{f1}(1-\beta_{f1})(p_{E_{f1_d}}(q_d-Q_{f2_d}-Q_{d_d})-p_{I_{E_{f1_d}}}I_d-p_{L_{E_{f1_d}}}L_d)^{-2}-(\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2\phi_{f1}(1-\phi_{f1})(q_{f1}-E_{d_{f1}}-Q_{f2_{f1}})-p_{I_{f1}}I_d-p_{L_{f1}}L_d)^{-2}$, $n'_{f1_{f2}}=-(1-\beta_{f1}-\phi_{f1})\theta'^2_{f13}(q_{f1}-E_{d_{f1}}-Q_{f2_{f1}})-p_{I_{f1}}I_d-p_{L_{f1}}L_d)$, and $v'_{f1_{f2}}=\theta'^2_{f14}(p_{E_{f1_d}}(q_d-Q_{f2_d}-Q_{d_d})-p_{I_{E_{f1_d}}}I_d-p_{L_{E_{f1_d}}}L_d)^2(1-\beta_{f1}-\phi_{f1})(\beta_{f1}+\phi_{f1})$.

$$\frac{1}{12}\sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{f2_d})^2+\sqrt{\left(-768(v'_{f2_d})^3m'_{f2_d}+81(n'_{f2_d})^4\right)}\right)m'_{f2_d}\right)}}{m'_{f2_d}}-\frac{24\left(\sqrt[3]{12}\right)^2v'_{f2_d}}{\sqrt[3]{\left(\left(9(n'_{f2_d})^2+\sqrt{\left(-768(v'_{f2_d})^3m'_{f2_d}+81(n'_{f2_d})^4\right)}\right)m'_{f2_d}\right)}}-\frac{72n'_{f2_d}\sqrt{6}}{\sqrt{M'_{f2_d}}m'_{f2_d}}} \quad (64')^{26}$$

$$\tilde{Q}_{f2_{f1}}=\frac{\Pi_{f2_{f1}}+p_{I_{f2_d}}I_d+p_{L_{f2_d}}L_d}{p_{Q_{f2_{f1}}}} \quad (65)$$

where

$$\Pi_{f2_{f1}}=\frac{1}{12}\sqrt{6}\sqrt{M'_{f2_{f1}}}+\sqrt{-\frac{6\sqrt[3]{12}\sqrt[3]{\left(\left(9(n'_{f2_{f1}})^2+\sqrt{\left(-768(v'_{f2_{f1}})^3m'_{f2_{f1}}+81(n'_{f2_{f1}})^4\right)}\right)m'_{f2_{f1}}\right)}}{m'_{f2_d}}-\frac{24\left(\sqrt[3]{12}\right)^2v'_{f2_{f1}}}{\sqrt[3]{\left(\left(9(n'_{f2_{f1}})^2+\sqrt{\left(-768(v'_{f2_{f1}})^3m'_{f2_{f1}}+81(n'_{f2_{f1}})^4\right)}\right)m'_{f2_{f1}}\right)}}-\frac{72n'_{f2_{f1}}\sqrt{6}}{\sqrt{M'_{f2_{f1}}}m'_{f2_{f1}}}} \quad (65')^{27}$$

$$\tilde{Q}_{f2_{f2}}=\frac{\sqrt[3]{\frac{-(\phi'^2_{f22}\Pi^2_{f2_d}(1-\beta_{f2}-\phi_{f2})(\beta_{f2}+\phi_{f2})+(1-\beta_{f2}-\phi_{f2}-\theta'_{f21}-\theta'_{f22})^2\Pi^2_{f2_{f1}}(1-\beta_{f2}-\phi_{f2})(\beta_{f2}+\phi_{f2}))^2}{\beta_{f2}\frac{1}{\Pi_{f2_d}}\beta'_{f21}+\phi_{f2}\Pi^{-1}_{f2_{f1}}\phi'_{f21}}}+p_{I_{f2}}\frac{I_d}{\eta'}+p_{L_{f2}}\frac{L_d}{\gamma'}}{P_{Q_{f2}}}$$

[26] In (64'), $M'_{f2_d}=\sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9(n'_{f2_d})^2+\sqrt{\left(-768(v'_{f2_d})^3m'_{f2_d}+81(n'_{f2_d})^4\right)}\right)m'_{f2_d}\right)}\right)^2+4v'_{f2_d}\sqrt[3]{12}m'_{f2_d}}{m'_{f2_d}\sqrt[3]{\left(\left(9(n'_{f2_d})^2+\sqrt{\left(-768(v'_{f2_d})^3m'_{f2_d}+81(n'_{f2_d})^4\right)}\right)m'_{f2_d}\right)}}$, $m'_{f2_d}=-\theta'^2_{f22}(1-\beta_{f2}-\phi_{f2})(\beta_{f2}+\phi_{f2})(p_{Q_{f2}}(q_{f2}-E_{d_{f2}}-E_{f1_{f2}})-p_{I_{f2}}\frac{1}{\eta'}I_d-p_{L_{f2}}\frac{1}{\gamma'}L_d)^{-2}-\phi'^2_{f22}\phi_{f2}(1-\phi_{f2})(p_{Q_{f2_{f1}}}(q_{f1}-E_{d_{f1}}-Q_{f1_{f1}})-p_{I_{f2_{f1}}}I_d-p_{L_{f2_{f1}}}L_d)^{-2}$, $n'_{f2_d}=-\beta_{f2}\beta'_{f21}(p_{Q_{f2}}(q_{f2}-E_{d_{f2}}-E_{f1_{f2}})-p_{I_{f2}}\frac{1}{\eta'}I_d-p_{L_{f2}}\frac{1}{\gamma'}L_d)$, and $v'_{f2_d}=(\beta_{f2}-\beta'_{f21}-\beta'_{f22})^2(p_{Q_{f2_{f1}}}(q_{f1}-E_{d_{f1}}-Q_{f1_{f1}})-p_{I_{f2_{f1}}}I_d-p_{L_{f2_{f1}}}L_d)^2\beta_{f2}(1-\beta_{f2})$.

[27] In (65'), $M'_{f2_{f1}}=\sqrt[3]{12}\frac{\left(\sqrt[3]{\left(\left(9(n'_{f2_{f1}})^2+\sqrt{\left(-768(v'_{f2_{f1}})^3m'_{f2_{f1}}+81(n'_{f2_{f1}})^4\right)}\right)m'_{f2_{f1}}\right)}\right)^2+4v'_{f2_{f1}}\sqrt[3]{12}m'_{f2_{f1}}}{m'_{f2_d}\sqrt[3]{\left(\left(9(n'_{f2_{f1}})^2+\sqrt{\left(-768(v'_{f2_{f1}})^3m'_{f2_{f1}}+81(n'_{f2_{f1}})^4\right)}\right)m'_{f2_{f1}}\right)}}$, $m'_{f2_{f1}}=-(\beta_{f2}-\beta'_{f21}-\beta'_{f22})^2\beta_{f2}(1-\beta_{f2})(p_{Q_{f2_d}}(q_d-Q_{d_d}-E_{f1_d})-p_{I_{f2_d}}I_d-p_{L_{f2_d}}L_d)^{-2}-(1-\beta_{f2}-\phi_{f2}-\theta'_{f21}-\theta'_{f22})^2(1-\beta_{f2}-\phi_{f2})(\beta_{f2}+\phi_{f2})(p_{Q_{f2}}(q_{f2}-E_{d_{f2}}-E_{f1_{f2}})-p_{I_{f2}}\frac{1}{\eta'}I_d-p_{L_{f2}}\frac{1}{\gamma'}L_d)^{-2}$, $n'_{f2_{f1}}=-\phi_{f2}\phi'_{f21}(p_{Q_{f2}}(q_{f2}-E_{d_{f2}}-E_{f1_{f2}})-p_{I_{f2}}\frac{1}{\eta'}I_d-p_{L_{f2}}\frac{1}{\gamma'}L_d)$, and $v'_{f2_{f1}}=\phi^2_{22}(p_{Q_{f2_d}}(q_d-Q_{d_d}-E_{f1_d})-p_{I_{f2_d}}I_d-p_{L_{f2_d}}L_d)^2\phi_{f2}(1-\phi_{f2})$.

$$= \frac{\sqrt[3]{\begin{array}{c}-(\phi'^2_{f22}(p_{Q_{f2_d}}(q_d - Q_{d_d} - E_{f1_d}) - \\ p_{I_{f2_d}} I_d - p_{L_{f2_d}} L_d)^2 (1-\beta_{f2}-\phi_{f2})(\beta_{f2}+\phi_{f2}) + \\ (1-\beta_{f2}-\phi_{f2}-\theta'_{f21}-\theta'_{f22})^2 (p_{Q_{f2_{f1}}}(q_{f1} - E_{d_{f1}} - Q_{f1_{f1}}) \\ -p_{I_{f2_{f1}}} I_d - p_{L_{f2_{f1}}} L_d)^2 (1-\beta_{f2}-\phi_{f2})(\beta_{f2}+\phi_{f2}))^2\end{array}}}{\sqrt{\begin{array}{c}\beta_{f2}(p_{Q_{f2_d}}(q_d - Q_{d_d} - E_{f1_d}) - p_{I_{f2_d}} I_d - p_{L_{f2_d}} L_d)^{-1} \beta'_{f21} + \\ \phi_{f2}(p_{Q_{f2_{f1}}}(q_{f1} - E_{d_{f1}} - Q_{f1_{f1}}) - p_{I_{f2_{f1}}} I_d - p_{L_{f2_{f1}}} L_d)^{-1} \phi'_{f21} \\ + p_{I_{f2}} \frac{I_d}{\eta'} + p_{L_{f2}} \frac{L_d}{\gamma'}\end{array}}} = \frac{}{P_{Q_{f2}}} \quad (66)$$

Substitute $\tilde{Q}_{f2_d}$, $\tilde{Q}_{f2_{f1}}$, and $\tilde{Q}_{f2_{f2}}$ into (58) to (63) and solving the nine simultaneous equations with nine unknown variables, the relationships among $Q^*_{d_d}$, $E^*_{d_{f1}}$, $E^*_{d_{f2}}$, $E^*_{f1_d}$, $Q^*_{f1_{f1}}$, $E^*_{f1_{f2}}$, $Q^*_{f2_d}$, $Q^*_{f2_{f1}}$, and $Q^*_{f2_{f2}}$ can be found out analytically in the end. Factually, based on the discussion of the model, we have already had the result for $Q^*_{f2_{f2}}$ which should be equal to zero. The rest variables are expressed by (67) to (73):

$$\begin{aligned} Q^*_{d_d} = & -\frac{b}{4a} + \frac{1}{2}\sqrt{\frac{b^2}{4a^2} - \frac{2c}{3a} + \frac{1}{8}(c^2 - 3bd + 12ae)} \\ & - \frac{1}{3a}\sqrt[3]{\frac{2c^3 - 9bcd + 27ad^2 + 27b^2e - 72ace}{2} + \frac{\sqrt{(-4(c^2-3bd+12ae)^3 + (2c^3 - 9bcd + 27ad^2 + 27b^2e - 72ace)^2}}{2}} \\ & + \frac{1}{2}\sqrt{\frac{b^2}{2a^2} - \frac{4c}{3a} - \frac{1}{8}\sqrt{\frac{b^2}{4a^2} - \frac{2c}{3a} + \frac{1}{8}(c^2 - 3bd + 12ae)}} \\ & + \frac{1}{3a}\sqrt[3]{\frac{2c^3 - 9bcd + 27ad^2 + 27b^2e - 72ace}{2} + \frac{\sqrt{(-4(c^2-3bd+12ae)^3 + (2c^3 - 9bcd + 27ad^2 + 27b^2e - 72ace)^2}}{2}} \\ & + \frac{(-\frac{b^3}{a^3} + \frac{4bc}{a^2} - \frac{8d}{a})}{4\sqrt{\frac{b^2}{4a^2} - \frac{2c}{3a} + \frac{1}{8}\sqrt{\frac{b^2}{4a^2} - \frac{2c}{3a} + \frac{1}{8}(c^2 - 3bd + 12ae)}}} \\ & - \frac{1}{3a}\sqrt[3]{\frac{2c^3 - 9bcd + 27ad^2 + 27b^2e - 72ace}{2} + \frac{\sqrt{(-4(c^2-3bd+12ae)^3 + (2c^3 - 9bcd + 27ad^2 + 27b^2e - 72ace)^2}}{2}} \\ & + \frac{8}{3a}\sqrt[3]{\frac{2c^3 - 9bcd + 27ad^2 + 27b^2e - 72ace + \sqrt{(-4(c^2-3bd+12ae)^3 + (2c^3 - 9bcd + 27ad^2 + 27b^2e - 72ace)^2}}{2}} \end{aligned} \quad (67)$$[28]

[28] In (67), $a = -P^3_{Q_d}(1-\beta_d-\phi_d)\phi'_{d3}p_{E_{d_{f1}}}$, $b = 3P^2_{Q_d}(1-\beta_d-\phi_d)\phi'_{d3}p_{E_{d_{f1}}}A + P^3_{Q_d}(\phi_d\phi'_{d3}Z -$

$$E^*_{d_{f1}} = \frac{1}{p_{Q_{f2_d}}}(-\sqrt[3]{\frac{(-p_{I_{f2}}\frac{I_d}{\eta'}-p_{L_{f2}}\frac{L_d}{\gamma'})^3}{\frac{((1-\beta_{f2}-\phi_{f2}-\theta'_{f21}-\theta'_{f22})^2(1-\beta_{f2}-\phi_{f2})(\beta_{f2}+\phi_{f2}))^2-\phi'^2_{f22}(1-\beta_{f2}-\phi_{f2})(\beta_{f2}+\phi_{f2}))}{\beta_{f2}\beta'_{f21}+\phi_{f2}\phi'_{f21}}}} - p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d) + q_d - Q^*_{d_d} \quad (68)$$

$$E^*_{d_{f2}} = -\frac{2}{3}\frac{\frac{1}{6a'}\sqrt[3]{12\sqrt{3}\sqrt{\begin{array}{c}36b'c'a'-108d'(a')^2-8(b')^3+\\ 12\sqrt{3}\sqrt{\begin{array}{c}4(c')^3a'-(c')^2(b')^2\\ -18b'c'a'd'+\\ 27(d')^2(a')^2+4d'(b')^3\end{array}}a'\end{array}}} - \frac{3c'a'-(b')^2}{a'\sqrt[3]{\left(\begin{array}{c}36b'c'a'-108d'(a')^2-8(b')^3+\\ 12\sqrt{3}\sqrt{\begin{array}{c}4(c')^3a'-(c')^2(b')^2-\\ 18b'c'a'd'+27(d')^2(a')^2+4d'(b')^3\end{array}}a'\end{array}\right)}} - \frac{1}{3}\frac{b'}{a'}}{} \quad (69)^{29}$$

$$E^*_{d_{f1}} = E^*_{f1_d} \ (70)$$
$$Q^*_{d_d} = Q^*_{f1_{f1}} \ (71)$$
$$E^*_{d_{f2}} = E^*_{f1_{f2}} \ (72)$$
$$Q^*_{f2_d} = Q^*_{f2_{f1}} \ (73)$$

(70)-(73) reflect that the corporation $d$ and the corporation $f1$ are symmetric, which is not only represented in their exports to the markets of each other and the market of the developing country, but also in the FDI from the developing

$(1-\beta_d-\phi_d)\phi'_{d3}w+(1-\beta_d-\phi_d)\phi'_{d3}p_{E_{d_{f1}}}H)$, $c = 3P^2_{Q_d}A(\phi_d\phi'_{d3}Z-(1-\beta_d-\phi_d)\phi'_{d3}w+(1-\beta_d-\phi_d)\phi'_{d3}p_{E_{d_{f1}}}H)+\beta'^2_{d4}p^2_{E_{d_{f1}}}(p_{E_{d_{f1}}}H-w)ZN$, $d = 3P_{Q_d}(\phi_d\phi'_{d3}Z-(1-\beta_d-\phi_d)\phi'_{d3}w+(1-\beta_d-\phi_d)\phi'_{d3}p_{E_{d_{f1}}}H)A^2-(\beta'^2_{d4}p^2_{E_{d_{f1}}}2HN(p_{E_{d_{f1}}}H-w)Z-2\beta'^2_{d4}p_{E_{d_{f1}}}wN)$, $e = A^3(1-\beta_d-\phi_d)\phi'_{d3}p_{E_{d_{f1}}}-[(2\beta'^2_{d4}p_{E_{d_{f1}}}HN-\beta'^2_{d4}p^2_{E_{d_{f1}}}H^2N-\beta'^2_{d4}w^2N+(\beta_d-\beta'_{d3}-\beta'_{d4})^2Z^2N)(p_{E_{d_{f1}}}H-w)Z]$, $Z = \sqrt{\frac{v'_{d_{f1}}}{(\phi_d-\phi'_{d3}-\phi'_{d4})^2\phi_d(1-\phi_d)}}$, $v'_{d_{f1}} = (\phi_d-\phi'_{d3}-\phi'_{d4})^2(p_{E_{d_{f2}}}(q_{f2}-E^*_{d_{f2}})-p_{I_{E_{d_{f2}}}}I_d-p_{L_{E_{d_{f2}}}}L_d)^2\phi_d(1-\phi_d)$, $w = p_{I_{E_{d_{f1}}}}I_d+p_{L_{E_{d_{f1}}}}L_d$, $N = \beta_d(1-\beta_d)$, $A = p_{I_d}I_d+p_{L_d}L_d$, and $H = q_{f1}-Q^*_{f2_d}$.

[29] In (69), $a' = -(\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2p^3_{E_{f1_{f2}}}$, $b' = (\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2[p^3_{E_{f1_{f2}}}3q_{f2}-3p^2_{E_{f1_{f2}}}B'^2]$, $c' = (\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2[-3p^3_{E_{f1_{f2}}}q^2_{f2}-6p^2_{E_{f1_{f2}}}B'q_{f2}+p_{E_{f1_{f2}}}C']$, $d' = -(1-\beta_{f1}-\phi_{f1})(p_{E_{f1_{f2}}}\theta'_{f13})+(\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2(3p_{E_{f1_{f2}}}q_{f2}B'^2-B'^3)\phi_{f1}(1-\phi_{f1}))+(\beta_{f1}-\beta'_{f13}-\beta'_{f14})^2{q_{f2}}^3-(\beta_{f1}-\beta'_{f13}-\beta'_{f14})^23p^2_{E_{f1_{f2}}}q^2_{f2}B'(p_{E_{f1_{f2}}}q_{f2}-B')C'$, $A' = p_{I_{E_{f1_d}}}I_d+p_{L_{E_{f1_d}}}L_d$, $B' = p_{I_{E_{f1_{f2}}}}I_d+p_{L_{E_{f1_{f2}}}}L_d$, and $C' = (Q^*_{f1_{f1}}P_{Q_{f1}}-p_{I_{f1}}I_d-p_{L_{f1}}L_d)^3(\beta_{f1}(p_{E_{f1_d}}(q_d-Q^*_{f2_d}-Q^*_{d_d})-A')^{-1}\beta'_{f13}+(\phi'^2_{f14}(p_{E_{f1_d}}(q_d-Q^*_{f2_d}-Q^*_{d_d})-A')^2\phi_{f1}(1-\phi_{f1})$.

counterpart in the markets of these two countries. From (67) to (73)[30], we can easily find out such a relationship as the higher $Q^*_{d_d}$, the lower $E^*_{d_{f1}}$ [see (68)]. Other ones we are most interested in are among $Q^*_{f2_d}$, $E^*_{d_{f2}}$, and $E^*_{d_{f1}}$. The comparative statics relationships among them can be drawn through the variables $C'$, $c'$, $d'$, and $Z$ (see footnotes 27 and 28), which have been approximately represented by Figures 1 to 5:

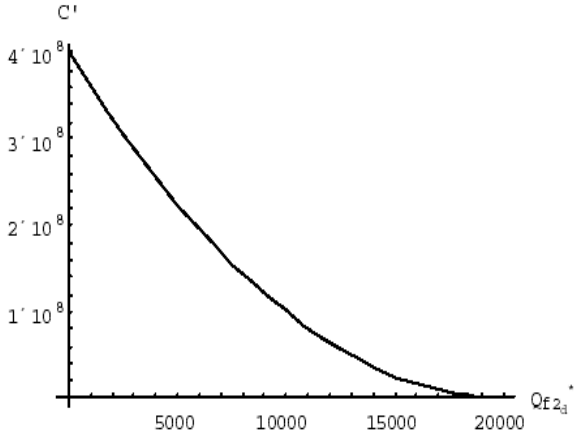


Figure 1

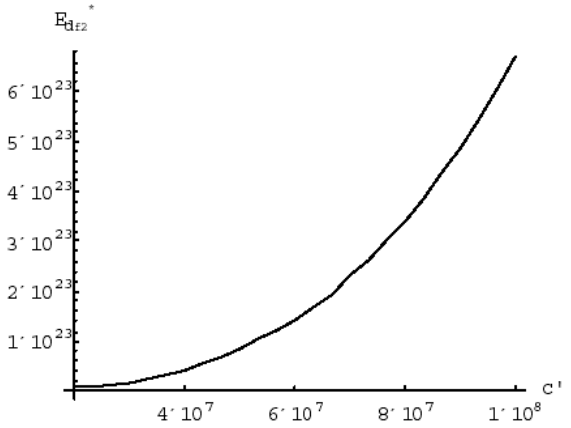


Figure 2

[30]We can notice that these expressions and optimal solutions in the section 1.3 are not related with the discount term $r$.

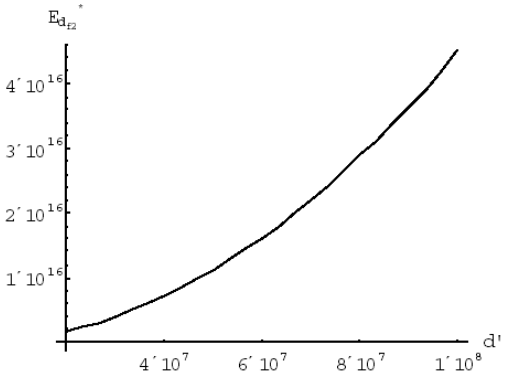


Figure 3

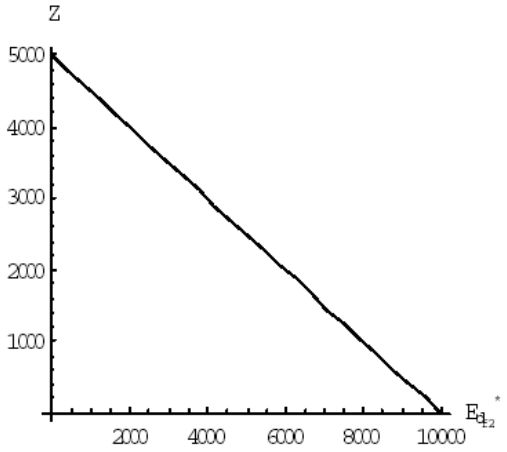


Figure 4

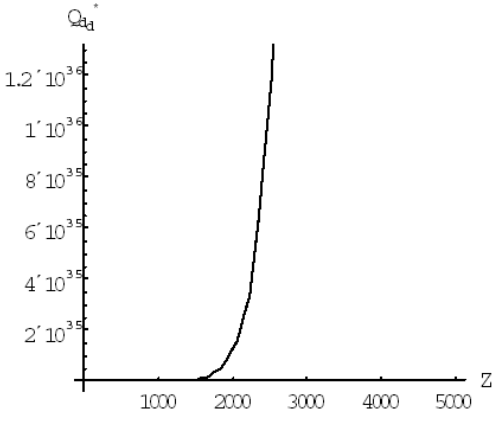


Figure 5

The five figures depict:

$$Q^*_{f2_d}\uparrow \Longrightarrow \left\{ C'\downarrow \Longrightarrow \left\{ \begin{array}{l} c'\downarrow \\ d'\uparrow \end{array} \right. \Longrightarrow \left\{ \begin{array}{l} E^*_{d_{f2}}\downarrow \Longrightarrow Z\uparrow \\ E^*_{d_{f2}}\uparrow \Longrightarrow Z\downarrow \end{array} \right\} \right.$$
$$\Longrightarrow \left\{ \begin{array}{c} \left\{ \begin{array}{c} Q^*_{d_d}\uparrow \\ \text{or } Q^*_{d_d}\downarrow \end{array} \right\} \\ \text{Combining (68)} \end{array} \right\} \Longrightarrow \left\{ \begin{array}{c} E^*_{d_{f1}}\downarrow \\ \text{or } E^*_{d_{f1}}\uparrow \end{array} \right\} \quad (74)$$

(74) argues that increase of $Q^*_{f2_d}$ would lead to two possibilities of changes of $E^*_{d_{f2}}$, $Q^*_{d_d}$ and $E^*_{d_{f1}}$ because of the higher complexity when considering the interaction of the three corporations. The finding here accounts that even direct investment from the developing corporation in the developed markets is increasing, trade or direct investment between the other two developed corporations can also rise while maintaining higher export to the developing one, which exactly serves as an indirect proof that intraindustry would more likely happen between developed countries.

It can be seen, when there is higher amount of trade and direct investment taking place among the three corporations, it is likelier that more trade or FDI between the two from the developed countries is of intraindustry (if the corporations from the developed countries are from a same industry) or is of interindustry (if the corporations from the developed countries are from different industries), and more exports from the two developed corporations to the developing one which is obviously one-way (it can be equivalent to say the developing country imports unilaterally); when there is lower amount of trade and direct investment among the three corporations, it is more likely that trade or FDI between the two developed corporations and export[31] to the developing country decreases simultaneously. Though the result allows a lower volume of trade between the two developed countries, it does not weaken our argument after all. Since in that case, export from the two developed countries to the developing one would also decline. From (74), we can settle with the judgement, which is, if there is higher volume of (two-way) trade or direct investment happening, it will only happen between developed countries.

[31]The one way export in most cases is of interindustry in the real economy.

Till now, according to the definition of Södersten and Reed (1994) about IIT, it is clear that IIT or intraindustry investment would more likely occur between developed countries, for FDI from developing countries in developed ones and export from developed countries to developing ones can not constitute the so-called IIT.

Therefore, from the model, it is not difficult to infer that not only intraindustry trade or investment, but also interindustry trade or investment would more likely happen between themselves.

Another trade pattern, i.e., intrafirm trade, can also be intuitively explained by the chapter. It is argued that intrafirm trade "plays a critical role in the operations of multinational companies" and mentions there is positive relationship "...between the intrafirm-trade shares and trading-partner income levels..." and "U.S.-MNC manufacturing production is largely concentrated in high-income countries"[32]. Beyond a doubt, it is conceivable that intrafirm trade mainly centers in developed countries from the model. Since trade or investment, no matter whether it is interindustry or intraindustry, would more likely occur between developed countries, intrafirm trade (which can be intraindustry or interindustry) would be more possible to happen between them too. To developing countries, investment in developed countries is more salutary than trade with them, therefore, intrafirm trade would less likely happen between developing, i.e., lower income countries[33].

The model itself does not cover the information of non-foreign-oriented corporations. We need to have some coupe de plume on it for the sake of completeness of the chapter. Foreign-oriented corporations and non-foreign-oriented corporations differ in the perspective of the goods they produce. These two types of corporations of a same country type will employ labor and capital of a same technological level when they are in an autarchy economy. The cost they pay to labor and capital should be the same resulted from market-setting pricing assumption. When the economy be-

[32]See Zeile, W. J. (1997), "US intrafirm trade in goods, " *Survey of Current Business*, http://www.bea.doc.gov/bea/ai/0297iid/maintext.htm.

[33]On the contrary, Helpman (1984) suggests the likelihood of intrafirm trade (headquarters services of a MNC exported to its subsidiaries in a foreign country) would be higher when the difference in factor endowments is higher. As an extension of Helpman (1984), intrafirm trade in Helpman (1985) is involved with intermediate inputs instead of headquarters services. Both the papers make use of assumption of increasing return or monopolistic competition.

comes an open one, we have known that foreign-oriented corporations of developing countries will not produce in their home market any more[34], since they can produce more at a same cost level in developed countries. A potential question may be why the non-foreign-oriented corporations would not follow their foreign-oriented counterparts to conduct international exchange. The answer is they can if they produce a foreign-oriented type of goods. They would also consider a trade-off of whether it is worthy of doing so, since when the foreign-oriented corporations leave the home market, the employable amount of labor and capital would be relatively higher, and it may be more profitable to continue to be non-foreign-oriented. Vice versa, although a foreign-oriented corporation of developing countries would prefer to go to invest in developed markets, it is not necessary for all foreign-oriented firms of the developing country to do so. The model implies the higher gap of technological level of productive factors with relatively lower increase of nominal wage gap between developed and developing countries, the more foreign-oriented corporations from the developing countries conduct FDI in the developed ones.

Moreover, the model has naturally let us have theoretical foundation of reviewing policies of introducing FDI in some developing countries, like China. China is the country that has the most FDI inflow in the developing would. It can be argued that cheap labor force may matter, but, from the model, it is never an important factor since the majority of them are less skilled. Obviously, China's investment policies favorable to FDI plays the leading role instead. With China being acceded to the WTO, to commit the principle of National Treatment, a unified investment policy is expected to be enforced applicable to all domestic and foreign corporations in the country after a transition period. One of the causal results can be that capital (containing FDI) outflow may increase. In the past few years, capital outflow from China was in a high magnitude (for example, see Sicular, 1998). It is estimated China's capital outflow occupied 60 percent of total foreign capital inflow in 1997 (see Xing, 2000). In 1998, the amount of capital outflow was US$ 48 billion[35], compared to the actual FDI inflow of US$ 52.13 billion (from statistics of Ministry of Foreign Trade and Economic Cooperation of China). The optimistic expectation

[34]They still can be multinational corporations since their headquarters do not necessarily move to the developed countries.

[35]See "Falsified export claims boost capital flight in China, " *Asia Times*, July 2, 1999.

expressed by many Chinese scholars and government officials in a surge of FDI after entry into the WTO does not make much sense. Further, China's previous investment policy might be only tactically right, but not strategically. The strategic one should have at least made the top priority aiming at raising local labor skill in the industries that permit foreign investment, which has to be expanded to almost all the industries from the day of accession to the WTO on.

## 1.5 Conclusion

Applying human capital theory and an optimal control model within a perfect competition framework, this chapter has figured out why IIT or intraindustry investment more likely happen between developed countries.

The novelty of the model is that it offers a new way to capture realistic economic behavior of multinational corporations. Specification of stochastic disturbance and interdependence in dynamics of profit change, and interaction of three representative corporations are the marked characteristics of the model though it is involved with tedious algebraic calculation.

Through the general theoretical framework, we can also comprehend several international economic issues such as interindustry trade, interindustry investment and intrafirm trade. They, as IIT does, more probably take place between developed countries. The key theoretical question "why is there such a large volume of trade between countries with similar endowments?" mentioned in Bhagwati and Davis (1999) has thus been answered. Analogous to China, to other developing countries, the chapter has clearly implied and recommended skill upgrading of available labor force through various effective measures like promoting education would be the most farseeing approach for increase of FDI inflow.

The chapter tenders a profit-driven explanation about why a corporation likes to participate in international trade or become a multinational, which complements the available theories of multinational corporations and international business literature. From the chapter, it can be understood that traditional trade models are not necessary to be cast to the winds when observing IIT related with differentiated goods. Theories from supply side still should not be overlooked.

It should be pointed out that from the chapter we can not judge what on earth

trade and direct investment between developed countries is a pair of substitute or complement, but the distinction is not crucial for these findings. Since trade or direct investment between developed countries can gain the same level of profit in the model, it does not make much sense to discuss whether it is a substitute or not.

Noting there are quite a few empirical papers studying IIT, from which it can be seen that not all theories of IIT have not been well proved[36], nevertheless, a similar attempt based on the chapter is possible for the future research.

[36]There are abundant empirical studies on IIT. Hoftyzer (1975) and Kennedy and McHugh (1980) test the Linder's hypothesis without showing support. Hufbauer (1970) and Baldwin (1971) find mixed results about economies of scale and trade pattern. Greenaway and Milner (1989) survey relatively newer empirical literature around three hypotheses of IIT: country-specific, industry specific and policy-based, including Loertscher and Wolter (1980), Caves (1981), Bergstrand (1983), Havrylyshyn and Cwan (1983), Greenaway and Milner (1984), and Balassa (1986) etc., whose results are not overwhelmingly uniform yet.

# 2 Why is it important for a multinational corporation to hold technological leadership? A technological transfer perspective

Internalization theory teaches that a corporation should not transfer technology (which can be any type) out of its corporate precinct. Like other business measures such as licensing, technological transfer does happen between corporations or countries. As a kind of factor movement, technological transfer mainly flows from developed countries to developing ones. What can a developed corporation or country obtain from and how does it manage its technological transfer? Why hasn't the technological gap between developing and developed countries shrunk? Through studying why a corporation hopes to keep technological leadership, the answer has been offered by a theoretical model in the chapter.

The model points out: restrained or managed technological transfer from a corporation or a country with superior technology coexists with reduction of profit from FDI of the transferee in the domestic market of the transferrer and no explicit effect on profit from its own home market, though it positively but trivially affects the latter's research and development; on the opposite, benefit for a corporation or a country with advanced technology is substantial due to the fact of enjoying higher employment of its domestic productive factors, higher total profit level in both of its home and foreign markets and grasping the initiative of technological transfer which can be strategically used.

## 2.1 Introduction

In the chapter one, we have known that multinational corporations of developed countries would choose to export to developing countries rather than investing there. But in real economy, FDI in developing countries from developed ones is normal. The reasons causing this can be manifold. Traditional FDI theories argue existence of FDI is because, in the real economy, there is transport cost, trade barrier, and imperfect competition. Among others, a representative theory is OLI paradigm. The eclectic paradigm views FDI is the consequence when a corporation complies with three advantages, i.e., ownership, location and internalization. The chapter would be more closely related with the theory of internalization advantage. But in comparison, the chapter makes a stride forward.

According to the theory of internalization advantage, a corporation protects its ownership advantage by exclusively utilizing only in the internal corporate environment and not disseminating it through external markets. But this act is obviously passive and it is not really in agreement with the stylized fact that technological transfer does happens in the external environment of the corporation. With regard to the typical business behavior, from the walls outside the corporations or countries involved, there is a common understanding that developing corporations or countries would benefit from technological transfer, regarded as followers in terms of their lower level of technology and science, and of course their lower quality of economic development. Ironically, one may be confused at but have to admit the fact that the technological gap between developing and developed countries has not been closer and competitiveness of developing corporations or countries in the world market should have been stronger. With more clear-mindedness and attentiveness, it is not hard to find technological transfer from developed countries is always under various restrictions (or not the most advanced). A question mark for this kind of technological transfer rises naturally: whether would it really do good to the international and domestic economic performance of developing corporations or countries? To the best of my knowledge, it is rather surprising that concern of academia and relevant countries has not been aroused around this topic, at least on a theoretical basis.

For this reason, and as a contribution, in the chapter, we build a theoretical

model, from which it can be found out that a corporation can benefit from limited transfer of its ownership advantage, since in that way can the corporation from the developed country achieve a higher profit via reducing the one reaped from FDI conducted by the developing corporation in its domestic market.

Unlike the chapter one[37], the chapter permits mobility of labor and capital and technological gap would be endogenized. Even though free mobility of productive factors can not guarantee catching up in economic performance[38], under the circumstances such as that the freedom of movement is limited, it would be much less robust to support convergence in production, technology and so on.

Since limited factor movement may not bolster up catching up, we argue in the chapter that FDI and its affiliated technological transfer in developing countries may be the outcome of MNCs' strategy for keeping a higher level of return and maintaining its technological leadership.

The following text is organized as follows: section 2 is theoretical foundation; section 3 is the model; section 4 is policy implications and section 5 concludes.

## 2.2 Theoretical foundation

Technological leadership is a symbol of high competitiveness of a corporation and thus a country. It can lead to a superior position in international trade and FDI according to Ricardo's comparative advantage and the theory of internalization advantage. From these classical theories, it can be inferred that every corporation or every country would try its best to obtain technological leadership as a tool of obtaining markets, profit and competitive advantage permanently.

However, technological leadership of the leader can disappear if the follower catches up. How to achieve this catching up in the reality for followers? (Objective) technological spillover[39] and (subjective) imitation may be not sufficient since these

[37]The chapter one excludes the possibility that developed countries can be followed up by developing ones as a matter of fact where there is no labor and capital movement and technological gap is exogenous.

[38]The chapter four would have more details on this point.

[39]Markusen (1984) and Helpman (1984) explain a MNC would bring its technology abroad because of a lower production cost in the host markets. Though this technology flow has nothing to do with technological transfer, possibility of spillover from which can not be excluded. Another

forms of technological mobility are not very helpful for the follower to grasp the key of technological innovation and progress. In other words, technological spillover and imitation can endow the follower with a veil rather than a pith. We argue there are two essential ways: one is by means of their own research and development[40] and the other is through technological transfer sourced from trade or MNCs' existence.

Research and development is the cradle of any technological innovation and progress. Unless there is free lunch, research and development of a developing corporation or a country may be the most important for technological convergence[41]. In recent literature of endogenous growth theory, along an essentially same line which can be dated back to Schumpeter (1942), such as Lucas (1988), Romer (1986, 1990), and Grossman and Helpman (1990b, 1991), technology has been incorporated in growth models endogenously, which is in order to explain long run economic growth of a country. Obviously, research and development, especially an endogenous one, is one of the most important pinches of endogenous technological change and thus economic growth (also see Krugman, 1990).

Technological transfer[42] has been touched upon in trade theory literature. Vernon (1966) and Krugman (1979a) give birth to the so-called "product life cycle" model[43], which virtually exogenizes[44] unequal technological roles of developing and developed countries with an unchanged technology movement mode and international trade pattern.

Technological transfer is more discussed in literature with MNCs being involved. Related studies conveys the knowledge that technology can be transferred through

form of technological spillover is by way of reading scientific journals (see Eaton and Kortum, 1996).

[40]Research and development can also be understood as learning by doing (see Boldrin and Sheinkman, 1988, and Grossman and Helpman, 1990 for example).

[41]This point would be further illustrated in the following text.

[42]Of course, technological transfer would happen when there is technological gap between corporations (see Wang and Blomström, 1992, and Glass and Saggi, 1998).

[43]The product life cycle model assuming technological innovation only happens in the developed countries, describes that developed countries would export new products to the developing ones, while the developing ones export older products back to the developed ones after they have grasped the transferred (older) technologies of producing these older products.

[44]Rivera-Batiz and Romer (1991), and Grossman and Helpman (1991a) consider trade with endogenous technological innovation.

foreign direct investment (see Findlay, 1978, Mansfield and Romeo, 1980, and Wang, 1990), and technology licensing (see Ethier and Markusen, 1996 and Horstmann and Markusen, 1996) while the latter is less relevant to the chapter.

There is no doubt about the function of FDI as a channel of technological transfer (and spillover). However, previous studies have not brought into view why transfer from developed countries always happens to less advanced technology. Though as the majority of theoretical studies mentioned above, most empirical ones find out that FDI has a positive effect on productivity of host countries (for example, see Coe and Helpman, 1995, Coe, Helpman and Hoffmaister, 1997, and Audretsch 1991, 1995)[45], why would there be the statement that "developing countries set the pace for world economic growth during the past two decades, but the gap between leaders and laggards grew wider"? (The World Bank, 1999)

Among others, there may still be unintelligibility about the phenomenon that technological transfer is typically moving from developed countries to developing ones. This chapter will provide a clue to the issue by accounting for why a MNC would like to keep technological leadership.

## 2.3 The model

We would consider a theoretical model which can accommodate technological transfer and research and development within a single framework. From the model, we can know what the difference is when technological transfer happens in two distinct circumstances, i.e., when there is research and development in developing countries and when there is not (in both situations, there is research and development in developed countries). Based on the realistic events, we suppose technological transfer from the corporations of the developed countries is limited since the developed corporations and countries would manage to maintain a technological gap with the developing one.

There are two countries $d$ and $f$ producing two different products, within each of which the market is perfectly competitive and there are numerous symmetric corporations producing a same type of product, such that prices are determined by

[45] An exception is due to Djankov and Koekman (2000), which find there is a negative effect of FDI on domestic firms in Czech industry.

the market and there is no transport cost. Owing to the assumptions, we can view countries $d$ and $f$ are actually the aggregates of the corporations within each of them. Studying the behavior of an arbitrary corporation of a country is the same as studying the country itself.

We first look at the case when there is technological gap between the two corporations, which is embodied in difference of capability of productive factors they employ. From this part, an initial impression would be possessed about the necessity of keeping technological leadership.

We assume labor and investment from the arbitrary corporation $d$ of the country $d$ is more skillful than that from the one called $f$ of the country $f$. Following the chapter one, one unit of labor or capital of the corporation $d$ is a multiplication of that of the corporation $f$. The relationships of labor and investment employed by the corporations $d$ and $f$ can hence be denoted as:

$$L_d = \theta L_f,\ \theta \succ 1 \ (1)$$
$$I_d = \upsilon I_f,\ \upsilon \succ 1 \ (2)$$

The profit functions of the corporation $d$ and $f$ in their home markets are given in (3) and (4):

$$\Pi_d = P_d Q_d - c_d Q_d \ (3)$$
$$\Pi_f = P_f Q_f - c_f Q_f \ (4)$$

where the Cobb-Douglas production functions are $Q_d = a_d I_d^{\beta_d} L_d^{\gamma_d}$ and $Q_f = a_f I_f^{\beta_f} L_f^{\gamma_f}$, where $a_d$ and $a_f$ are TFP; $I_d$, $L_d$, $I_f$ and $L_f$ are investment/capital and labor employed by the corporations $d$ and $f$ in the countries $d$ and $f$ respectively.

Applying the same way of transformation, we can have the profit functions of corporations $d$ and $f$ in their corresponding host market:

$$\Pi_{d_f} = P_f Q_{d_f} - c_f Q_{d_f} \ (5)$$
$$\Pi_{f_d} = P_d Q_{f_d} - c_d Q_{f_d} \ (6)$$

where $Q_{d_f} = a_{d_f} I_{d_f}^{\beta_{d_f}} L_{d_f}^{\gamma_{d_f}}$ and $Q_{f_d} = a_{f_d} I_{f_d}^{\beta_{f_d}} L_{f_d}^{\gamma_{f_d}}$; $I_{d_f}$ means the amount of investment of the corporation $d$ in the country $f$; $L_{d_f}$ is the amount of labor employed by the corporation $d$ in the country $f$ and so on.

With (3) and (5), subject to (1) and (2), and suppose demand for products of the two corporations $d$ and $f$ in the country $d$ is $q_d$ which is a constant equal to the sum of $Q_d$ and $Q_{f_d}$. Similarly, $q_f$ is equal to the sum of $Q_f$ and $Q_{d_f}$. We can have the following expression of maximization of total profit of the corporation $d$:

$$\begin{aligned}\max T\Pi_d = T\Pi_d = \Pi_d + \Pi_{d_f} = Q_d(P_d - c_d) + Q_{d_f}(P_f - c_f) \\ = a_d I_d^{\beta_d} L_d^{\gamma_d}(P_d - c_d) + a_{d_f} I_{d_f}^{\beta_{d_f}} L_{d_f}^{\gamma_{d_f}}(P_f - c_f) \\ = a_d I_d^{\beta_d} L_d^{\gamma_d}(P_d - c_d) + (q_f - a_f I_f^{\beta_f} L_f^{\gamma_f})(P_f - c_f) \\ = a_d I_d^{\beta_d} L_d^{\gamma_d}(P_d - c_d) + (q_f - a_f(\tfrac{I_d}{\upsilon})^{\beta_f}(\tfrac{L_d}{\theta})^{\gamma_f})(P_f - c_f) \quad (7)\end{aligned}$$

To solve for the optimal employment of labor and the optimal quantity of investment in the home market of the corporation $d$, let the Lagrangian be

$$l_d = a_d I_d^{\beta_d} L_d^{\gamma_d}(P_d - c_d) + (q_f - a_f(\tfrac{I_d}{\upsilon})^{\beta_f}(\tfrac{L_d}{\theta})^{\gamma_f})(P_f - c_f) \quad (8)$$

The FOCs are:

$$\begin{aligned}\tfrac{dl_d}{dL_d} = 0 = a_d I_d^{\beta_d}\gamma_d L_d^{\gamma_d - 1}(P_d - c_d) - a_f(\tfrac{I_d}{\upsilon})^{\beta_f}\gamma_f(\tfrac{L_d}{\theta})^{\gamma_f - 1}\tfrac{1}{\theta}(P_f - c_f) \quad (9) \\ \tfrac{dl_d}{dI_d} = 0 = a_f\beta_f I_f^{\beta_f - 1} L_f^{\gamma_f}(P_f - c_f) - a_d\beta_d(\upsilon I_f)^{\beta_d - 1}\upsilon(\theta L_f)^{\gamma_d}(P_d - c_d) \quad (10)\end{aligned}$$

(9) can be written as

$$\frac{a_d I_d^{\beta_d}\gamma_d(P_d - c_d)}{a_f(\frac{I_d}{\upsilon})^{\beta_f}\gamma_f\frac{1}{\theta^{\gamma_f}}(P_f - c_f)} = \frac{L_d^{\gamma_f - 1}}{L_d^{\gamma_d - 1}} = L_d^{\gamma_f - \gamma_d} \quad (11)$$

Taking natural logarithm on both sides, (11) is changed into

$$\begin{aligned}\ln a_d - \ln a_f + \beta_f \ln \upsilon + (\beta_d - \beta_f)\ln I_d + \ln\gamma_d - \ln\gamma_f + \\ \ln(P_d - c_d) + \ln\theta^{\gamma_f} - \ln(P_f - c_f) = (\gamma_f - \gamma_d)\ln L_d \quad (12)\end{aligned}$$

Similarly, (10) can be written as

$$\frac{a_d\beta_d L_d^{\gamma_d}(P_d - c_d)}{a_f\beta_f\frac{1}{\upsilon^{\beta_f}}(\frac{L_d}{\theta})^{\gamma_f}(P_f - c_f)} = \frac{I_d^{\beta_f - 1}}{I_d^{\beta_d - 1}} \quad (13),$$

whose natural logarithm form is

$$\begin{aligned}\ln a_d - \ln a_f + \beta_f \ln \upsilon + \ln\beta_d - \ln\beta_f + (\gamma_d - \gamma_f)\ln L_d + \ln\theta^{\gamma_f} + \\ \ln(P_d - c_d) - \ln(P_f - c_f) = (\beta_f - \beta_d)\ln I_d \quad (14)\end{aligned}$$

Rearranging (13) and (14), we would have

$$\begin{cases} L_d^* = \exp \frac{\ln a_d - \ln a_f + \beta_f \ln \upsilon + (\beta_d - \beta_f) \ln I_d^* + \ln \gamma_d - \ln \gamma_f + \ln(P_d - c_d) + \ln \theta^{\gamma_f} - \ln(P_f - c_f)}{\gamma_f - \gamma_d} \\ I_d^* = \exp \frac{\ln a_d - \ln a_f + \beta_f \ln \upsilon + \ln \beta_d - \ln \beta_f + (\gamma_d - \gamma_f) \ln L_d^* + \ln \theta^{\gamma_f} + \ln(P_d - c_d) - \ln(P_f - c_f)}{\beta_f - \beta_d} \end{cases} \quad (16)^{46}$$

where

$$\ln \gamma_d - \ln \gamma_f = \ln \beta_d - \ln \beta_f \ (16')$$

$L_d^*$ and $I_d^*$ is the total amount of labor and capital from the country $d$ employed in its home market $d$. Given the assumption that factors can be mobile between the two countries, in this chapter, we consider the case that a corporation employs only its home factors in both markets. From (16), we can see that the higher $\theta$ and $\upsilon$, the higher employment of $L_d^*$ and $I_d^*$. That is to say, the higher gap in capability of labor and investment between two corporations, the technological leader would enjoy higher factors employment.

The optimal profit of the corporation $d$ in both its home and host markets is therefore:

$$T\Pi_d^* = a_d I_d^{*\beta_d} L_d^{*\gamma_d} (P_d - c_d) + (q_f - a_f (\tfrac{I_d^*}{\upsilon})^{\beta_f} (\tfrac{L_d^*}{\theta})^{\gamma_f})(P_f - c_f) \ (17)$$

Now we turn to the profit maximization problem of the corporation $f$ of the developing country $f$. Its objective function is

$$\begin{aligned} \max T\Pi_f &= \Pi_f + \Pi_{f_d} = a_f I_f^{\beta_f} L_f^{\gamma_f} (P_f - c_f) + (q_d - a_d I_d^{\beta_d} L_d^{\gamma_d})(P_d - c_d) \\ &= a_f I_f^{\beta_f} L_f^{\gamma_f} (P_f - c_f) + (q_d - a_d (\upsilon I_f)^{\beta_d} (\theta L_f)^{\gamma_d})(P_d - c_d) \ (18) \end{aligned}$$

The FOCs are:

$$\frac{dT\Pi_f}{dL_f} = 0 = a_f I_f^{\beta_f} \gamma_f L_f^{\gamma_f - 1} (P_f - c_f) - a_d (\upsilon I_f)^{\beta_d} \gamma_d (\theta L_f)^{\gamma_d - 1} \theta (P_d - c_d) \ (19)$$

$$\frac{dT\Pi_f}{dI_f} = 0 = a_f \beta_f I_f^{\beta_f - 1} L_f^{\gamma_f} (P_f - c_f) - a_d \beta_d (\upsilon I_f)^{\beta_d - 1} \upsilon (\theta L_f)^{\gamma_d} (P_d - c_d) \ (20)$$

(19) and (20) can be written as

$$\frac{a_f I_f^{\beta_f} \gamma_f (P_f - c_f)}{a_d (\upsilon I_f)^{\beta_d} \gamma_d \theta^{\gamma_d} (P_d - c_d)} = \frac{L_f{}^{\gamma_d - 1}}{L_f^{\gamma_f - 1}} \ (21)$$

$$\frac{a_f \beta_f L_f^{\gamma_f} (P_f - c_f)}{a_d \beta_d \upsilon^{\beta_d} L_f{}^{\gamma_d} \theta^{\gamma_d} (P_d - c_d)} = \frac{I_f{}^{\beta_d - 1}}{I_f^{\beta_f - 1}} \ (22)$$

[46] It is easy to prove that $\frac{L_d^*}{L_f^*} = \theta$ and $\frac{I_d^*}{I_f^*} = \upsilon$.

which can be transformed into

$$\ln a_f - \ln a_d + (\beta_f - \beta_d)\ln I_f - \beta_d \ln \upsilon + \ln \gamma_f - \ln \gamma_d - \ln \theta^{\gamma_d} + \ln(P_f - c_f) - \ln(P_d - c_d) = (\gamma_d - \gamma_f)\ln L_f \quad (23)$$

$$\ln a_f - \ln a_d + \ln \beta_f - \ln \beta_d - \beta_d \ln \upsilon - \ln \theta^{\gamma_d} + (\gamma_f - \gamma_d)\ln L_f + \ln(P_f - c_f) - \ln(P_d - c_d) = (\beta_d - \beta_f)\ln I_f \quad (24)$$

(23) and (24) give the optimal amount of labor and investment from the country $f$ employed by the corporation $f$ in its home market:

$$\begin{cases} L_f^* = \exp \frac{\ln a_f - \ln a_d + (\beta_f - \beta_d)\ln I_f^* - \beta_d \ln \upsilon + \ln \gamma_f - \ln \gamma_d - \ln \theta^{\gamma_d} + \ln(P_f - c_f) - \ln(P_d - c_d)}{\gamma_d - \gamma_f} \\ I_f^* = \exp \frac{\ln a_f - \ln a_d + \ln \beta_f - \ln \beta_d - \beta_d \ln \upsilon - \ln \theta^{\gamma_d} + (\gamma_f - \gamma_d)\ln L_f^* + \ln(P_f - c_f) - \ln(P_d - c_d)}{\beta_d - \beta_f} \end{cases} \quad (25)$$

where (16') is still satisfied.

The corresponding optimal profit of the corporation $f$ in both its home and host markets is:

$$T\Pi_f^* = a_f I_f^{*\beta_f} L_f^{*\gamma_f}(P_f - c_f) + (q_d - a_d(\upsilon I_f^*)^{\beta_d}(\theta L_f^*)^{\gamma_d})(P_d - c_d) \quad (26)$$

From (25), we can see higher $\theta$ and $\upsilon$ will lead to lower employment of $L_f^*$, $I_f^*$. The intuition is just on the opposite to the technology leader, i.e., the corporation $d$, which suggests that the larger technological gap, the lower factors employment in the technology follower.

Besides the relationship between technological gap and employment level, we are also interested in another one between the gap and total profit of a corporation. We can turn to (17) and (26), where the relationship between total profit and the variables $\theta$ and $\upsilon$ for both corporations $d$ and $f$ is given.

Without violating the equality $\ln \gamma_f - \ln \gamma_d = \ln \beta_f - \ln \beta_d$, we can look at a special case where $\gamma_f = \gamma_d$ and $\beta_f = \beta_d$, meaning structure of production functions of the corporations $d$ and $f$ is the same. It is not hard to find that $T\Pi_d^*$ is positively correlated, but $T\Pi_f^*$ negatively correlated with $\theta$ and $\upsilon$. Total profit of the corporation $d$ would become higher while total profit of the corporation $f$ suffers a loss with increase of $\theta$ and $\upsilon$.

The above text has shown the advantage of holding technological leadership for a corporation and a country initially through investigating its impact on factors employment and total profit. In the following sections, we will go further to look into the issue by considering when technological transfer happens.

### 2.3.1 Technological transfer

In this section, we would take into account two situations when technological transfer happens. As mentioned above, developed countries will always have research and development. The developing country, as a transferee of technology, which may or may not have research and development. We will investigate the effect of whether there is research and development in the developing country on the production and factors employment of both the developed and developing countries.

**When there is no research and development in the corporation** $f$ We assume technological transfer is only a proportional part (due to the expounding of the text above) of research and development of the corporation $d$, i.e., $Tr = \psi R_d$,where $\psi \in (0,\ 1)$, while $R_d$ is a function of labor employment and one lag variable of itself[47]:

$$R_d = {L_d}^{\varsigma} {R_{d,-1}}^{1-\varsigma} \quad (27)$$

With (27), technological transfer can be written as:

$$Tr = \psi R_d = \psi {L_d}^{\varsigma} {R_{d,-1}}^{1-\varsigma} \quad (28)$$

whose natural logarithm is

$$\ln R_d = \varsigma \ln L_d + (1-\varsigma) \ln R_{d,-1} \quad (29)$$

Solving the difference equation, we can have

$$\ln R_d = D(1-\varsigma) + \ln L_d \quad (30)$$

That is

$$R_d = \exp\left(D(1-\varsigma) + \ln L_d\right) \quad (31)$$

$D$ is a positive constant. Substituting the optimal labor employment of the corporation $d$ into (31), we will have its optimal research and development for achieving the technological gap embodied in (1):

[47]So research and development is also modeled endogeneously in the chapter.

$$R_d^* = \exp\left(D(1-\varsigma) + \ln L_d^*\right) \quad (32)$$

Since (27) can be written as

$$R_d^* = L_d^{*\varsigma} {R_{d,-1}^*}^{1-\varsigma} \quad (33)$$

let (33) be equal to (32), which gives

$$D(1-\varsigma) + \ln L_d^* = \ln L_d^{*\varsigma} + \ln {R_{d,-1}^*}^{1-\varsigma} \quad (34)$$

Therefore, $L_d^*$ is given by (35):

$$L_d^* = \exp \frac{\ln {R_{d,-1}^*}^{1-\varsigma} - D(1-\varsigma)}{(1-\varsigma)} \quad (35)$$

The one lag of $R_d$, i.e., $R_{d,-1}$ mimics the function of learning by doing[48], which is "the steady improvement of productivity engendered by the experience of producing" (Aghion and Howitt, 1998, pp. 137).

We continue to write down the optimal production functions of the corporations $d$ and $f$ for both markets:

$$Q_d^* = a_d(\exp \frac{\ln a_d - \ln a_f + \beta_f \ln \upsilon + \ln \beta_d - \ln \beta_f + (\gamma_d - \gamma_f) \ln L_d^* + \ln \theta^{\gamma_f} + \ln(P_d - c_d) - \ln(P_f - c_f)}{\beta_f - \beta_d})^{\beta_d}$$
$$(\exp \frac{\ln {R_{d,-1}^*}^{1-\varsigma} - D(1-\varsigma)}{(1-\varsigma)})^{\gamma_d} \quad (36)$$

$$Q_f^* = a_f(\exp \frac{\ln a_f - \ln a_d + (\beta_f - \beta_d) \ln I_f^* - \beta_d \ln \upsilon + \ln \gamma_f - \ln \gamma_d - \ln \theta^{\gamma_d} + \ln(P_f - c_f) - \ln(P_d - c_d)}{\gamma_d - \gamma_f})^{\beta_f}$$
$$(\exp \frac{\ln a_f - \ln a_d + \ln \beta_f - \ln \beta_d - \beta_d \ln \upsilon - \ln \theta^{\gamma_d} + (\gamma_f - \gamma_d) \ln L_f^* + \ln(P_f - c_f) - \ln(P_d - c_d)}{\beta_d - \beta_f})^{\gamma_f} \quad (37)$$

From (36) and (37), it can be seen that only the corporation $d$ can have a long run production growth. This result adapts itself to endogenous growth theory. Without research and development, the corporation $f$ and the country $f$ can not survive a long run growth.

To increase $Q_d^*$ and therefore its profit, the corporation $d$ may potentially widen the gap by increasing its research and development and (35) is the mechanism it can rely on, given the advantage of being a technological leader mentioned above.

[48] With similar spirit of Young (1991) and Stokey (1991) where learning is bounded, in the chapter, we exclude the possibility of technological leapfrogging (see Brezis, Krugman and Tsiddon, 1993).

In this chapter, we argue technological transfer from the corporation $d$ can be, on the one hand, based on the requirement from the developing country, on the other hand, based on a certain strategic demand of the corporation $d$ itself. To the former consideration, as a kind of economic exchange, the corporation $d$ transfers technology in return for its share in the market of the developing country $f$. To the latter consideration, technological transfer from the corporation may have whatsoever negative effect on the corporation $f$, which will be confirmed in the following text.

Applying the optimal values of $I_d$ and $L_d$, there are two following expressions in (38) and (39):

$$\frac{\Pi_d^*}{\Pi_f^*} = \frac{a_d(P_d - c_d)}{a_f(P_f - c_f)} I_f^{*\beta_d - \beta_f} L_f^{*\gamma_d - \gamma_f} \upsilon^{\beta_d} \theta^{\gamma_d} \quad (38)$$

$$\frac{\Pi_{f_d}^*}{\Pi_{d_f}^*} = \frac{a_{f_d}(P_d - c_d)}{a_{d_f}(P_f - c_f)} I_d^{*\beta_{f_d} - \beta_{d_f}} L_d^{*\gamma_{f_d} - \gamma_{d_f}} \upsilon^{-\beta_{f_d}} \theta^{-\gamma_{f_d}} \quad (39)$$

When would technological transfer would reasonably happen, which can be required by the developing corporation or country $f$ or completely decided by the corporation or country $d$? Among others, the chapter argues that it may occur when (39) is not an equality any more, say,

$$\frac{\Pi_{f_d}^{'}}{\Pi_{d_f}^{'}} \prec \frac{a_{f_d}(P_d - c_d)}{a_{d_f}(P_f - c_f)} I_d^{*\beta_{f_d} - \beta_{d_f}} L_d^{*\gamma_{f_d} - \gamma_{d_f}} \upsilon^{-\beta_{f_d}} \theta^{-\gamma_{f_d}} \quad (40)$$

when

$$\frac{\exp \frac{\ln {R_{d,-1}^{'}}^{1-\varsigma} - D(1-\varsigma)}{(1-\varsigma)}}{\exp \frac{\ln a_d - \ln a_f + \beta_f \ln \upsilon + (\beta_d - \beta_f) \ln I_d^* + \ln \gamma_d - \ln \gamma_f + \ln(P_d - c_d) + \ln \theta^{\gamma_f} - \ln(P_f - c_f)}{\gamma_f - \gamma_d}} \succ \theta \quad (40')$$

where

$$R_{d,-1}^{'} \succ R_{d,-1}^{*}$$

which means the profit of the corporation $f$ in the market $d$ over that of the corporation $d$ in the market $f$, has been broken to be less than before (the likely case is that $\Pi_{d_f}^{'}$ increases or $\Pi_{f_d}^{'}$ decreases), because research and development of the corporation $d$ has surpassed the level of maintaining (1). We can reach the following result.

**Proposition 1** *When the corporation $f$ does not participate in research and development, technological transfer from the corporation $d$ is negatively correlated with the profit from FDI of the corporation $f$ in the home market of the corporation $d$ (i.e., the developed market).*

***P roof.*** *We can prove this by observing the relationship between technological transfer and profit from FDI of the corporation $f$ in the developed counterpart is negative. Technological transfer (the corporation $d$ should control the amount of technological transfer) is given by extra total profit of the corporation $f$ in the two markets:*

$ET\Pi_f = P_{Tr}Tr^{'} = \Pi^{'}_{d_f}(\frac{a_{f_d}(P_d-c_d)}{a_{d_f}(P_f-c_f)}I_d^{*\beta_{f_d}-\beta_{d_f}}L_d^{*\gamma_{f_d}-\gamma_{d_f}}\upsilon^{-\beta_{f_d}}\theta^{-\gamma_{f_d}} - \frac{\Pi^{'}_{f_d}}{\Pi^{'}_{d_f}})$, *where* $P_{Tr}$ *is the net benefit per unit* $Tr$. *The above equation can be written as:*

$\Pi^{'}_{f_d} = \Pi^{'}_{d_f}\frac{a_{f_d}(P_d-c_d)}{a_{d_f}(P_f-c_f)}I_d^{*\beta_{f_d}-\beta_{d_f}}(\exp(\ln R_d^* - D(1-\varsigma)))^{\gamma_{f_d}-\gamma_{d_f}}\upsilon^{-\beta_{f_d}}\theta^{-\gamma_{f_d}} - P_{Tr}Tr^{'}$.
*Given other variables, higher* $Tr^{'}$ *is accompanied with lower* $\Pi^{'}_{f_d}$. ■

**When there is research and development in the corporation $f$** We assume the function of research and development of the corporation $f$ has a same structure as the corporation $d$ does.

$$\ln R_f = \eta \ln L_f + (1-\eta)\ln R_{f,-1} \quad (41)$$

Solving the difference equation, (41) becomes

$$\ln R_f = F(1-\eta) + \ln L_f \quad (42)$$

Getting rid of the natural logarithm operator, we have

$$R_f = \exp\left(F(1-\eta) + \ln L_f\right) \quad (43)$$

Easily, the optimal research and development of the corporations $f$ when (1) is maintained are given by:

$$R_f^* = \exp\left(F(1-\eta) + \ln L_f^*\right) \quad (44)$$

Dividing (44) by (32), we will have

$$\frac{R_d^*}{R_f^*} = \frac{\exp\left(D(1-\varsigma)+\ln L_d^*\right)}{\exp\left(F(1-\eta)+\ln L_f^*\right)} \quad (45)$$

Then,

$$\ln R_d^* - \ln R_f^* = D(1-\varsigma) + \ln L_d^* - F(1-\eta) - \ln L_f^* \ (46)$$

After necessary adjustment, (46) would be evolved into

$$L_d^* = L_f^* \exp(\ln R_d^* - \ln R_f^* - D(1-\varsigma) + F(1-\eta)) \ (47)$$

where

$$\exp(\ln R_d^* - \ln R_f^* - D(1-\varsigma) + F(1-\eta)) = \theta \ (48).$$

From (48), it is clear that there is a negative relationship between $R_f^*$ and $\theta$, which argues the research and development in the corporation $f$ would help reduce the technological gap with the corporation $d$ and thus the country $d$.

However, (48) can also become an inequality when competition in research and development in both corporations deviates from the equilibrium in (1). We assume the corporation $d$ occupies the winning side and (48) turns into

$$\exp(\ln R_d^{'} - \ln R_f^{'} - D(1-\varsigma) + F(1-\eta)) \succ \theta \ (48')$$

where

$$\frac{R_d^{'}}{R_f^{'}} \succ \frac{R_d^*}{R_f^*}$$

What will happen if there is technological transfer from the corporation $d$ to the corporation $f$?

**Proposition 2** *When the corporation f participates in research and development, technological transfer from the corporation d has a positive but trivial effect on research and development of the former.*

**P roof.** *(45) can be transformed into:* $\frac{Tr^{'}}{\psi} \succ \frac{\exp\left(D(1-\varsigma)+\ln L_d^{'}\right)}{\exp\left(F(1-\eta)+\ln L_f^{'}\right)} R_f^{'}$. *Then it can be seen that technological transfer from the corporation d does not help narrow the technological gap between the corporations d* and $f$. ■

**Proposition 3** *When the corporation f participates in research and development, technological transfer from the corporation d is negatively correlated with its profit of FDI in the developed country.*

**P roof.** *The extra total profit of the corporation $f$ in two markets is given by* $ET\Pi_f = P_{Tr}Tr^{'} = \Pi^{'}_{d_f}(\frac{a_{f_d}(P_d-c_d)}{a_{d_f}(P_f-c_f)} I_d^{*\beta_{f_d}-\beta_{d_f}} L_d^{*\gamma_{f_d}-\gamma_{d_f}} \upsilon^{-\beta_{f_d}} \theta^{-\gamma_{f_d}} - \frac{\Pi^{'}_{f_d}}{\Pi^{'}_{d_f}})$.

And $\Pi^{'}_{f_d} = \Pi^{'}_{d_f} \frac{a_{f_d}(P_d-c_d)}{a_{d_f}(P_f-c_f)} I_d^{*\beta_{f_d}-\beta_{d_f}} (L_f^* \exp(\ln R_d^* - \ln R_f^* - D(1-\varsigma) + F(1-\eta)))^{\gamma_{f_d}-\gamma_{d_f}} \upsilon^{-\beta_{f_d}} \theta^{-\gamma_{f_d}} - P_{Tr}\psi \exp \begin{pmatrix} D(1-\varsigma) + \ln L^{'}_f \exp(\ln \frac{Tr^{'}}{\psi} - \\ \ln R^{'}_f - D(1-\varsigma) + F(1-\eta)) \end{pmatrix}$.

*Given other variables, it can be seen that $Tr^{'}$ is negatively correlated with $\Pi^{'}_{f_d}$.*

■

In summary, technological transfer would not increase the international competitiveness of the corporation $f$ no matter whether it conducts research and development or not if changes of $\Pi_{f_d}$ can be counted as an reference indicator.

Another two relevant propositions are as follows:

**Proposition 4** *Higher $R^{'}_d$ leads to higher $\Pi^{'}_d$, the profit of the corporation $d$ in its domestic market. Higher $R^{'}_f$ as a whole may lead to lower $\Pi^{'}_d$.*

***P roof.*** $\Pi^{'}_d = a_d I_d^{'\beta_d} L_d^{'\gamma_d} (P_d - c_d)$

$= a_d I_d^{'\beta_d} [L^{'}_f \exp(\ln R^{'}_d - \ln R^{'}_f - D(1-\varsigma) + F(1-\eta))]^{\gamma_d} (P_d - c_d)$. *There is a positive relationship between $\Pi^{'}_d$ and $R^{'}_d$, but a negative one between $\Pi^{'}_d$ and $R^{'}_f$.* ■

**Proposition 5** *Higher $R^{'}_f$ leads to higher $\Pi^{'}_f$, the profit of the corporation $f$ in its domestic market.*

***P roof.*** $\Pi^{'}_f = a_f I_f^{'\beta_f} L_f^{'\gamma_f} (P_f - c_f)$

$= a_f I_f^{'\beta_f} (\frac{\exp(\ln \frac{Tr^{'}}{\psi} - D(1-\varsigma))}{\exp(\ln \frac{Tr^{'}}{\psi} - \ln R^{'}_f - D(1-\varsigma) + F(1-\eta))})^{\gamma_f} (P_f - c_f)$. *Hence, there is a positive relationship between $\Pi^{'}_f$ and $R^{'}_f$.* ■

From the Proposition 5, it can be seen that the effect of $Tr^{'}$ has been offset by the numerator ($\exp(\ln \frac{Tr^{'}}{\psi} - D(1-\varsigma))$) and the denominator ($\exp(\ln \frac{Tr^{'}}{\psi} - \ln R^{'}_f - D(1-\varsigma) + F(1-\eta))$) in the expression of $\Pi^{'}_f$. $Tr^{'}$ can positively affect $\Pi^{'}_f$ through $R^{'}_f$ if it benefits $R^{'}_f$ (see the possibility from the Proposition 2). However, the Proposition 4 virtually implies that technological transfer threatening profit level in the domestic market of the corporation $d$ would be cautiously conducted. That is why international competitiveness of the corporation $f$ can not be materially enhanced (see the negative relationship between $\Pi^{'}_{f_d}$ and $Tr'$ in the Proposition 3). Alternatively speaking, the Proposition 5 (with the Proposition 2) argues technological transfer

not essentially jeopardizing the interest of the corporation $d$ in the counterpart $f$'s market can be implemented. With the Proposition 3, we can derive the fact that profit level of the corporation $d$ in the market $f$ is positively associated with the transfer. Henceforth, it is justified to say that economic performance of the corporation $f$ in the home market might be trivially positively affected or even unaffected by the transfer.

When research and development happens in both corporations $d$ and $f$, we will have new production functions of the two corporations:

$$Q_d^{'} = a_d(\exp\frac{\ln a_d - \ln a_f + \beta_f \ln \upsilon + \ln \beta_d - \ln \beta_f + (\gamma_d - \gamma_f)\ln L_d^{'} + \ln \theta^{\gamma_f} + \ln(P_d - c_d) - \ln(P_f - c_f)}{\beta_f - \beta_d})^{\beta_d} L_f^{'}$$
$$\exp(\ln R_d^{'} - \ln R_f^{'} - D(1-\varsigma) + F(1-\eta))^{\gamma_d} \quad (49)$$

$$Q_f^{'} = a_f(\exp\frac{\ln a_f - \ln a_d + (\beta_f - \beta_d)\ln I_f^{'} - \beta_d \ln \upsilon + \ln \gamma_f - \ln \gamma_d - \ln \theta^{\gamma_d} + \ln(P_f - c_f) - \ln(P_d - c_d)}{\gamma_d - \gamma_f})^{\beta_f}$$
$$(\frac{\exp(\ln \frac{Tr^{'}}{\psi} - D(1-\varsigma))}{\exp(\ln R_d^{'} - \ln R_f^{'} - D(1-\varsigma) + F(1-\eta))})^{\gamma_f} \quad (50)$$

Not surprisingly, conducting research and development of the corporation $f$ would help it realize a sustainable growth of production. In other words, research and development can inject force to the developing country $f$ for a long run growth. However, technological transfer does not substantially help the corporation $f$ achieve a higher $Q_f^{'}$ from (50) as it does not explicitly help increase domestic profit $\Pi_f^{'}$.

Therefore, to the corporation $f$, technological transfer can be viewed as a kind of remuneration. But to the corporation $d$, it has strategic implications since it can be used to exchange for lower profit of its developing rival in the market $d$ and thus a decline of its total profit in both markets.

All in all, the above analysis has illustrated the importance of controlling technological leadership. And now, we will simply look back at the case supposing the corporation $f$ has followed up, i.e.,

$$L_d = L_f \text{ and } I_d = I_f \quad (51)$$

In this situation, there is no need for technological transfer from the corporation $d$, and we will have symmetric equilibrium for the two corporations.

**Proposition 6** *When there is no technological gap between the two corporations, research and development of the corporations $d$ and $f$ will help increase both of its domestic and foreign profit.*

When there is no technological gap between the corporations $d$ and $f$, and for simplicity we suppose the amount of labor and capital employed in home and foreign markets by each corporation is identical, it is easy to show that the corresponding profit functions of the two corporations in both markets are given by (52) to (55).

$$\Pi_d^{''} = a_d I_d^{''\beta_d} [\exp \frac{(1-\varsigma)\ln R_{d,-1}^{''} - D(1-\varsigma)}{(1-\varsigma)}]^{\gamma_d} (P_d - c_d) \quad (52)^{49}$$

$$\Pi_{d_f}^{''} = a_{d_f} I_{d_f}^{'''\beta_{d_f}} [\exp \frac{(1-\varsigma)\ln R_{d,-1}^{'''} - D(1-\varsigma)}{(1-\varsigma)}]^{\gamma_{d_f}} (P_f - c_f) \quad (53)$$

$$\Pi_f^{''} = a_f I_f^{''\beta_f} [\exp \frac{(1-\eta)\ln R_{f,-1}^{''} - F(1-\eta)}{1-\eta}]^{\gamma_f} (P_f - c_f) \quad (54)$$

$$\Pi_{f_d}^{''} = a_{f_d} I_{f_d}^{'''\beta_{f_d}} [\exp \frac{(1-\eta)\ln R_{f,-1}^{'''} - F(1-\eta)}{1-\eta}]^{\gamma_{f_d}} (P_d - c_d) \quad (55)$$

From (52) to (55), $\Pi_d^{''}$ and $\Pi_{d_f}^{''}$ can be seen that they are positively correlated with $R_{d,-1}$ ($R_{d,-1}^{''}$ and $R_{d,-1}^{'''}$ is the equivalent amount of research and development for $L_d^{''}$ and $L_{d_f}^{'''}$ respectively) , while $\Pi_f^{''}$ and $\Pi_{f_d}^{''}$ is positively associated with $R_{f,-1}$.

There is not any negative impact on the profit of the corporation $d$ in its home and foreign markets, resulted from a full catching up of the late-starter $f$. The Proposition 6 is merely a theoretical judgement. So what is the justification for a developed corporation/country to set restrictions on technological transfer to a developing one? Firstly, according to the model, we can see restrictive technological transfer as a type of restrictive business measures (RBM) can be employed to prevent the interest of a developed corporation in its home market from being harmed (see the Proposition 4) during the process of catching up from the developing corporation[50]. Secondly, no evidence gives sign that contemporary social mechanism encourages and can retain such a positive sum game as realization of full technological convergence. Differences in economic institution, political system and social environment among countries are contributing factors.

## 2.4 Policy implications

The text above has accounted a long-lasting ignored matter by reconsidering why a MNC would strive to hold technological leadership. When referring to assistance to

[49]The evolution of $L_d^{''}$, and the following $L_{df}^{'''}$, $L_f^{''}$, and $L_{f_d}^{'''}$ is the same as that of $L_d^*$ given in (35).

[50]Another argument is provided in Krugman (1986), which argues that technological advantage of the developed one would fall and no real wage changes for its own products.

developing countries, many academicians would succumb to the idea of technological transfer. But the problem is how developing countries can benefit from it.

The chapter has provided an almost totally contrasting evidence for the perception of assisting developing countries through technological transfer. Not aiming to veto the feasibility of the form of assistance, the chapter just hopes to activate relevant re-evaluation. In a world with limited technological transfer or factor movement, how much on earth can developing countries be helped? From the chapter, the kind of restrained technological transfer may never be related with what developing countries can look forward to. We do not deny the fact that technological transfer can be availed by research and development of these countries, but it does nothing more subsidiary else like lessening technological gap and promoting international economic performance.

The centrality of the problem is in the end causally connected with the extent of freedom of factor mobility. Yet, we would not expect there would be free mobility of technological transfer at least in the current world system.

Two egregious policy prescriptions are listed below for references if there are no favorably prominent changes in social institution, and international economic and political relations in the world, or we can simply say, when factor movement is not totally free in the world:

- Developing corporations and countries should strengthen their own research and development and should not hold opportunistic attitude to refrained technological transfer from developed ones;
- Excessive conditions should be avoided in technological transfer from developed corporations and countries, especially in the case exceeding pure economic consideration, such as inter-governmental international assistance.

## 2.5 Conclusion

Through studying why a corporation hopes to keep technological leadership, the chapter has answered what a developed corporation or country can gain from and how it manages its technological transfer.

We obtain the result from the framework where factors can not be freely mobile between countries, since the developed corporation or country will keep the technological gap between itself and the developing one. In this situation, we can not see technological transfer brings any substantial benefit to a developing corporation or country.

The theoretical model reveals the following points:

- The higher technological gap, the higher domestic factors employment in a developed corporation or country, but less domestic factors employment in a developing corporation or country;
- Restricted technological transfer is negatively correlated with profit of a developing corporation or country in its foreign market, but has no explicit effect on its profit in its home market, not helping diminish its technological gap; a developed corporation or country does not suffer anything but possesses a higher total profit level sourced from both its domestic and foreign markets;
- Research and development is the key of generating higher production, profit, and a long run growth for a developing corporation or country. And it is the sole lane of effectuating technological catching up with its developed counterpart when RBM is prevalent.

Like managed trade between countries, restrained technological transfer between corporations can be vividly viewed as a micro protectionist mirror image of the former, i.e., a macro one. In sum, being a technological leader, a multinational corporation benefits materially, not only can enjoy a higher level of employment of its domestic productive factors, higher total profit level, but also grasps the initiative of technological transfer by using it strategically rather than merely apparently handing out assistance or compensation to the inferior one. And that is one of the reasons why the gap between developing and developed countries is hard to be filled up or becomes even larger.

# 3 Multinational corporations and market risk: A real market perspective

Common sense tells us that market risk seems to affect negatively the operation of a risk-averse corporation. However, an experience from life enlightens that the negativity effect of a thing can always be availed positively, without exception to market risk. With the philosophy of life in mind, the chapter explains why it seems that a corporation is willing to conduct FDI in foreign markets confronting various market risks.

This chapter studies how market risk can affect the investment, labor employment, and thus production of a MNC in both its home and foreign (real) markets. We conduct the inquiry by considering two alternatives in the framework of monopolistic market structure: one is that market risk is not correlated among domestic and foreign markets and the other one is that market risk is correlated across markets. The core finding and conclusion is that it is more superior for a corporation to become a multinational one such that market risk from various sources can be dealt with more conformably, for it is unlikely to neutralize all of those market risk from different sources which is very likely correlated due to deeper global economic integration.

## 3.1 Introduction

Being a successful corporation, no matter whether it is risk-averse, a risk lover or risk-neutral, has to cope well with market risk from various sources. Under fierce market competition, whether a corporation can make its decision properly in complex market situations, concerning its factors employment and production in different markets, may be one of the most important prerequisites for retaining its market share.

Potential market risk of a corporation may face is uncountable. According to the difference of its inherence, market risk can be classified into two categories, i.e., economic one and non-economic one. Basically, economic risk would be related with investment by a corporation in financial market (like foreign portfolio investment) and real market (like FDI). Non-economic risk sources socially, politically or naturally. For a corporation itself, market risk it should deal with can be simply divided into the internal one and the external one. If a corporation can scrutinize more varieties of market risk than others in its operating decisions, it would certainly be embedded in an unconquerable position.

It is recognized that market risk can be avoided partially. For example, in financial markets, stipulating certain contracts with using specific financial instruments, interest or foreign exchange risk can be diverted. In comparison to this relatively full-fledged analysis of market risk in financial markets, there is still much work for the counterpart about market risk in real ones. This chapter tends to contribute to the theoretic pamphlet in this area, with focusing on how the market risk is related to investment, labor employment and thus production of a risk-averse MNC in its home and foreign markets.

There are still not complete theories explaining why it seems that a corporation is willing to conduct FDI in foreign markets in front of myriads of market risk. Di Mauro (2000) argues "sales of foreign affiliates are now greater than world total exports of goods, implying that firms use FDI more than they use exports to service foreign markets". Given multinational corporations have reaped what they expect through FDI, we conjecture if direct investment in foreign markets is a practicable way to evade market risk. Through this chapter, we would prove this with finding out relevant candid algebraic expressions related to how a (risk-averse) corporation

determines its business issues. From these formulas, we can easily understand why a corporation's becoming a MNC would be more attractive in open economies than being the one home market oriented, where market risks are correlated given a regime of monopolistic market structure.

The following text is organized as follows: section 2 is theoretical foundation; section 3 is the model; section 4 is further extension and section 5 concludes.

## 3.2 Theoretical foundation

Popular theories of international business and international management teaching why a corporation would like to become a MNC can be resolved into imperfect markets theory [e.g., Kindleberger (1969)'s structural market imperfection theory, Buckley and Casson (1976)'s natural market imperfection theory], Vernon's product cycle theory and the theoretical synthesis, i.e., OLI paradigm. These theories almost uniformly conclude FDI is an inevitable way of increasing international business of any kind such as trade, licensing, joint venture and the like. Generally speaking, they are not concerned about and can not provide a commensurate reply to why total amount of FDI across countries is continuously in an accelerating tendency[51] given world market situation is full of risky elements (and imperfectly structured) which are value-destroying[52]. One may argue the causes of market imperfection are related with market risks. Internalization of production and operation behavior of a MNC can effectively avoid market imperfection and thus market risks. It only sounds reasonable on a shallow theoretical layer and does not help much raise degree of precision of market participation of a MNC in reality, e.g., these theories can not show how market risk affects employment plan in different markets of a MNC.

In fact, corresponding to imperfect markets theory, there is a branch theory indeed from international business literature called perfect markets theory whose main hypotheses accounting for FDI includes differential rates of return, portfolio diversification, and market size (see Liyondo, 1995). But in the theoretical field of international business, the role of perfect markets theory is much less important than those popular ones more familiarly known. However, it exactly is a major approach

[51] According to UNCTAD, the amount of global FDI in 1997 was twice of that in 1990.

[52] Non-direct evidences can be referred to Haar (1989) and Christophe (1997).

that relates FDI with risk among the forum of international business literature. The key hypothesis of portfolio diversification states that decentralization of investment can enfeeble concentration of risk through FDI. This theory seems to be somewhat close to the topic of the chapter, but it is not essentially the same. Firstly, the theory emphasizes diversification instead of FDI in risk aversion; secondly, it meets a same difficulty as those popular ones do mentioned above; and thirdly, it is discredited to a large extent because of its theoretical foundation. As referred in Liyondo (1995), "a more fundamental criticism of this theory has been the argument that in a perfect capital market there is no reason to have firms diversifying activities just to reduce risk for their shareholders... This criticism implies that for the diversification motive to have any explanatory power for foreign direct investment, the assumption of perfect capital markets must be dropped."

To achieve theoretical improvement for the literature of international business and international management, we may need to borrow approaches from other theoretical sources about MNCs and market risks.

On the one side, there has been a great amount of literature on decision making concerning portfolio investment. For example, those famous theories like modern portfolio theory pioneered by Markowitz (1952) and Tobin (1958), Sharpe ratio (Sharpe, 1966, 1975, 1994) and option pricing theory (Black and Scholes, 1973, Black, 1976) are all related with portfolio investment and market risk. Conspicuously, there lacks of due theoretical concern on the relationship between foreign direct investment and market risk. However, some valuable findings and arguments from the literature about portfolio investment and market risk are not necessarily inutile when we are studying MNCs and market risk in a real market perspective. The reason is simple because an agent would be risk-averse and take corresponding risk avoiding countermeasures in a real market as he or she behaves in a financial one.

On the other side, to date, inquires concerning FDI and market risk are always umbilical on some aspect and lack of general studies. For example, they would just discuss MNCs and political risk (e.g., Kobrin, 1978, Erol, 1985), or FDI and exchange rate risk (Kohlhagen, 1977, Itagaki, 1981, Dixit, 1989a, 1989b, Cushman, 1988). MNCs and other business risk like illegal technology imitation and diffusion have

been discussed by Grossman and Helpman (1991a) and Ethier and Markusen (1996). Most of these works find that FDI is negatively correlated with these specific risks, but there are also opposite discoveries, such as an empirical piece from Goldberg and Kolstad (1995).

Coming to a conclusion, the above text has pointed out various shortcomings of available theories. In order to corroborate MNCs theories, it can be ascertained that a more appropriate and general treatment of MNCs and market risk is needed. The chapter would explain why FDI can function as a means of risk aversion in real markets. In other words, we will find out why being a MNC is more advantageous, which can serve as another explication about why a MNC "...would be able to compete with locally owned establishments in performing these activities despite the disadvantages that derive from unfamiliarity with local customs, language, business practices..." (see Grossman and Helpman, 1995)

There is such literature as Doukas and Travlos (1988), Gomes and Ramaswamy (1999), and Morck and Yeung (1991) arguing that being a MNC can benefit from its multinationality. These papers voice their viewpoints not based on risk aversion however. They stress the advantage of being a MNC lies in factor price differential, economies of scale and shareholders' valuation. The chapter would step forward and discuss the benefit of being a MNC from the aspect of risk aversion instead and will solve the dilemma international business literature comes across.

## 3.3 The model

We design a symmetric two corporations-two countries model. Assumed to be two open economies, different from the perfect competition framework specified in the chapters one and two, each country in the model has only one corporation. Each corporation would invest in both domestic and foreign markets ($d$ and $f$). Since allowing different types of market risks in both markets which can be economic and non-economic, we assume each corporation is risk-averse, and would set its respective price considering the information of market risk. Therefore, the market structure is monopolistic and price determination is endogenous, which is not subject to the curse upon the assumption of perfect capital markets.

The corporations are profit maximizers and risk-averse. Total profit function of

a corporation is specified as the addition of profit in domestic and foreign markets adjusted by market risk. Since the corporations are symmetric mentioned above, we only write down the objective function for the corporation $d$, given by (1):

$$\max T\Pi_d = \Pi_d + \Pi_{d_f} - \tfrac{1}{\omega} Var(r_{d_d} + r_{d_f} + r_{f_d} + r_{f_f}) \quad (1)$$

$T\Pi_d$ means total profit of the corporation $d$, which is addition of the profit in its home market $\Pi_d$ and the foreign market $\Pi_{d_f}$ by FDI. The total profit has been adjusted by the variance term $Var(r_{d_d} + r_{d_f} + r_{f_d} + r_{f_f})$. $r_{d_d}$, $r_{d_f}$, $r_{f_d}$, and $r_{f_f}$ are assumed to be total four kinds of risk in the two markets. $r_{d_d}$ is the market risk in the home market of the corporation $d$, and $r_{d_f}$ is the one the corporation $d$ would face when directly investing in the market $f$. Similar interpretation applies to $r_{f_d}$ and $r_{f_f}$. $\omega$ is risk tolerance, which is the same for both the corporations $d$ and $f$. As before, the production functions for the corporation $d$ in its home and foreign markets are Cobb-Douglas:

$$Q_d = a_d I_d^{\beta_d} L_d^{\gamma_d} \quad (2)$$
$$Q_{d_f} = a_{d_f} I_{d_f}^{\beta_{d_f}} L_{d_f}^{\gamma_{d_f}} \quad (2')$$

Now we would denote the risk of individual market more specifically. With a similar form to the so-called RiskMetrics[53] estimation in financial literature, we assume the relationship between market risk and profit having a formula as follows:

$$r_{d_d}^2 = \varphi_{d_d} \Pi_{d_d-1}^2 + (1 - \varphi_{d_d}) r_{d_d-1}^2 \quad (3)$$

That is to say, the current home market risk square faced by the corporation $d$ is equal to the weighted sum of the risk square it faced and its profit square in the market of last period. Solving the difference equation, we can have

$$r_{d_d} = \sqrt{\frac{A_{d_d}(1-\varphi_{d_d}) + \Pi_{d_d}^2 - \varphi_{d_d}\Pi_{d_d}^2}{(1-\varphi_{d_d})}} \quad (4)$$

Similarly, we can have the formula for $r_{d_f}$, $r_{f_d}$, and $r_{f_f}$ :

[53] RiskMetrics model is a benchmark for measuring financial risk. For a brief introduction of its history of evolution, one can refer to "Return to RiskMetrics: The evolution of a standard, " http://www.gloriamundi.org/var/pub/rrm.pdf and Longerstaey and Zangari (1996).

$$r_{d_f} = \sqrt{\frac{A_{d_f}(1-\varphi_{d_f})+\Pi_{d_f}^2-\varphi_{d_f}\Pi_{d_f}^2}{(1-\varphi_{d_f})}} \quad (5)$$

$$r_{f_d} = \sqrt{\frac{A_{f_d}(1-\varphi_{f_d})+\Pi_{f_d}^2-\varphi_{f_d}\Pi_{f_d}^2}{(1-\varphi_{f_d})}} \quad (6)$$

$$r_{f_f} = \sqrt{\frac{A_{f_f}(1-\varphi_{f_f})+\Pi_{f_f}^2-\varphi_{f_f}\Pi_{f_f}^2}{(1-\varphi_{f_f})}} \quad (7)$$

Let the price function of the corporation $d$ be:

$$P_d = A_d - Q_{d_d} - Q_{f_d} \quad (8)$$

where $A_d$ is a positive constant. To expand the $Var(r_{d_d} + r_{d_f} + r_{f_d} + r_{f_f})$, we need to differentiate two possibilities: one is that $r_{d_d}$, $r_{d_f}$, $r_{f_d}$ and $r_{f_f}$ is uncorrelated and the other is on the contrary.

### 3.3.1 When the market risk of the two countries is uncorrelated

Substituting $\Pi_d$ and $\Pi_{d_f}$ with $Q_{d_d}(P_d - c_d)$ and $Q_{d_f}(P_f - c_f)$, (1) can be rewritten as (9).

$$T\Pi_d = Q_{d_d}(P_d - c_d) + Q_{d_f}(P_f - c_f) \\ -\tfrac{1}{\omega}Var(r_{d_d} + r_{d_f} + r_{f_d} + r_{f_f}) \quad (9)$$

Replacing (2) and (2') into (9), we can have

$$T\Pi_d = a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}}(P_d - c_d) + a_{d_f} I_{d_f}^{\beta_{d_f}} L_{d_f}^{\gamma_{d_f}}(P_f - c_f) \\ -\tfrac{1}{\omega}r_{d_d}^2 - \tfrac{1}{\omega}r_{d_f}^2 - \tfrac{1}{\omega}r_{f_d}^2 - \tfrac{1}{\omega}r_{f_f}^2 \quad (10)$$

which can be further rewritten as:

$$T\Pi_d = a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}}(A_d - Q_{d_d} - Q_{f_d} - c_d) + a_{d_f} I_{d_f}^{\beta_{d_f}} L_{d_f}^{\gamma_{d_f}}(A_f - Q_{f_f} \\ -Q_{d_f} - c_f) + a_{f_d} I_{f_d}^{\beta_{f_d}} L_{f_d}^{\gamma_{f_d}}(A_d - Q_{f_d} - Q_{d_d} - c_d) + \\ a_{f_f} I_{f_f}^{\beta_{f_f}} L_{f_f}^{\gamma_{f_f}}(A_f - Q_{d_f} - Q_{f_f} - c_f) - \tfrac{1}{\omega}\frac{r_{d_d+1}^2 - \varphi_{d_d}\Pi_{d_d}^2}{(1-\varphi_{d_d})} \\ -\tfrac{1}{\omega}\frac{r_{d_f+1}^2 - \varphi_{d_f}\Pi_{d_f}^2}{(1-\varphi_{d_f})} - \tfrac{1}{\omega}\frac{r_{f_d+1}^2 - \varphi_{f_d}\Pi_{f_d}^2}{(1-\varphi_{f_d})} - \tfrac{1}{\omega}\frac{r_{f_f+1}^2 - \varphi_{f_f}\Pi_{f_f}^2}{(1-\varphi_{f_f})} \quad (11)$$

where

$$P_f = A_f - Q_{f_f} - Q_{d_f} \quad (12)$$

$$Q_{f_d} = a_{f_d} I_{f_d}^{\beta_{f_d}} L_{f_d}^{\gamma_{f_d}} \quad (13)$$

$$Q_{f_f} = a_{f_f} I_{f_f}^{\beta_{f_f}} L_{f_f}^{\gamma_{f_f}} \quad (14)$$

To solve for optimal investment and labor employment, we need to expand all the related terms in (11), and reattain a more detailed one in (15):

$$
\begin{gathered}
T\Pi_d = a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} (A_d - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} - Q_{f_d} - c_d) \\
+(q_f - a_{f_f} I_{f_f}^{\beta_{f_f}} L_{f_f}^{\gamma_{f_f}})(A_f - Q_{f_f} - Q_{d_f} - c_f) + a_{f_d} I_{f_d}^{\beta_{f_d}} L_{f_d}^{\gamma_{f_d}} (A_d - Q_{f_d} \\
-Q_{d_d} - c_d) + a_{f_f} I_{f_f}^{\beta_{f_f}} L_{f_f}^{\gamma_{f_f}} (A_f - Q_{d_f} - Q_{f_f} - c_f) \\
A_{d_d}(1-\varphi_{d_d}) + (a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} (A_d - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} - Q_{f_d} - c_d))^2 \\
-\frac{1}{\omega} \frac{-\varphi_{d_d}(a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} (A_d - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} - Q_{f_d} - c_d))^2}{(1-\varphi_{d_d})} \\
A_{d_f}(1-\varphi_{d_f}) + (a_{d_f} {I_{d_f}}^{\beta_{d_f}} {L_{d_f}}^{\gamma_{d_f}} (A_f - Q_{f_f} - Q_{d_f} - c_f))^2 \\
-\frac{1}{\omega} \frac{-\varphi_{d_f}(a_{d_f} {I_{d_f}}^{\beta_{d_f}} {L_{d_f}}^{\gamma_{d_f}} (A_f - Q_{f_f} - Q_{d_f} - c_f))^2}{(1-\varphi_{d_f})} \\
-\frac{1}{\omega} \frac{r_{f_d+1}^2 - \varphi_{f_d} \Pi_{f_d}^2}{(1-\varphi_{f_d})} - \frac{1}{\omega} \frac{r_{f_f+1}^2 - \varphi_{f_f} \Pi_{f_f}^2}{(1-\varphi_{f_f})} \quad (15)
\end{gathered}
$$

Applying FOC with respect to $I_{d_d}$,

$$
\begin{gathered}
\frac{dT\Pi_d}{dI_{d_d}} = a_{d_d} \beta_{d_d} I_{d_d}^{\beta_{d_d}-1} L_{d_d}^{\gamma_{d_d}} (A_d - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} - \\
Q_{f_d} - c_d) - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} \beta_{d_d} a_{d_d} I_{d_d}^{\beta_{d_d}-1} L_{d_d}^{\gamma_{d_d}} \\
2a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} (A_d - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} - Q_{f_d} - c_d)[a_{d_d} \beta_{d_d} I_{d_d}^{\beta_{d_d}-1} L_{d_d}^{\gamma_{d_d}} (A_d - \\
a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} - Q_{f_d} - c_d) - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} \beta_{d_d} a_{d_d} I_{d_d}^{\beta_{d_d}-1} L_{d_d}^{\gamma_{d_d}}] - \\
\varphi_{d_d} 2a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} (A_d - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} - Q_{f_d} - c_d)[a_{d_d} \beta_{d_d} I_{d_d}^{\beta_{d_d}-1} L_{d_d}^{\gamma_{d_d}} (A_d \\
-a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} - Q_{f_d} - c_d) - a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} \beta_{d_d} a_{d_d} I_{d_d}^{\beta_{d_d}-1} L_{d_d}^{\gamma_{d_d}}] \\
-\frac{1}{\omega} 2r_{d_d} \frac{}{(1-\varphi_{d_d})} = 0 \\
(16)
\end{gathered}
$$

which can be simplified as:

$$
\begin{gathered}
\frac{\omega}{2a_{d_d} 2r_{d_d}} = I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} (A_d - Q_{f_d} - c_d) - I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} a_{d_d} I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} \\
I_{d_d}^{2\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} a_{d_d} L_{d_d}^{\gamma_{d_d}} - I_{d_d}^{\beta_{d_d}} L_{d_d}^{\gamma_{d_d}} (A_d - Q_{f_d} - c_d) - \frac{\omega}{2a_{d_d} 2r_{d_d}} = 0 \quad (17)
\end{gathered}
$$

(15) is factually a quadratic equation, solved from which

$$
I_{d_d}^{\beta_{d_d}} = \frac{L_{d_d}^{\gamma_{d_d}} (A_d - Q_{f_d} - c_d) \pm \sqrt{L_{d_d}^{2\gamma_{d_d}} (A_d - Q_{f_d} - c_d)^2 + L_{d_d}^{\gamma_{d_d}} a_{d_d} L_{d_d}^{\gamma_{d_d}} \frac{\omega}{a_{d_d} r_{d_d}}}}{2 L_{d_d}^{\gamma_{d_d}} a_{d_d} L_{d_d}^{\gamma_{d_d}}} \quad (18)
$$

Since $(L_{d_d}^{\gamma_{d_d}} (A_d - Q_{f_d} - c_d) - \sqrt{L_{d_d}^{2\gamma_{d_d}} (A_d - Q_{f_d} - c_d)^2 + L_{d_d}^{\gamma_{d_d}} a_{d_d} L_{d_d}^{\gamma_{d_d}} \frac{\omega}{a_{d_d} r_{d_d}}})$ is less than zero, the positive one of $I_{d_d}^{\beta_{d_d}}$ in (18) would be kept. Then, the optimal investment and labor employment for the corporation $d$ in its home and foreign markets is:

$$I^*_{d_d} = \sqrt[\beta_{d_d}]{\frac{(A_d - Q^*_{f_d} - c_d) + \sqrt{(A_d - Q^*_{f_d} - c_d)^2 + \frac{\omega}{r_{d_d}}}}{2L^{*\gamma_{d_d}}_{d_d} a_{d_d}}} \quad (19)$$

$$L^*_{d_d} = \sqrt[\gamma_{d_d}]{\frac{(A_d - Q^*_{f_d} - c_d) + \sqrt{(A_d - Q^*_{f_d} - c_d)^2 + \frac{\omega}{r_{d_d}}}}{2I^{*\beta_{d_d}}_{d_d} a_{d_d}}} \quad (20)$$

$$I^*_{d_f} = \sqrt[\beta_{d_f}]{\frac{(A_f - Q^*_{f_f} - c_f) + \sqrt{(A_f - Q^*_{f_f} - c_f)^2 + \frac{\omega}{r_{d_f}}}}{2L^{*\gamma_{d_f}}_{d_f} a_{d_f}}} \quad (21)$$

$$L^*_{d_f} = \sqrt[\gamma_{d_f}]{\frac{(A_f - Q^*_{f_f} - c_f) + \sqrt{(A_f - Q^*_{f_f} - c_f)^2 + \frac{\omega}{r_{d_f}}}}{2I^{*\beta_{d_f}}_{d_f} a_{d_f}}} \quad (22)$$

Easily, the symmetric results for the corporation $f$ are given by (23) to (26):

$$I^*_{f_d} = \sqrt[\beta_{f_d}]{\frac{(A_d - Q^*_{d_d} - c_d) + \sqrt{(A_d - Q^*_{d_d} - c_d)^2 + \frac{\omega}{r_{f_d}}}}{2L^{*\gamma_{f_d}}_{f_d} a_{f_d}}} \quad (23)$$

$$L^*_{f_d} = \sqrt[\gamma_{f_d}]{\frac{(A_d - Q^*_{d_d} - c_d) + \sqrt{(A_d - Q^*_{d_d} - c_d)^2 + \frac{\omega}{r_{f_d}}}}{2I^{*\beta_{f_d}}_{f_d} a_{f_d}}} \quad (24)$$

$$I^*_{f_f} = \sqrt[\beta_{f_f}]{\frac{(A_f - Q^*_{d_f} - c_f) + \sqrt{(A_f - Q^*_{d_f} - c_f)^2 + \frac{\omega}{r_{f_f}}}}{2L^{*\gamma_{f_f}}_{f_f} a_{f_f}}} \quad (25)$$

$$L^*_{f_f} = \sqrt[\gamma_{f_f}]{\frac{(A_f - Q^*_{d_f} - c_f) + \sqrt{(A_f - Q^*_{d_f} - c_f)^2 + \frac{\omega}{r_{f_f}}}}{2I^{*\beta_{f_f}}_{f_f} a_{f_f}}} \quad (26)$$

And now we would go on to find out the optimal production of the corporation $d$ in its domestic market ($Q^*_{d_d}$) and the foreign market ($Q^*_{d_f}$). For this purpose, (19) would be rewritten into (27):

$$2L^{*\gamma_{d_d}}_{d_d} 2I^{*\beta_{d_d}}_{d_d} a_{d_d}(A_d - Q^*_{f_d} - c_d) = (L^{*\gamma_{d_d}}_{d_d} 2I^{*\beta_{d_d}}_{d_d} a_{d_d})^2 - \frac{\omega}{r_{d_d}} \quad (27)$$

It is straightforward to solve for $Q^*_{d_d}$, given by

$$Q^*_{d_d} = A_d - c_d - L^{*\gamma_{f_d}}_{f_d} I^{*\beta_{f_d}}_{f_d} a_{f_d} + \frac{\frac{\omega}{r_{d_d}}}{4L^{*\gamma_{f_d}}_{f_d} I^{*\beta_{f_d}}_{f_d} a_{f_d}} \quad (28)$$

$$Q^*_{d_f} = A_f - c_f - L^{*\gamma_{f_f}}_{f_f} I^{*\beta_{f_f}}_{f_f} a_{f_f} + \frac{\frac{\omega}{r_{d_f}}}{4L^{*\gamma_{f_f}}_{f_f} I^{*\beta_{f_f}}_{f_f} a_{f_f}} \quad (29)$$

The optimal productions of the corporation $f$ in its home and foreign markets are:

$$Q^*_{f_f} = A_f - c_f - I^{*\beta_{d_f}}_{d_f} L^{*\gamma_{d_f}}_{d_f} a_{d_f} + \frac{\frac{\omega}{r_{f_f}}}{4I^{*\beta_{d_f}}_{d_f} L^{*\gamma_{d_f}}_{d_f} a_{d_f}} \quad (30)$$

$$Q^*_{f_d} = A_d - c_d - L^{*\gamma_{d_d}}_{d_d} I^{*\beta_{d_d}}_{d_d} a_{d_d} + \frac{\frac{\omega}{r_{f_d}}}{4L^{*\gamma_{d_d}}_{d_d} I^{*\beta_{d_d}}_{d_d} a_{d_d}} \quad (31)$$

From (19) to (26), and (28) to (31), it is clear to see that optimal domestic investment, FDI, labor employment and production of a corporation is negatively correlated with the market risk which may concern. For example, $I^*_{d_d}$, $L^*_{d_d}$ and $Q^*_{d_d}$ is only related with their domestic risk $r_{d_d}$. In shortness, to a corporation, when the market risk of the two countries is not correlated, it only needs to consider the type of risk it would be sure to run counter to without worrying about others, given the market shares of the two corporations in both markets. In the meantime, higher tolerance is positively correlated with investment, labor employment and production of a MNC in both markets[54].

### 3.3.2 When the market risk of the two countries is correlated

On the other way around, when the market risk of the two countries is correlated, (9) should be replaced by (32)

$$\begin{aligned} T\Pi_d = a_{d_d} I^{\beta_{d_d}}_{d_d} L^{\gamma_{d_d}}_{d_d} (P_d - c_d) + a_{d_f} I^{\beta_{d_f}}_{d_f} L^{\gamma_{d_f}}_{d_f} (P_f - c_f) - \tfrac{1}{\omega} r^2_{d_d} \\ -2\tfrac{1}{\omega} r_{d_d} r_{d_f} - 2\tfrac{1}{\omega} r_{d_d} r_{f_d} - 2\tfrac{1}{\omega} r_{d_d} r_{f_f} - 2\tfrac{1}{\omega} r_{d_f} r_{f_d} - \\ 2\tfrac{1}{\omega} r_{d_f} r_{f_f} - 2\tfrac{1}{\omega} r_{f_d} r_{f_f} - \tfrac{1}{\omega} r^2_{d_f} - \tfrac{1}{\omega} r^2_{f_d} - \tfrac{1}{\omega} r^2_{f_f} \quad (32) \end{aligned}$$

The FOCs for optimal investment and labor employment are

$$\begin{aligned} \tfrac{dT\Pi_d}{dI_{d_f}} = 0 = a_{d_f} \beta_{d_f} I^{\beta_{d_f}-1}_{d_f} L^{\gamma_{d_f}}_{d_f} (A_f - Q_{f_f} - \\ a_{d_f} I^{\beta_{d_f}}_{d_f} L^{\gamma_{d_f}}_{d_f} - c_f) - a_{d_f} I^{\beta_{d_f}}_{d_f} L^{\gamma_{d_f}}_{d_f} a_{d_f} \beta_{d_f} I^{\beta_{d_f}-1}_{d_f} L^{\gamma_{d_f}}_{d_f} \\ A_{d_f}(1 - \varphi_{d_f}) + (a_{d_f} {I_{d_f}}^{\beta_{d_f}} {L_{d_f}}^{\gamma_{d_f}} (A_f - Q_{f_f} - Q_{d_f} - c_f))^2 \\ -2\tfrac{1}{\omega} r_{d_d} \tfrac{1}{2} [\frac{-\varphi_{d_f} (a_{d_f} {I_{d_f}}^{\beta_{d_f}} {L_{d_f}}^{\gamma_{d_f}} (A_f - Q_{f_f} - Q_{d_f} - c_f))^2}{(1-\varphi_{d_f})}]^{-\frac{1}{2}} \end{aligned}$$

[54] Additionally, we can see from the model that production of FDI in a foreign market is a substitute to the local production of the local corporation.

$$\frac{2(a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f))[a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}(A_f-Q_{f_f}-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}-c_f)-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}]-2\varphi_{d_f}a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f)[a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}(A_f-Q_{f_f}-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}-c_f)-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}]}{(1-\varphi_{d_f})}-$$

$$2\tfrac{1}{\omega}r_{f_d}\tfrac{1}{2}[\frac{A_{d_f}(1-\varphi_{d_f})+(a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f))^2-\varphi_{d_f}(a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f))^2}{(1-\varphi_{d_f})}]^{-\frac{1}{2}}$$

$$\frac{2(a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f))[a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}(A_f-Q_{f_f}-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}-c_f)-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}]-2\varphi_{d_f}a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f)[a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}(A_f-Q_{f_f}-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}-c_f)-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}]}{(1-\varphi_{d_f})}$$

$$-2\tfrac{1}{\omega}r_{f_f}\tfrac{1}{2}[\frac{A_{d_f}(1-\varphi_{d_f})+(a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f))^2-\varphi_{d_f}(a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f))^2}{(1-\varphi_{d_f})}]^{-\frac{1}{2}}$$

$$\frac{2(a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f))[a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}(A_f-Q_{f_f}-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}-c_f)-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}]-2\varphi_{d_f}a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f)[a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}(A_f-Q_{f_f}-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}-c_f)-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}]}{(1-\varphi_{d_f})}$$

$$\frac{2\varphi_{d_f}a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f)[a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}(A_f-Q_{f_f}-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}-c_f)-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}]}{2-\varphi_{d_f}}-$$

$$-\tfrac{1}{\omega}2r_{d_f}\frac{2\varphi_{d_f}a_{d_f}{I_{d_f}}^{\beta_{d_f}}{L_{d_f}}^{\gamma_{d_f}}(A_f-Q_{f_f}-Q_{d_f}-c_f)[a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}(A_f-Q_{f_f}-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}-c_f)-a_{d_f}I_{d_f}^{\beta_{d_f}}L_{d_f}^{\gamma_{d_f}}a_{d_f}\beta_{d_f}I_{d_f}^{\beta_{d_f}-1}L_{d_f}^{\gamma_{d_f}}]}{(1-\varphi_{d_f})} \quad (33)$$

With simplification and rearrangement, the optimal investment, labor employment and production by the corporation is given from (34) to (39):

$$I_{d_d}^*=\sqrt[\beta_{d_d}]{\frac{(A_d-Q_{f_d}^*-c_d)+\sqrt{(A_d-Q_{f_d}^*-c_d)^2+2\frac{\omega}{r_{d_f}r_{d_d}^{-1}+r_{f_d}r_{d_d}^{-1}+r_{f_f}r_{d_d}^{-1}+2r_{d_d}}}}{2L_{d_d}^{*\gamma_{d_d}}a_{d_d}}} \quad (34)$$

$$I^*_{d_f} = \sqrt[\beta_{d_f}]{\frac{(A_f - Q^*_{f_f} - c_f) + \sqrt{(A_f - Q^*_{f_f} - c_f)^2 + 2\frac{\omega}{r_{d_d} r_{d_f}^{-1} + r_{f_d} r_{d_f}^{-1} + r_{f_f} r_{d_f}^{-1} + 2r_{d_f}}}}{2L^{*\gamma_{d_f}}_{d_f} a_{d_f}}} \quad (35)$$

$$L^*_{d_d} = \sqrt[\gamma_{d_d}]{\frac{(A_d - Q^*_{f_d} - c_d) + \sqrt{(A_d - Q^*_{f_d} - c_d)^2 + 2\frac{\omega}{r_{d_f} r_{d_d}^{-1} + r_{f_d} r_{d_d}^{-1} + r_{f_f} r_{d_d}^{-1} + 2r_{d_d}}}}{2I^{*\beta_{d_d}}_{d_d} a_{d_d}}} \quad (36)$$

$$L^*_{d_f} = \sqrt[\gamma_{d_f}]{\frac{(A_f - Q^*_{f_f} - c_f) + \sqrt{(A_f - Q^*_{f_f} - c_f)^2 + 2\frac{\omega}{r_{d_d} r_{d_f}^{-1} + r_{f_d} r_{d_f}^{-1} + r_{f_f} r_{d_f}^{-1} + 2r_{d_f}}}}{2I^{*\beta_{d_f}}_{d_f} a_{d_f}}} \quad (37)$$

$$Q^*_{d_d} = A_d - c_d - L^{*\gamma_{f_d}}_{f_d} I^{*\beta_{f_d}}_{f_d} a_{f_d} + \frac{\frac{\omega}{r_{d_d} r_{f_d}^{-1} + r_{d_f} r_{f_d}^{-1} + r_{f_f} r_{f_d}^{-1} + 2r_{f_d}}}{L^{*\gamma_{f_d}}_{f_d} 2I^{*\beta_{f_d}}_{f_d} a_{f_d}} \quad (38)$$

$$Q^*_{d_f} = A_f - c_f - L^{*\gamma_{f_f}}_{f_f} I^{*\beta_{f_f}}_{f_f} a_{f_f} + \frac{\frac{\omega}{r_{d_d} r_{f_f}^{-1} + r_{f_d} r_{f_f}^{-1} + r_{d_f} r_{f_f}^{-1} + 2r_{f_f}}}{L^{*\gamma_{f_f}}_{f_f} 2I^{*\beta_{f_f}}_{f_f} a_{f_f}} \quad (39)$$

The corresponding results for the corporation $f$ are given from (40) to (45):

$$I^*_{f_f} = \sqrt[\beta_{f_f}]{\frac{(A_f - Q^*_{d_f} - c_f) + \sqrt{(A_f - Q^*_{d_f} - c_f)^2 + 2\frac{\omega}{r_{d_f} r_{f_f}^{-1} + r_{f_d} r_{f_f}^{-1} + r_{d_d} r_{f_f}^{-1} + 2r_{f_f}}}}{2L^{*\gamma_{f_f}}_{f_f} a_{f_f}}} \quad (40)$$

$$I^*_{f_d} = \sqrt[\beta_{f_d}]{\frac{(A_d - Q^*_{d_d} - c_d) + \sqrt{(A_d - Q^*_{d_d} - c_d)^2 + 2\frac{\omega}{r_{d_d} r_{f_d}^{-1} + r_{d_f} r_{f_d}^{-1} + r_{f_f} r_{f_d}^{-1} + 2r_{f_d}}}}{2L^{*\gamma_{f_d}}_{f_d} a_{f_d}}} \quad (41)$$

$$L^*_{f_f} = \sqrt[\gamma_{f_f}]{\frac{(A_f - Q^*_{d_f} - c_f) + \sqrt{(A_f - Q^*_{d_f} - c_f)^2 + 2\frac{\omega}{r_{d_f} r_{f_f}^{-1} + r_{f_d} r_{f_f}^{-1} + r_{d_d} r_{f_f}^{-1} + 2r_{f_f}}}}{2I^{*\beta_{f_f}}_{f_f} a_{f_f}}} \quad (42)$$

$$L^*_{f_d} = \sqrt[\gamma_{f_d}]{\frac{A_d - Q^*_{d_d} - c_d) + \sqrt{(A_d - Q^*_{d_d} - c_d)^2 + 2\frac{\omega}{r_{d_d} r_{f_d}^{-1} + r_{d_f} r_{f_d}^{-1} + r_{f_f} r_{f_d}^{-1} + 2r_{f_d}}}}{2I^{*\beta_{f_d}}_{f_d} a_{f_d}}} \quad (43)$$

$$Q^*_{f_d} = A_d - c_d - L^{*\gamma_{d_d}}_{d_d} I^{*\beta_{d_d}}_{d_d} a_{d_d} + \frac{\frac{\omega}{r_{d_f} r_{f_d}^{-1} + r_{d_d} r_{f_d}^{-1} + r_{f_f} r_{f_d}^{-1} + 2r_{f_d}}}{L^{*\gamma_{d_d}}_{d_d} 2I^{*\beta_{d_d}}_{d_d} a_{d_d}} \quad (44)$$

$$Q^*_{f_f} = A_f - c_f - I^{*\beta_{d_f}}_{d_f} L^{*\gamma_{d_f}}_{d_f} a_{d_f} + \frac{\frac{\omega}{r_{d_d} r_{f_f}^{-1} + r_{f_d} r_{f_f}^{-1} + r_{d_f} r_{f_f}^{-1} + 2r_{f_f}}}{I^{*\beta_{d_f}}_{d_f} 2L^{*\gamma_{d_f}}_{d_f} a_{d_f}} \quad (45)$$

As compared with the section 3.3.1, we still can conclude, from (34) to (45), that the optimal domestic investment, FDI, labor employment and production of a corporation is negatively correlated with market risk. But the finding here shows the corporation would be much more sensitive to the risk, when different kinds of which from different markets are correlated with one another. For example, $I^*_{d_d}$, $L^*_{d_d}$ and $Q^*_{d_d}$ is negatively correlated with any one of $r_{d_d}$, $r_{d_f}$, $r_{f_d}$, and $r_{f_f}$.

The other two facts that higher tolerance is positively correlated with investment, labor employment and production and production of FDI in a foreign market is a substitute to the local production of the local corporation still remain the same.

Supplementarily, when we view the price functions for the corporations $d$ and $f$ in their home markets, it can be alluded to that the higher risk, the higher price would be set by the corporations. The fact is also true for the case in the section 3.3.1[55].

$$P_d^* = A_d - Q_{d_d}^* - Q_{f_d}^* = 2c_d + L_{f_d}^{*\gamma_{f_d}} I_{f_d}^{*\beta_{f_d}} a_{f_d} - \frac{\overset{\omega}{\overline{r_{d_d} r_{f_d}^{-1} + r_{d_f} r_{f_d}^{-1} + r_{f_f} r_{f_d}^{-1} + 2r_{f_d}}}}{L_{f_d}^{*\gamma_{f_d}} 2 I_{f_d}^{*\beta_{f_d}} a_{f_d}} -$$
$$A_d + L_{d_d}^{*\gamma_{d_d}} I_{d_d}^{*\beta_{d_d}} a_{d_d} - \frac{\overset{\omega}{\overline{r_{d_f} r_{d_d}^{-1} + r_{f_d} r_{d_d}^{-1} + \sigma_{f_f} r_{d_d}^{-1} + 2r_{d_d}}}}{L_{d_d}^{*\gamma_{d_d}} 2 I_{d_d}^{*\beta_{d_d}} a_{d_d}} \quad (46)$$

$$P_f^* = A_f - Q_{f_f}^* - Q_{d_f}^* = 2c_f + I_{d_f}^{*\beta_{d_f}} L_{d_f}^{*\gamma_{d_f}} a_{d_f} - \frac{\overset{\omega}{\overline{r_{d_d} r_{d_f}^{-1} + r_{f_d} r_{d_f}^{-1} + r_{f_f} r_{d_f}^{-1} + 2r_{d_f}}}}{I_{d_f}^{*\beta_{d_f}} 2 L_{d_f}^{*\gamma_{d_f}} a_{d_f}}$$
$$-A_f + L_{f_f}^{*\gamma_{f_f}} I_{f_f}^{*\beta_{f_f}} a_{f_f} - \frac{\overset{\omega}{\overline{r_{d_d} r_{f_f}^{-1} + r_{f_d} r_{f_f}^{-1} + r_{d_f} r_{f_f}^{-1} + 2r_{f_f}}}}{L_{f_f}^{*\gamma_{f_f}} 2 I_{f_f}^{*\beta_{f_f}} a_{f_f}} \quad (47)$$

Till now, we already can understand why being a MNC is more superior than a counterpart which orients domestically only. Since we know, in the open economies, if the risk of different markets is correlated (the case is extremely likely with integration of world markets), as a non-MNC, it hardly can evade the risk of the foreign markets which can well be conveyed to its home market. Under this circumstance, its decision about investment (domestic), labor employment (domestic), and therefore production would be probably inadequate. Even if assuming the corporation has considered these sources of risk in its operation in the home market, its business behavior is not rational, since it positions itself inferiorly by shouldering unsymmetrical market risk compared to its market share in the world.

On the contrary, being a MNC is a better countermeasure against risk sourced from various markets, reflected in would-be more suitable decision on investment (domestic and FDI), labor employment (domestic and foreign), production (domestic

[55]The corresponding price setings in the home market of the corporations $d$ and $f$ when the market risk of the two countries is not correlated are given by $P_d^* = A_d - Q_{d_d}^* - Q_{f_d}^* = 2c_d + L_{f_d}^{*\gamma_{f_d}} I_{f_d}^{*\beta_{f_d}} a_{f_d} - \frac{\overset{\omega}{\overline{r_{d_d}}}}{4 L_{f_d}^{*\gamma_{f_d}} I_{f_d}^{*\beta_{f_d}} a_{f_d}} - A_d + L_{d_d}^{*\gamma_{d_d}} I_{d_d}^{*\beta_{d_d}} a_{d_d} - \frac{\overset{\omega}{\overline{r_{f_d}}}}{4 L_{d_d}^{*\gamma_{d_d}} I_{d_d}^{*\beta_{d_d}} a_{d_d}}$ and $P_f^* = A_f - Q_{f_f}^* - Q_{d_f}^* = 2c_f + I_{d_f}^{*\beta_{d_f}} L_{d_f}^{*\gamma_{d_f}} a_{d_f} - \frac{\overset{\omega}{\overline{r_{f_f}}}}{4 I_{d_f}^{*\beta_{d_f}} L_{d_f}^{*\gamma_{d_f}} a_{d_f}} - A_f + L_{f_f}^{*\gamma_{f_f}} I_{f_f}^{*\beta_{f_f}} a_{f_f} - \frac{\overset{\omega}{\overline{r_{d_f}}}}{4 L_{f_f}^{*\gamma_{f_f}} I_{f_f}^{*\beta_{f_f}} a_{f_f}}$).

and foreign) and market shares it deserves. A complementary remark is that the function of FDI in risk aversion is only owing to the business behavior of itself and has nothing to do with the notion that diversification of investment can diversify risk.

## 3.4 Further extension

The solutions of the model are ready for more specific problems. For example, $r_{d_d}$ can be subdivided into $r_{dir}$ and $r_{der}$, which represents internal risk and external risk[56] faced by the corporation $d$. Therefore, the home market risk of the corporation $d$ is determined by (48):

$$r_{d_d} = \sqrt{Var(r_{d_d ir}, r_{d_d er})} = \begin{cases} \sqrt{r_{d_d ir}^2 + r_{d_d er}^2} \text{ or} \\ \sqrt{r_{d_d ir}^2 + r_{d_d er}^2 + 2r_{d_d ir, d_d er}} \end{cases} \quad (48)$$

while $r_{d_d ir}^2 = \varphi_{d_d ir}\Pi_{d_d}^2 + (1-\varphi_{d_d ir})r_{d_d ir-1}^2$ and $r_{d_d er}^2 = \varphi_{d_d er}\Pi_{d_d}^2 + (1-\varphi_{d_d er})r_{d_d er-1}^2$. When the risk of the two countries is not correlated, for simplicity, we only observe the optimal domestic production of the corporation $d$ which is:

$$Q_{d_d}^* = A_d - c_d - L_{d_d}^{*\gamma_{d_d}} I_{d_d}^{*\beta_{d_d}} a_{d_d} + \frac{\overset{\omega}{\overline{r_{d_d ir} + r_{d_d er}}}}{4L_{d_d}^{*\gamma_{d_d}} I_{d_d}^{*\beta_{d_d}} a_{d_d}} \quad (49)$$

or

$$Q_{d_d}^* = A_d - c_d - L_{d_d}^{*\gamma_{d_d}} I_{d_d}^{*\beta_{d_d}} a_{d_d} + \frac{\overset{\omega}{\overline{2r_{d_d ir} + 2r_{d_d er} + \frac{r_{d_d er}}{r_{d_d ir}} + \frac{r_{d_d ir}}{r_{d_d er}}}}}{4L_{d_d}^{*\gamma_{d_d}} I_{d_d}^{*\beta_{d_d}} a_{d_d}} \quad (50)$$

The difference between (49) and (50) is subject to whether $r_{d_d ir}$ and $r_{d_d er}$ is correlated or not. Oppositely, when the risk of the two countries is correlated,

$$Q_{d_d}^* = A_d - c_d - L_{f_d}^{*\gamma_{f_d}} I_{f_d}^{*\beta_{f_d}} a_{f_d} + \frac{\overset{\omega}{\overline{(r_{d_d ir}+r_{d_d er})(r_{f_d ir}+r_{f_d er})^{-1} + (r_{d_f ir}+r_{d_f er})(r_{f_d ir}+r_{f_d er})^{-1} + (r_{f_f ir}+r_{f_f er})(r_{f_d ir}+r_{f_d er})^{-1} + 2(r_{f_d ir}+r_{f_d er})}}}{L_{f_d}^{*\gamma_{f_d}} 2I_{f_d}^{*\beta_{f_d}} a_{f_d}} \quad (51)$$

when the internal and external risk of the corporation $d$ and the corporation $f$ is not correlated; or

[56] Internal risk $r_{imr}$ mainly refers to that arising from the corporation itself, such as that arising from internal capital market (see Wulf, 2000). External risk $r_{emr}$ can be inflation risk, exchange rate risk, political risk, environment risk and so on.

$$Q^*_{d_d} = A_d - c_d - L^{*\gamma_{f_d}}_{f_d} I^{*\beta_{f_d}}_{f_d} a_{f_d} +$$

$$\frac{\begin{array}{c}(2r_{d_dir} + 2r_{d_der} + \frac{r_{d_der}}{r_{d_dir}} + \frac{r_{d_dir}}{r_{d_der}})(2r_{f_dir} + 2r_{f_der} + \frac{r_{f_der}}{r_{f_dir}} + \frac{r_{f_dir}}{r_{f_der}})^{-1} + \\ (2r_{d_fir} + 2r_{d_fer} + \frac{r_{d_fer}}{r_{d_fir}} + \frac{r_{d_fir}}{r_{d_fer}})(2r_{f_dir} + 2r_{f_der} + \frac{r_{f_der}}{r_{f_dir}} + \frac{r_{f_dir}}{r_{f_der}})^{-1} + \\ (2r_{f_fir} + 2r_{f_fer} + \frac{r_{f_fer}}{r_{f_fir}} + \frac{r_{f_fir}}{r_{f_fer}})(2r_{f_dir} + 2r_{f_der} + \frac{r_{f_der}}{r_{f_dir}} + \frac{r_{f_dir}}{r_{f_der}})^{-1} \\ +2(2r_{f_dir} + 2r_{f_der} + \frac{r_{f_der}}{r_{f_dir}} + \frac{r_{f_dir}}{r_{f_der}})\end{array}}{L^{*\gamma_{f_d}}_{f_d} 2 I^{*\beta_{f_d}}_{f_d} a_{f_d}} \quad (52)$$

when the internal and external risk of the corporation $d$ and the corporation $f$ is correlated. From (49) to (52), though the exposition of $Q^*_{d_d}$ is becoming more and more complicated, the reflected essential point has no changes, which bears the same argument as the section 3.3.2 does.

Therefore, except those of pricing, functions of investment, labor employment and thus production of a risk-averse MNC in its home and foreign markets monopolistically structured are strictly inverse to risk no matter whether it is correlated or not across markets. And these algebraic formulas indeed can serve as a decision reference for the risk-averse MNC to counter market risk and maximize its total profit.

In sum, in an imperfect competition markets system framed by the chapter, and there is no way to neutralize various market risk from different sources with deeper global economic integration, becoming a multinational is more selectable.

## 3.5 Conclusion

The chapter has shown that, within a monopolistic market framework, a MNC is a better way to evade or counteract market risk coming from various sources, analyzing two different contingencies of market risk, i.e., when risk of the home and foreign markets is correlated and its opposite counterpart.

The finding is embodied in its making more proper decisions about domestic and foreign investment (FDI), labor employment and production and being a MNC is a proper way to shoulder these risks conformably. That may be an (unmindful) rational that a corporation is willing to conduct FDI in foreign markets encountering numerous market risks. Similar to the chapter one, we here obtain another explanation about why a corporation would become a multinational. From the solutions

of employment, production and pricing formula of a MNC, we can see the precision degree of its operation behavior can be raised if it takes into account of various market risks as much as possible. The unresolved theoretical issue in international business and international management literature is done.

There is a convergence hypothesis by Markusen and Venables (1995): "multinationals displace national firms and trade as countries become more similar in size, technology and relative factor endowments". For the two corporations-two countries model is symmetric, the conclusions of the chapter are in line with the hypothesis. However, the hypothesis can not explain why there is no proportionate amount of FDI between developing countries with similar factor endowments. Besides the argument in the chapter one, the model here suggests so, since market risk (like political risk or securities market risk) is relatively lower in developed countries. To developing countries, an induced policy recommendation from the chapter is that they should press down market risk for healthier economy and possible higher FDI inflow.

Over and above, we treat market risk as a broad concept in the chapter. We do not restrict it to be a certain domain, so our theoretical model is general enough to study any kind of risk, economic or non-economic, and is easy to be extended much further to multi-country or unsymmetrical risk degree case.

# 4 Multinational corporations and factor movement

Operation of multinational corporations is closely related to international factor movement and thus economic performance of a country. In the previous chapters, factor movement has been touched under different extent of restriction. How about if there is no restriction? Among the most interesting theoretical issues, one may want to know whether free factor movement can cause economic convergence, like the case of factor price equalization in trade theory where factors are permitted to move freely (though the chapter shows that the proposition may not be true). Some common theoretical and policy concern, like whether labor inflow from another corporation (or country) would do harm to current labor employment in the host corporation (or country), needs further discussion.

The chapter focuses on factors employment and production of MNCs under the circumstance where three kinds of factors, i.e., labor, capital and technology are freely mobile internationally. The chapter finds out, among the three kinds of factor movement, only labor inflow has a complementary effect on labor employment within the MNC concerned given returns to productive factors, social welfare, and property protection are improving and market risk is declining all the time in the related countries. Meanwhile, a numerical estimation shows production of MNCs of developing countries can (but not necessarily) follow up their developed counterparts when free factor movement is permitted. It is concluded therefore that a country (especially an underdeveloped one) should strive for a better social environment rather than economic objects only.

## 4.1 Introduction

MNCs are an important way of organizing global production. Factor movement doubtlessly would affect production of a MNC. For example, the chapter two is involved with factor movement, but the chapter only studies factor movement subject to a certain degree of restriction, i.e., factor movement is not totally free. This chapter will go deeper to study the case where factor movement is completely free, though it could be a utopian for the real economy.

Available theories about factor movement are still limited. We just can not find out there is a perfect theory about factor movement. Traditional international trade theories simply assume productive factors can not be mobile across borders. Wong (1995) has offered two notable reasons for factor movement being ignored by arguing "...historically economic relationships between countries have been determined mainly through the movement of goods" and "...under certain conditions, the theory of international trade in goods can be extended to cover international factor mobility". In the available literature, to the question why there would be international factor movement, most explanations have been given from the economic side. But non-economic ones seem to be far less concerned in those literature even including Wong (1995). As we know, to comprehend some phenomena like factor movement, dependance only on economic logic may not suffice. After all, one does not live just for economic interest.

With economic globalization and an inevitable trend of incessant and growing activities of MNCs, factor movement becoming relatively facilitated across borders. The effect of factor movement on a MNC and a related country may kindle lots of attention, which is not necessarily perfect. Among the most interesting issues, one would want to know whether free factor movement can cause economic convergence, like the case of factor price equalization in traditional trade theory where factors are permitted to move freely (though it has been shown that the proposition may not be true in the chapter). Some common theoretical and policy concern, like whether labor inflow from another corporation (or country) would do harm to current labor employment in the host corporation (or country), needs further enquiry.

The chapter develops corresponding discussion, especially in searching for the solutions of how freely mobile factor affects domestic factors employment in a MNC

when non-economic elements are considered; and whether free factor movement can contribute to production/economic convergence between developed and developing corporations/countries. The answers are elicited which include that labor inflow is positively associated with local labor employment, and that free international factor movement still can not guarantee production convergence between MNCs or economic convergence between countries. Through the study in the relationship between MNCs and factor movement, we have acquired relevant policy implications.

The rest of the text is organized as follows: section 2 is theoretical foundation; section 3 is the model; section 4 is discussion of production/economic convergence; section 5 is policy recommendations and section 6 concludes.

## 4.2 Theoretical foundation

Earlier economic theories about factor movement can be traced to Stolper-Samuelson theory (Stolper and Samuelson, 1941)[57], factor price equalization theory (Samuelson, 1948)[58], Rybczynski theory (Rybczynski, 1955)[59] and so on. They belong to international (goods) trade theories. Gravity of these theories does not lie in the form of factor movement we are interested in, where factors are only allowed to be mobile domestically rather than internationally. Assuming away international mobility of factors, these theories are criticized for being oversimplified and going short of a satisfactory depiction of the real economy. Certainly, these classical trade theories indeed can statically provide predictions associated with (domestic) factor movement under strict assumptions. But, grounding on these theories suggesting factors would flow to a higher paid place[60], we may have a following question: since a factor can move from a domestic sector to another one because of a higher return rate in the latter, why wouldn't the factor, at the very beginning, move to a country where it is scarce and when there exists no international transport cost? These theories, however, avoid the "conjecture" as we have known.

A relatively more direct study related to factor movement can be attributed to

[57] About the relationship between factor prices and product prices.

[58] About the relationship between factor prices and international (goods) trade.

[59] About the relationship between output levels and changes of factor supplies.

[60] A higher payment is an important reason why factors would mobile, but it is not exclusive. We will see this in more details in the following text.

the theory of factor contents of trade. It is also be noted that the starting point of these theories is not for studying international factor movement, but examining trade of goods through examining the amount of factors embodied in trade. The representative works include Travis (1964), Vanek (1968), Leamer (1980), Deardorff (1982) and Ethier (1984). To a large extent, the appearance of these theories is in response to Leontief Paradox. The theorists mean to show if predictions of the HO model are true in reality. No matter whether their test results are consistent or inconsistent with HO model [e.g., findings of Trefler (1995) are contrary to Bowen, Leamer and Sveikauskas (1987)'s, while the former argue that the HO model (more precisely speaking-its another version-Hecksher-Ohlin-Vanek model by Vanek, 1968) performs well], such microeconomic issues as motives of factor movement and how factor inflow affects factors employment of the host country have been seldom discussed. Hence, it requires rethinking if this transformation and arbitrary equivalence between traded goods and factors does make sense. Factor contained in goods is equal to factors endowment being consumed in quantity, but does not conform to the factor movement we usually describe. That is to say, the theory of factor contents of trade is not competent in explaining factor movement. For example, some productive factors can not move freely internationally in their original forms, but may be misunderstood that they can according to the theory.

Of course, there are many other authors who have more adequately studied factor movement, evidenced by the literature like Mundell (1957), Kemp (1966), Caves (1971), Bhagwati (1973), Brecher and Diaz Alejandro (1977), Bhagwati and Hamada (1974, 1982), Markusen and Melvin (1979), Grossman (1984), Markusen (1988) and the more comprehensive Wong (1995). The existent problem is that these works either assume capital movement is exogenous, or have relatively narrow horizon of analysis like studying the relationships of two factors (capital and labor) movement only and so on. Though these works substantially promote research in factor movement, likewise, they still need various modification. For example, they scarcely look into the causes why there would be international factor movement, which are the backbone of a full theory about factor movement. Granting that it can infer partially from these works that capital outflow would happen in a bigger country whose rental rate is lower, or less convincingly, capital would move from a

smaller country to the bigger one in free trade (see Wong, 1995), reasoning with non-economic perspective is evidently not up to the mark[61]. In reality, factor movement is not merely due to economic consideration. Obviously, under many circumstances, social, natural, environmental reasons and so on are crucial determinants. But theoretical development after Wong (1995) seems to be still deviated from deeper inquiry into factor movement. There is no specific reason. In our opinion, perhaps more interests still have been being centered on the theoretical field of intraindustry trade.

In sum, we do not have a perfect theory yet about factor movement till now because of various theoretical no goes mentioned above. As a result, economic theories regarding to international economy are incomplete too. Ineptitude and unjustification of contemporary economic or social policies based on these theories may lead to unanticipated negative consequences. We argue it is of necessity to pry the issues related to factor movement within a more general framework.

It has been shown by the following study which not only combines domestic factors employment and factor inflow, but economic and non-economic elements such as social institution and geography[62]. Based on this model, we can further expect to have some public policies implication for economic growth and development of a country, which could be especially intuitive for developing countries.

## 4.3 The model

We build up a $2 \times 3$ model, i.e., two countries $a$ and $b$, three factors[63] (capital, labor and technology). We still follow major assumptions of the chapters one and two such as perfectly competitive market structure and no transaction costs.

[61] Bhagwati (1985), Salvatore (1991) analyzing FDI in a political economy standing with a postulation that protectionism may cause FDI, and Bhagwati and Hamada (1982) relating international labor migration with education provide some non-economic explanations separately.

[62] Therefore, the chapter will deal with multi-factors production economies. In the academia, it is known that in the situation where there is more than a single productive factor and involvement of other non-economic elements, general relationships among the productive factors and those elements may be not easy to obtain (similar viewpoints can be found in Grossman and Helpman, 1995).

[63] Previous literature seldom explicitly enquires into three-factors (i.e., labor, capital and technology) in an integrated model.

Different from the chapters one, two, and three, the model here is further idealized owing to the assumption that factor movement is free (there is no intervention from each country for factor movement[64]) and legal[65]. We will study two arbitrary corporations from a same industry of these two countries first. $a$ is a corporation from the developed country $a$ and $b$ is from the developing country $b$. In the chapter, a developed country has better social institution, and closer to the market center (more details are in the following section 4.4). Since they are from a same industry, the products the corporations $a$ and $b$ produce can be either the same or differentiated. In the chapter, we assume they are the same.

The two corporations have similar production functions, so we will just specify the details of the corporation $a$ in the main text.

The corporation $a$ has a CES production function:

$$Y_a = (l_a L_a^{1-\varepsilon} + k_a K_a^{1-\varepsilon} + t_a T_a^{1-\varepsilon} + \hat{l}_a \hat{L}_a^{1-\varepsilon} + \hat{k}_a \hat{K}_a^{1-\varepsilon} + \hat{t}_a \hat{T}_a^{1-\varepsilon})^{\frac{1}{1-\varepsilon}} \quad (1)$$

where $\varepsilon$ can have a form theoretically assumed as:

$$\varepsilon = \int_0^{\zeta} (L_a(\Omega_{a_{L_a}}), \hat{L}_a(\Omega_{a_{\hat{L}_a}}), K_a(\Omega_{a_{K_a}}), \hat{K}_b(\Omega_{a_{\hat{K}_a}}), T_a(\Omega_{a_{T_a}}), \hat{T}_a(\Omega_{a_{\hat{T}_a}}), C(\Theta_{a1}), E(\Theta_{a2}), I(\Theta_{a3}))dt$$

$L_a$, $K_a$, and $T_a$ are labor, capital and technology employment in the corporation $a$. $\hat{L}_a$, $\hat{K}_a$, and $\hat{T}_a$ are labor, capital and technology inflow from the corporation $b$ (or the country $b$) and employed by the corporation $a$. $\zeta$ is larger than zero. When $\varepsilon$ tends to be infinitive, the elasticities of substitution among the multiple inputs including local factors employment and factors inflow, approaches to zero, i.e., no substitution among the independent variables on the right hand side of the equation (1); when $\varepsilon$ tends to be zero, the variables would be approximately perfect substitutes of one another.

[64] Although in the real economy, there is strong intervention in labor movement. For example, there is the unrestricted flow of professionals between North America, the European Union countries, Japan and other highly developed countries, from which unskilled migrants are generally excluded there are the flows of low-skilled workers between the Indian subcontinent and the Arabian peninsula, and from the Indian subcontinent and South-East Asia to those countries generally known as the Asian tigers (see Doomernik, 1998).

[65] Some papers like Ethier (1986), Bond and Chen (1987) and Djajic (1987) study illegal factor movement.

$C$, $E$, and $I$ denote culture, education level and social institution respectively[66]. All these non-economic indicators make the consumers goods characterized with social relationships such that we can provide social foundation for factor movement.

$\Theta_{a1}$, $\Theta_{a2}$, and $\Theta_{a3}$ are subsets of $\Theta_a$ which can contain such variables as geography[67], history, and time. $\Omega_{a_{L_a}}$, $\Omega_{a_{\hat{L}_a}}$, $\Omega_{a_{K_a}}$, $\Omega_{a_{\hat{K}_a}}$, $\Omega_{a_{T_a}}$ and $\Omega_{a_{\hat{T}_a}}$ are subsets of $\Omega_a$ which can include these variables such as payment to productive factors, social environment, natural environment, time, demographic structure[68], labor standard, and safeguard level of property rights and the like in the country $a$. $\Theta$ and $\Omega$ can have overlapping domains. In the case of labor migration, people always make decision based on their financial ability, compare economically, politically and institutionally among places they live and work and other ones where they intend to go, and then determine finally which are better for living and working temporarily or permanently. In fact, capital movement and technology transfer would have their own similar considerations too.

In the mathematical expression (1), international factor inflow is an external factors employment modeled as having symmetric function contributing to production of the corporation $a$. The way we model this type of factors employment is on the basis of three considerations: (1) in the process of economic globalization, restrictions on factor movement are expected to be less severe than before, it can be reasonable to assume more and more countries would eventually adopt positive measures to encourage productive factor inflow including labor, capital and tech-

[66]If all these variables can overlap, then the corporations or countries $a$ and $b$ can be viewed as homogeneous, otherwise, these two corporations are heterogeneous. The categorization is more or less different from most literature which argues whether a country is homogeneous or not to one another is basically based on the country's resource endowment.

[67]Geography is viewed as a dynamic concept in the chapter rather than a purely static geographic location [e.g., Baldwin and Forslid (1999) argue that economic growth and location are interactive]. Dynamics of geography is in the sense that when a developing corporation is converging to a developed one in production and the like, the location of the former is becoming more important, supposing the developed corporation is initially located closer to the market center while the developing one is closer to the market periphery.

[68]Demographic structure (such as rate of population growth or population migration characteristics) can affect production growth, which is closely related to factor employment in a country. Studies of direct relationship of growth and demography can be referred to Bloom, Canning and Malancy (1999), Ghose (1999) and so on.

nology; (2) inquiry of factor movement and production growth in a more general context is in order to contribute to the current literature; (3) to fix a groundwork for posterior discussion about what a developing country should do in knowledge economy or information times, since it may have been aware that factor movement is a key way to catch up with developed countries and thus stretch a hand for better understanding of functions of policies in economic development.

Let factor movement functions have the endogenous forms:

$$\hat{L}_a = \frac{\hat{w}_{L_{a/b}}^{x_2} \hat{W}_{a/b}^{x_5}}{D^{x_1} K_a^{x_3} T_a^{x_4}} t^{x_6} \quad (2)$$

From (2), we can see labor movement from the corporation $b$ is positively correlated with time, $\hat{w}_{L_{a/b}}$ and $\hat{W}_{a/b}$, where $\hat{w}_{L_{a/b}}$ is change of $w_{L_a}$ (wage rate of labor in the corporation $a$) divided by change of $w_{L_b}$ (wage rate of labor in the corporation $b$); and $\hat{W}_{a/b}$, change of $W_a$ divided by change of $W_b$, denotes comparison of a non-economic variable-social security (or social institution) between the two countries, where $W_a$ and $W_b$ is social security situation in the countries $a$ and $b$ respectively.

$\hat{L}_a$ is negatively correlated with $D$, where $D$ is distance between the corporations $a$ and $b$, and employment of capital and technology in the corporation $a$. (2) gives an account of why labor would move into another country economically and non-economically, i.e., labor mobility is also subject to situation of social security of a country. A good social security environment would be attractive to labor inflow. Similar specification and logic is applied in (3) and (4).

$$\hat{K}_a = \frac{\hat{w}_{K_{a/b}}^{x_{11}}}{D^{x_7} L_a^{x_8} T_a^{x_9} \hat{R}_{a/b}^{x_{10}}} t^{x_{12}} \quad (3)$$

Capital movement from the corporation $b$ is positively correlated with time and $\hat{w}_{K_{a/b}}$, where $\hat{w}_{K_{a/b}}$ is change of return to capital of the country $a$ ($w_{k_a}$) divided by change of $w_{k_b}$; but negatively correlated with distance, labor and technology employment in the corporation $a$ and risk degree. $\hat{R}_{a/b}$ is comparison of market risk between the countries $a$ and $b$, equal to change of $R_a$ divided by change of $R_b$[69].

$$\hat{T}_a = \frac{\hat{w}_{T_{a/b}}^{x_{17}}}{D^{x_{13}} L_a^{x_{14}} K_a^{x_{15}} \hat{P}n_{a/b}^{x_{16}}} t^{x_{18}} \quad (4)$$

[69]As discussed in the chapter three, market risk mentioned here can be economic or non-economic.

Technology movement from the corporation $b$ is positively correlated with time and $\hat{w}_{T_{a/b}}$, where $\hat{w}_{T_{a/b}}$ is change of return to technology of the country $a$ ($w_{T_a}$) divided by change of $w_{T_b}$; but negatively correlated with distance[70], labor and capital employment in the corporation $a$ and $\hat{P}n_{a/b}$. $\hat{P}n_{a/b}$ is comparison of protection of property rights between the countries $a$ and $b$, equal to change of $Pn_a$ divided by change of $Pn_b$.

In equations (2), (3) and (4), $D$, $t$, $L_a$, $K_a$ and $T_a$ are larger than zero, while $\hat{w}_{L_{a/b}}$, $\hat{w}_{K_{a/b}}$, $\hat{W}_{a/b}$, $\hat{w}_{T_{a/b}}$, $\hat{R}_{a/b}$, and $\hat{P}n_{a/b}$ can have positive or negative values. We do not exclude the possibility that absolute decrease in economic growth and social welfare could happen in both countries $a$ and $b$ here at a certain time. Through the simultaneous equations group (2), (3) and (4), we can have more illustrative functions for factors employment in the corporation $a$ from equations (8), (9) and (10).

Then we will have more illustrative functions for factors employment in the corporation $a$:

$$L_a = \left(\frac{\hat{w}_{K_{a/b}}^{x_{11}-\frac{x_{11}x_4x_{15}}{x_9(x_3-x_{15})}} \hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}} \hat{T}_a^{1+\frac{x_{15}}{x_3-x_{15}}} \hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}} \hat{P}n_{a/b}^{\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16}}}{D^F \hat{R}_{a/b}^{x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})}} \hat{K}_a^{1-\frac{x_4x_{15}}{x_9(x_3-x_{15})}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}}} t^B\right)^{\frac{1}{A}} \quad (5)$$

$$K_a = \left(\frac{\hat{w}_{T_{a/b}}^{x_{17}} \hat{w}_{K_{a/b}}^{\frac{x_{11}^2x_4x_{15}}{x_9(x_3-x_{15})}\frac{x_{14}}{A}} \hat{K}_a^{(1-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}} \hat{R}_{a/b}^{(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}}{D^{x_{13}-F\frac{x_{14}}{A}} \hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}} \hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}} \hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_{14}}{A}+1} \hat{P}n_{a/b}^{x_{16}+(\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16})\frac{x_{14}}{A}}} t^{x_{18}-\frac{B}{A}x_{14}}\right)^{\frac{1}{x_{15}}} \quad (6)$$

$$T_a = \left(\frac{\hat{w}_{K_{a/b}}^{x_{11}-(x_{11}-\frac{x_{11}x_4x_{15}}{x_3-x_{15}})\frac{x_{14}}{A}} \hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_8}{A}} \hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{P}n_{a/b}^{x_{16}+\frac{x_{16}x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_8}{A}}}{D^{x_7-F\frac{x_8}{A}} \hat{R}_{a/b}^{x_{10}-(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}} \hat{K}_a^{(1-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}} t^{x_{12}-\frac{B}{A}x_8}\right)^{\frac{1}{x_9}} \quad (7)$$

where

$$A = x_8 - x_4 - \frac{x_4x_{15}}{x_3-x_{15}} - \frac{x_8}{x_9}\frac{x_4x_{15}}{x_3-x_{15}}$$
$$B = x_{12} - x_{18} + \frac{(x_6-x_{18})x_{15}}{x_3-x_{15}} - \frac{x_{12}}{x_9}\frac{x_4x_{15}}{x_3-x_{15}}$$
$$F = x_7 - x_{13} + \frac{x_{15}(x_1-x_{13})}{x_7-x_{13}} - \frac{x_7}{x_9}\frac{x_4x_{15}}{x_3-x_{15}}$$

[70]We can see from (2), (3) and (4), that $\hat{L}$, $\hat{K}$, and $\hat{T}$ are all assumed to be negatively correlated with distance. There is empirical support for this specification, e.g., Blomstrom, Lipsey, and Kulchycky (1988) conclude that there is insignificant relationship between distance and MNCs activities.

Since we are interested to find out the effect of factor inflow of the corporation $b$ on the current employment of the corporation $a$, we can differentiate factors employment of the corporation $a$ with respect to the corresponding factor inflow, and the expression formulas of the differentiation are given by (8) to (16):

$$\frac{dL_a}{d\hat{L}_a} = \frac{1}{A} L_a^{A(\frac{1}{A}-1)} (-\frac{x_{15}}{x_3 - x_{15}}) \hat{L}_a^{-\frac{x_{15}}{x_3 - x_{15}} - 1} \Gamma_{13} \quad (8)$$

$$\frac{dK_a}{d\hat{L}_a} = \frac{1}{x_{15}} K_a^{x_{15}(\frac{1}{x_{15}}-1)} \frac{x_{15}x_{14}}{(x_3 - x_{15})A} \hat{L}_a^{\frac{x_{15}x_{14}}{(x_3 - x_{15})A} - 1} \Gamma_{14} \quad (9)$$

$$\frac{dT_a}{d\hat{L}_a} = \frac{1}{x_9} T_a^{x_9(\frac{1}{x_9}-1)} \frac{x_{15}x_8}{(x_3 - x_{15})A} \hat{L}_a^{\frac{x_{15}x_8}{(x_3 - x_{15})A} - 1} \Gamma_{15} \quad (10)$$

$$\frac{dL_a}{d\hat{K}_a} = \frac{1}{A} L_a^{A(\frac{1}{A}-1)} (\frac{x_4 x_{15}}{x_9(x_3 - x_{15})} - 1) \hat{K}_a^{\frac{x_4 x_{15}}{x_9(x_3 - x_{15})} - 2} \Gamma_{16} \quad (11)$$

$$\frac{dK_a}{d\hat{K}_a} = \frac{1}{x_{15}} K_a^{x_{15}(\frac{1}{x_{15}}-1)} (1 - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})}) \frac{x_{14}}{A} \hat{K}_a^{(1 - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})})\frac{x_{14}}{A} - 1} \Gamma_{17} \quad (12)$$

$$\frac{dT_a}{d\hat{K}_a} = \frac{1}{x_9} T_a^{x_9(\frac{1}{x_9}-1)} ((1 - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})}) \frac{x_8}{A} - 1) \hat{K}_a^{(1 - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})})\frac{x_8}{A} - 2} \Gamma_{18} \quad (13)$$

$$\frac{dL_a}{d\hat{T}_a} = \frac{1}{A} L_a^{A(\frac{1}{A}-1)} (1 + \frac{x_{15}}{x_3 - x_{15}}) \hat{T}_a^{\frac{x_{15}}{x_3 - x_{15}}} \Gamma_{19} \quad (14)$$

$$\frac{dK_a}{d\hat{T}_a} = \frac{1}{x_{15}} K_a^{x_{15}(\frac{1}{x_{15}}-1)} (-(1 + \frac{x_{15}}{x_3 - x_{15}}) \frac{x_{14}}{A} - 1) \hat{T}_a^{-(1 + \frac{x_{15}}{x_3 - x_{15}})\frac{x_{14}}{A} - 2} \Gamma_{20} \quad (15)$$

$$\frac{dT_a}{d\hat{T}_a} = \frac{1}{x_9} T_a^{x_9(\frac{1}{x_9}-1)} (1 + \frac{x_{15}}{x_3 - x_{15}}) \frac{x_8}{A} \hat{T}_a^{(1 + \frac{x_{15}}{x_3 - x_{15}})\frac{x_8}{A} - 1} \Gamma_{21} \quad (16)$$

Due to the uncertainty of the signs of $\hat{w}_{L_{a/b}}$, $\hat{w}_{K_{a/b}}$, $\hat{w}_{T_{a/b}}$, $\hat{W}_{a/b}$, $\hat{R}_{a/b}$ and $\hat{P}n_{a/b}$, $\Gamma_{13}, ...,$ and $\Gamma_{21}$, which are provided in the Appendix B, are also uncertain in the sense of the sign. But, we simply assume they are all positive[71], where returns to factors, social welfare, and property protection are improving and market risk is decreasing simultaneously all the time in both the countries $a$ and $b$. Therefore, we can have: the larger $\hat{W}_{a/b}$, the faster progress of social security in the country $a$; the larger $\hat{R}_{a/b}$, the more improvement in reducing market risk in the country $a$ (in which $x_{10}$ is less than zero); and the larger $\hat{P}n_{a/b}$, the more likely a better property institution in the country $a$ (in which $x_{16}$ is less than zero). So it is permitted that there can be larger divergence (economic, social or institutional) between the two countries if a country improves faster than the other one does. From the initial specification of (2), (3) and (4), except $x_{10}$ and $x_{16}$ are negative, $x_1$, $x_2$,..., and $x_{18}$ are all positive numbers. Observing (8) to (16), we would need to determine the sign

[71]The assumption factually excludes the possibility that factors moving in may flee out, which happens in many developing countries. The results of the chapter may be different without the assumption that the factors like social welfare and property rights protection in these two countries are not improving all the time.

of $(x_3 - x_{15})$. To guarantee that $\frac{dK_a}{d\hat{L}_a}$, $\frac{dT_a}{d\hat{L}_a}$, $\frac{dL_a}{d\hat{K}_a}$, $\frac{dT_a}{d\hat{K}_a}$, $\frac{dL_a}{d\hat{T}_a}$ and $\frac{dK_a}{d\hat{T}_a}$ are negative from (2), (3) and (4), there can be two possibilities. The first one is: $(x_3 - x_{15})$ is smaller than zero and $A$ and $(1 - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})})$ are larger than zero; the other alternative is: $(x_3 - x_{15})$ is larger than zero and $A$ and $(1 - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})})$ are less than zero at the same time.

But only the second possibility is feasible. Since from the expressions of $L_a$, $K_a$ and $T_a$ in (5), (6) and (7), it can be inferred that $A$ and $(1 - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})})$ have to be less than zero, while $(1 + \frac{x_{15}}{x_3 - x_{15}})$ and $\frac{x_{15}}{x_3 - x_{15}}$ are larger than zero. If $A$ and $(1 - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})})$ are larger than zero, while $(1 + \frac{x_{15}}{x_3 - x_{15}})$ and therefore $\frac{x_{15}}{x_3 - x_{15}}$ are less than zero, there will be contradiction between (2)-(4) and (5)-(7).

So we can find out that the key result, i.e., $\frac{dL_a}{d\hat{L}_a} \succ 0$, $\frac{dK_a}{d\hat{K}_a} \prec 0$ and $\frac{dT_a}{d\hat{T}_a} \prec 0$, which shows that labor inflow from the corporation $b$ is a complement to the current labor employment of the corporation $a$, but capital and technology inflow is a substitute. $(x_3 - x_{15})$ larger than zero can be interpreted as the substitution effect of capital employment in the corporation $a$ on capital inflow is larger than that on technology inflow, which conforms to the common economic sense[72].

Now we skip from the individual profit function of the corporation $a$, and directly

[72]Though domestic factor employment is not the main concern of the chapter compared to factor movement, there are three points worthy of being noticed:

(a) $L_a$ is negatively correlated with $\hat{W}_{a/b}$, which implies the better the social security of a country, the less domestic labor employment. Intuitively, domestic labor in a country with better social environment is less willing to work;

(b) $K_a$ is positively correlated with $\hat{R}_{a/b}$, which can be shown by a positive

$$\underbrace{(x_{10} - \frac{x_4 x_{15}}{x_9(x_3 - x_{15})})}_{\prec 0} \underbrace{\frac{x_{14}}{A}}_{\prec 0}$$

which means less market risk of a country would also encourages its domestic investment;

and (c) the relationship between $T_a$ and $\hat{P}n_{a/b}$ is uncertain, since it would rely on the sign of

$$(\underbrace{x_{16}}_{\prec 0} + \underbrace{\frac{x_{16} x_{15}}{x_3 - x_{15}} \frac{x_8}{A}}_{\succ 0})$$

The intuition is that a sounder property rights protection does not necessarily lead to higher application of domestic technology.

turn to the total profit function of the country $a$ which is given by (17).

$$\Pi_{Ta} = \max \sum_{i=1}^{n} (P_{ai}X_{ai} - w_{Lai}L_{ai} - w_{Kai}K_{ai} - w_{Tai}T_{ai} - w_{\hat{L}ai}\hat{L}_{ai} - w_{\hat{K}ai}\hat{K}_{ai} - w_{\hat{T}ai}\hat{T}_{ai}) \quad (17)$$

The objective function is subject to the resource constraints as $\sum_{i=1}^{n} L_{ai} = L_{Ta}$, $\sum_{i=1}^{n} K_{ai} = K_{Ta}$ and $\sum_{i=1}^{n} T_{ai} = T_{Ta}$. $\Pi_{Ta}$ is total corporate profit of the country $a$; $L_{Ta}$, $K_{Ta}$ and $T_{Ta}$ are the total labor, capital and technology endowment of the country $a$. $w_{Lai}$, $w_{Kai}$, $w_{Tai}$ are the employment prices of labor (wage), capital (interest rate) and technology (covering expenses used for such as innovation and maintenance in producing the ith product) of the corporation $i$ of the country $a$. $w_{\hat{L}ai}$, $w_{\hat{K}ai}$, and $w_{\hat{T}ai}$ are the employment prices of labor, capital and technology inflow from the corporation $b$. $P_{ai}X_{ai}$ is factually $Y_{ai}$. $w_{Lai} = w_{\hat{L}ai}$, $w_{Kai} = w_{\hat{K}ai}$, or $w_{Tai} = w_{\hat{T}ai}$ may or may not hold.

Principally, the optimal employment level of domestic factors and international factors can be determined by solving the FOCs, i.e., $\frac{d\Pi_{Ta}}{dL_{ai}} = 0$, $\frac{d\Pi_{Ta}}{dK_{ai}} = 0$, $\frac{d\Pi_{Ta}}{dT_{ai}} = 0$, $\frac{d\Pi_{Ta}}{d\hat{L}_{ai}} = 0$, $\frac{d\Pi_{Ta}}{d\hat{K}_{ai}} = 0$ and $\frac{d\Pi_{Ta}}{d\hat{T}_{ai}} = 0$. Because we concern more factor movement, the concrete expressions of the FOCs of factor inflow are given from (18) to (20):

$$\begin{aligned}
&\frac{d\Pi_{Ta}}{d\hat{L}_{ai}} = \sum_{i=1}^{n} \frac{dY_{ai}}{d\hat{L}_{ai}} - \sum_{i=1}^{n} (w_{Lai}\frac{dL_{ai}}{d\hat{L}_{ai}} + w_{Kai}\frac{dK_{ai}}{d\hat{L}_{ai}} + \\
&w_{Tai}\frac{dT_{ai}}{d\hat{L}_{ai}} + w_{\hat{L}ai} + w_{\hat{K}ai}\frac{d\hat{K}_{ai}}{d\hat{L}_{ai}} + w_{\hat{T}ai}\frac{d\hat{T}_{ai}}{d\hat{L}_{ai}}) = \\
&\sum_{i=1}^{n} [Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)} l_{ai} L_{ai}^{-\varepsilon} \frac{1}{A_i} (L_{ai}^{A_i})^{\frac{1}{A_i}-1} (-\frac{x_{15i}}{x_{3i}-x_{15i}}) \hat{L}_{ai}^{-\frac{x_{15i}}{x_{3i}-x_{15i}}-1} \Gamma_{4i} + \\
&Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)} k_{ai} K_{ai}^{-\varepsilon} \frac{1}{x_{15i}} (K_{ai}^{x_{15i}})^{\frac{1}{x_{15i}}-1} \frac{x_{15i}x_{14i}}{(x_{3i}-x_{15i})A_i} \hat{L}_{ai}^{\frac{x_{15i}x_{14i}}{(x_{3i}-x_{15i})A_i}-1} \Gamma_{5i} \\
&+Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)} t_{ai} T_{ai}^{-\varepsilon} \frac{1}{x_{9i}} (T_{ai}^{x_{9i}})^{\frac{1}{x_{9i}}-1} \frac{x_{15i}x_{8i}}{(x_{3i}-x_{15i})A_i} \hat{L}_{ai}^{\frac{x_{15i}x_{8i}}{(x_{3i}-x_{15i})A_i}-1} \Gamma_{6i} + \\
&Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)} \hat{l}_{ai} \hat{L}_{ai}^{-\varepsilon}] - \sum_{i=1}^{n} [w_{Lai}\frac{1}{A_i}(L_{ai}^{A_i})^{\frac{1}{A_i}-1}(-\frac{x_{15i}}{x_{3i}-x_{15i}})\hat{L}_{ai}^{-\frac{x_{15i}}{x_{3i}-x_{15i}}-1}\Gamma_{13i} + \\
&w_{Kai}\frac{1}{x_{15i}}(K_{ai}^{x_{15i}})^{\frac{1}{x_{15i}}-1}\frac{x_{15i}x_{14i}}{(x_{3i}-x_{15i})A_i}\hat{L}_{ai}^{\frac{x_{15i}x_{14i}}{(x_{3i}-x_{15i})A_i}-1}\Gamma_{14i} \\
&+w_{Tai}\frac{1}{x_{9i}}(T_{ai}^{x_{9i}})^{\frac{1}{x_{9i}}-1}\frac{x_{15i}x_{8i}}{(x_{3i}-x_{15i})A_i}\hat{L}_{ai}^{\frac{x_{15i}x_{8i}}{(x_{3i}-x_{15i})A_i}-1}\Gamma_{15i} \\
&+w_{\hat{L}ai} + w_{\hat{K}ai}\frac{d\hat{K}_{ai}}{d\hat{L}_{ai}} + w_{\hat{T}ai}\frac{d\hat{T}_{ai}}{d\hat{L}_{ai}}] = 0 \quad (18)
\end{aligned}$$

$$\begin{aligned}
&\frac{d\Pi_{Ta}}{d\hat{K}_{ai}} = \sum_{i=1}^{n} \frac{dY_{ai}}{d\hat{K}_{ai}} - \sum_{i=1}^{n} (w_{Lai}\frac{dL_{ai}}{d\hat{K}_{ai}} + w_{Kai}\frac{dK_{ai}}{d\hat{K}_{ai}} + w_{Tai}\frac{dT_{ai}}{d\hat{K}_{ai}} + w_{\hat{K}ai} + \\
&w_{\hat{L}ai}\frac{d\hat{L}_{ai}}{d\hat{K}_{ai}} + w_{\hat{T}ai}\frac{d\hat{T}_{ai}}{d\hat{K}_{ai}}) = \sum_{i=1}^{n} [Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)} l_{ai} L_{ai}^{-\varepsilon} \frac{1}{A_i} (L_{ai}^{A_i})^{\frac{1}{A_i}-1} \\
&(\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}} - 1)\hat{K}_{ai}^{\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}}-2}\Gamma_{7i} + Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)} k_{ai} K_{ai}^{-\varepsilon} \frac{1}{x_{15i}} (K_{ai}^{x_{15i}})^{\frac{1}{x_{15i}}-1} \\
&(1 - \frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}})\frac{x_{14i}}{A_i}\hat{K}_{ai}^{(1-\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}})\frac{x_{14i}}{A_i}-1}\Gamma_{8i}
\end{aligned}$$

$$+Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)}t_{ai}T_{ai}^{-\varepsilon}\frac{1}{x_{9i}}(T_{ai}^{x_{9i}})^{\frac{1}{x_{9i}}-1}[(1-\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}})\frac{x_{18i}}{A_i}$$
$$-1]\hat{K}_{ai}^{(1-\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}})\frac{x_{18i}}{A_i}-2}\Gamma_{9i}+Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)}\hat{k}_{ai}\hat{K}_{ai}^{-\varepsilon}]$$
$$-\sum_{i=1}^{n}[w_{Lai}\frac{1}{A_i}(L_{ai}^{A_i})^{\frac{1}{A_i}-1}(\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}}-1)\hat{K}_{ai}^{\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}}-2}\Gamma_{16i}+$$
$$w_{Kai}\frac{1}{x_{15i}}(K_{ai}^{x_{15i}})^{\frac{1}{x_{15i}}-1}(1-\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}})\frac{x_{14i}}{A_i}\hat{K}_{ai}^{(1-\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}})\frac{x_{14i}}{A_i}-1}\Gamma_{17i}$$
$$+w_{Tai}\frac{1}{x_{9i}}(T_{ai}^{x_{9i}})^{\frac{1}{x_{9i}}-1}[(1-\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}})\frac{x_{18i}}{A_i}$$
$$-1]\hat{K}_{ai}^{(1-\frac{1}{x_{9i}}\frac{x_{4i}x_{15i}}{x_{3i}-x_{15i}})\frac{x_{18i}}{A_i}-2}\Gamma_{18i}+w_{\hat{K}ai}+w_{\hat{L}ai}\frac{d\hat{L}_{ai}}{d\hat{K}_{ai}}+w_{\hat{T}ai}\frac{d\hat{T}_{ai}}{d\hat{K}_{ai}}]=0 \quad (19)$$

$$\frac{d\Pi_{Ta}}{d\hat{T}_{ai}}=\sum_{i=1}^{n}\frac{dY_{ai}}{d\hat{T}_{ai}}-\sum_{i=1}^{n}(w_{Lai}\frac{dL_{ai}}{d\hat{T}_{ai}}+w_{Kai}\frac{dK_{ai}}{d\hat{T}_{ai}}+w_{Tai}\frac{dT_{ai}}{d\hat{T}_{ai}}+w_{\hat{T}_{ai}}$$
$$+w_{\hat{L}ai}\frac{d\hat{L}_{ai}}{d\hat{T}_{ai}}+w_{\hat{K}ai}\frac{d\hat{K}_{ai}}{d\hat{T}_{ai}})=\sum_{i=1}^{n}[Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)}l_{ai}L_{ai}^{-\varepsilon}\frac{1}{A_i}(L_{ai}^{A_i})^{\frac{1}{A_i}-1}(1+$$
$$\frac{x_{15i}}{x_{3i}-x_{15i}})\hat{T}_{ai}^{\frac{x_{15i}}{x_{3i}-x_{15i}}}\Gamma_{10i}+Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)}k_{ai}K_{ai}^{-\varepsilon}\frac{1}{x_{15i}}(K_{ai}^{x_{15i}})^{\frac{1}{x_{15i}}-1}[-(1+$$
$$\frac{x_{15i}}{x_{3i}-x_{15i}})\frac{x_{14i}}{A_i}-1]\hat{T}_{ai}^{-(1+\frac{x_{15i}}{(x_{3i}-x_{15i})})\frac{x_{14i}}{A_i}-2}\Gamma_{11i}+Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)}t_{ai}T_{ai}^{-\varepsilon}\frac{1}{x_{9i}}(T_{ai}^{x_{9i}})^{\frac{1}{x_{9i}}-1}(1+$$
$$\frac{x_{15i}}{x_{3i}-x_{15i}})\frac{x_{8i}}{A_i}\hat{T}_{ai}^{(1+\frac{x_{15i}}{(x_{3i}-x_{15i})})\frac{x_{8i}}{A_i}-1}\Gamma_{12i}+\frac{1}{1-\varepsilon}Y_{ai}^{(1-\varepsilon)(\frac{1}{1-\varepsilon}-1)}\hat{t}_{ai}(1-\varepsilon)\hat{T}_{ai}^{-\varepsilon}]$$
$$-\sum_{i=1}^{n}[w_{Lai}\frac{1}{A_i}(L_{ai}^{A_i})^{\frac{1}{A_i}-1}(1+\frac{x_{15i}}{x_{3i}-x_{15i}})\hat{T}_{ai}^{\frac{x_{15i}}{x_{3i}-x_{15i}}-1}\Gamma_{19i}+$$
$$w_{Kai}\frac{1}{x_{15i}}(K_{ai}^{x_{15i}})^{\frac{1}{x_{15i}}-1}[-(1+\frac{x_{15i}}{(x_{3i}-x_{15i})})\frac{x_{14i}}{A_i}-1]\hat{T}_{ai}^{-(1+\frac{x_{15i}}{(x_{3i}-x_{15i})})\frac{x_{14i}}{A_i}-2}\Gamma_{20i}$$
$$+w_{Tai}\frac{1}{x_{9i}}(T_{ai}^{x_{9i}})^{\frac{1}{x_{9i}}-1}(1+\frac{x_{15i}}{x_{3i}-x_{15i}})\frac{x_{8i}}{A_i}\hat{T}_{ai}^{(1+\frac{x_{15i}}{x_{3i}-x_{15i}})\frac{x_{8i}}{A_i}-1}\Gamma_{21i}$$
$$+w_{\hat{T}ai}+w_{\hat{L}ai}\frac{d\hat{L}_{ai}}{d\hat{T}_{ai}}+w_{\hat{K}ai}\frac{d\hat{K}_{ai}}{d\hat{T}_{ai}}]=0 \quad (20)$$

Within these derivative equations from (18), (19) and (20), we know they are just pure addition of positive and negative terms ($\Gamma_{4i}$, ..., and $\Gamma_{21i}$ are given by $\Gamma_4$, ..., and $\Gamma_{21}$ with the subscript $i$ added in the Appendix B). The optimal employment of factor inflow for the country $a$ can be solved from (18), (19) and (20) theoretically. We do not provide the explicit solutions for the optimal factor inflows for the country $a$ since they are not crucial for the theme of the chapter. Intuitively, the country $a$ may potentially desire an optimal amount of employment of factor inflow for each of its corporations from the country $b$ if maximization of total profit is firmly its objective.

Regarding to the corporation $b$ and the country $b$, since they have similar production, factor movement and profit functions, it is easy to get the similar results inferred from the corporation $a$ and the country $a$. That is, there is also complementary effect of labor inflow from the corporation $a$ on the labor employment in the corporation $b$, capital and technology inflow having substitution effect (the corresponding factor movement and related derivative functions are provided in the

Appendix B). To the corporation $b$, maximization of total profit may not be its highest goal. Pursuance of technological progress or production convergence may be more salutary for its long run interest. The Proposition 6 of the chapter two which implies production convergence can be an explanation.

Before we proceed to the next section discussing production/economic convergence, we would talk a little bit about some side results from the model. The model permits two types of general equilibria not subject to factor price equalization within countries $a$ and $b$. One is that factor movement becomes standstill. For example, if the social welfare of the developed country $a$ is much better than that of the developing country $b$, labor of the developing country would still have a tendency to migrate out even though the remuneration is the same in both countries. The equilibrium will end up with when the migration in certain or all industries across the two countries comes to a steady state. The other one is production of both countries and thus trade between them can reach their local maximum values for a certain period of time. The second type will be expounded numerically in the following text. So a general equilibrium of trade is not necessarily accompanied with factor price equalization in our model – different from traditional trade models. In other words, free mobility of factor movement may not lead to factor price equalization when non-economic factors are considered.

Since the market structure in both countries is perfectly competitive, the result of the general equilibrium is more like a multi-cone equilibrium termed by Deardorff (2000)[73]. However, our model has shown a multi-cone equilibrium does not need to exist in groups of countries. On the contrary, it can also exist in a two-country case within each of which factor price equalization is allowed. And a multi-cone equilibrium is not necessarily caused by contrasting factor endowment[74]. The multi-cone equilibrium or failure of global factor price equalization can well survive in

[73]The definition of "multi-cone" equilibrium is, according to Deardorff (2000), "in which different groups of countries have different factor prices and specialize with free trade in different collections of goods."

[74]Deardorff (1998) argues there are two kinds of global free trade equilibria. The equilibria are characterized with scope of factor prices equalization. One is global when factor endowment of countries are not too different, and the other one is regional when the endowment of countries are rather different.

the long run if there is lasting, say, distinction in social environment between the countries $a$ and $b$.

## 4.4 Discussion of production/economic convergence

Production convergence and economic convergence is treated the same in the chapter. Therefore, the assumption that products produced by the corporations $a$ and $b$ are the same is not just for simplification, which makes it feasible to conduct comparison of production of the two corporations. Production/economic convergence here is defined as that total production of the corporation $b$ is growing faster than that of the corporation $a$[75].

With the fact that corporation $a$ (or the country $a$) may desire an optimal quantity of factor inflow in mind, pursuance of the corporation $b$ (or the country $b$) for production convergence (or economic convergence) in the perfectly competitive environment is within the bounds of possibility, where geography, culture, and social institution can play a critical role.

We have provided a numerical study on economic convergence with the above theoretical model. As a preliminary step of more rigorously enquiring into the effect of non-economic factors, the following study does not fully employ the complete theoretical forms of $\varepsilon$ of the corporation $a$ and $\theta$ of the corporation $b$[76]. It only considers a simpler case that $\varepsilon$ and $\theta$ are the function of geography, social institution and time. The simplified forms of $\varepsilon$ and $\theta$ are

$$\varepsilon = \int_0^{\zeta} G_{agro}(.)^{\alpha_{ageo}} I_{asoc}(.)^{\beta_{asoc}} tdt, \quad (21)$$

$$\theta = \int_0^{\psi} G_{bgro}(.)^{\alpha_{bgeo}} I_{bsoc}(.)^{\beta_{bsoc}} tdt \quad (22)$$

respectively.

Because there are no well-performed indicators to denote geography $G$ and social institution $I$, we assume values of $G$ and $I$ are valued from one to ten. If $G$ and

[75] The meaning is different from that in Barro and Sala-i-Martin (1992) however, where economic convergence is in the sense that economies tend to grow faster in per capita terms.

[76] The production function of the corporation $b$ is given by $Y_b = (l_b L_b^{1-\theta} + k_b K_b^{1-\theta} + t_b T_b^{1-\theta} + \hat{l}_b \hat{L}_b^{1-\theta} + \hat{k}_b \hat{K}_b^{1-\theta} + \hat{t}_b \hat{T}_b^{1-\theta})^{\frac{1}{1-\theta}}$, where $\theta = \int_0^{\psi} (L_b(\Omega_{b_{L_b}}), \hat{L}_b(\Omega_{b_{\hat{L}_b}}), K_b(\Omega_{b_{K_b}}), \hat{K}_b(\Omega_{b_{\hat{K}_b}}), T_b(\Omega_{b_{T_b}}), \hat{T}_b(\Omega_{b_{\hat{T}_b}}), C(\Theta_{b1}), E(\Theta_{b2}), I(\Theta_{b3}))dt$.

$I$ are all equal to ten, then they represent the best state of geography and social institution, i.e., a corporation locates in the center of the world market and the social institution benefits the most to its production growth and vice versa. $G_{ageo}$ denotes geography of the corporation $a$; $I_{ageo}$ denotes the social institution faced by the corporation $a$. $G_{bgeo}$ and $I_{bgeo}$ denote geography and the social institution for the corporation $b$.

To study whether there is a possibility of convergence between these two corporations, we can calculate the values of $Y_a$ and $Y_b$ in the cases, for example, when $\zeta = 10$ (the tenth year) and 20 (the twentieth year) with 0 being the base year. The values of $G$ and $I$ of the corporation $a$ should be larger than those of the corporation $b$ according to the assumption. Arbitrarily, we pick $G = 6$ and $I = 7$ for the corporation $a$, while $G = 4$ and $I = 5$ for the corporation $b$.

Due to the specification of the model, it can be inferred that elasticities of substitution among the multiple inputs of the country $a$ (the developed one) would be lower than those of the country $b$, which is contrasting to the argument of the literature such as Olarreaga (2000) or Klump and Grandville (2000). An intuition can be, compared to developing ones, in developed countries, better social institution may lead to more rules-based employment which is however less substitutable among different productive factors.

We can initially obtain some visual impression from presentment of Figures 6 to 13. Figures 6, 8, 10 and 11 are for the corporation $a$ (whose $G = 6$ and $I = 7$), whereas Figures 7, 9, 12 and 13 are for the corporation $b$ (whose $G = 4$ and $I = 5$). Values for $\alpha_{ageo}$, $\beta_{asoc}$, $\alpha_{bgeo}$, $\beta_{bsoc}$ and parameters like $l_a$, $k_a$, $t_a$ and so on are simply set to be 1. These figures plot out the relationships of three variables, i.e., $Y$, $L$ and $K$, similar inference applied when more productive factors are included.

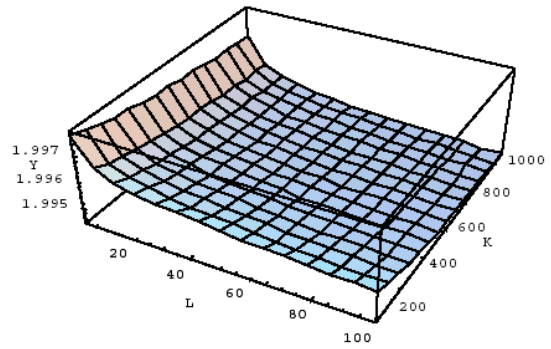


Figure 6 (when time is $t$, $t \in [0, 10]$)

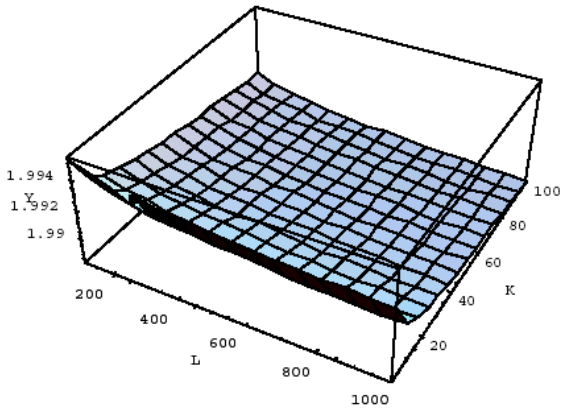


Figure 7 (when time is $t$, $t \in [0, 10]$)

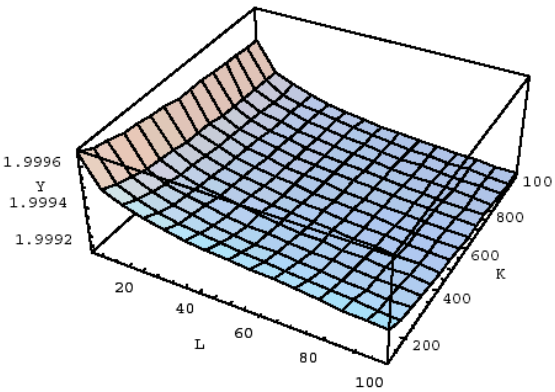


Figure 8 (when time is $t^2$ , $t \in [0, 10]$)

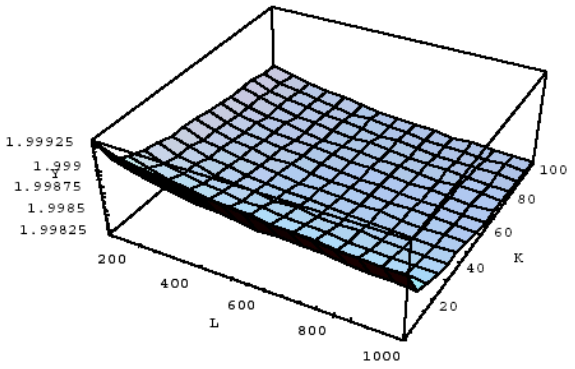


Figure 9 (when time is $t^2$, $t \in [0, 10]$)

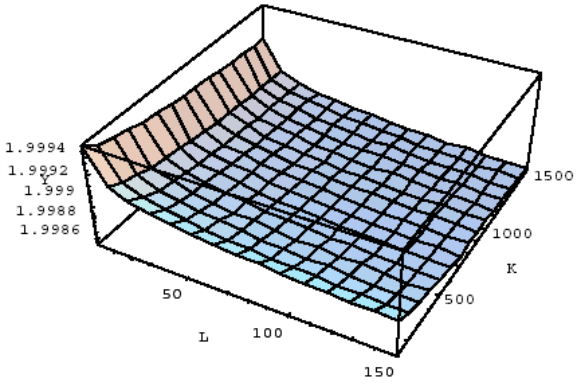


Figure 10 (when time is $t$, $t \in [0, 20]$)

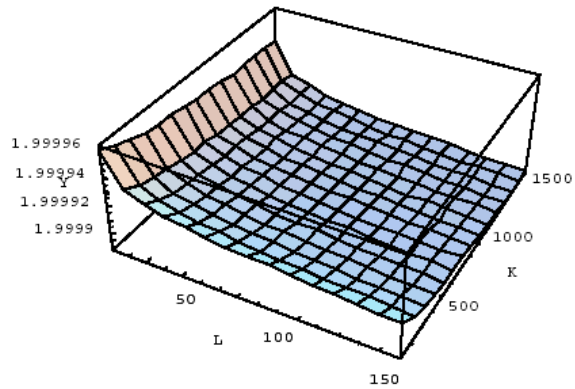


Figure 11 (when time is $t^2$, $t \in [0, 20]$)

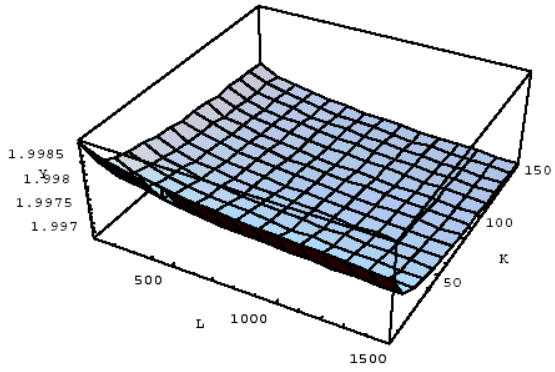


Figure 12 (when time is $t$, $t \in [0, 20]$)

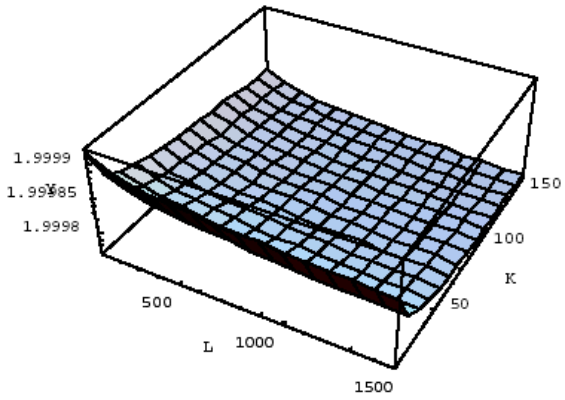


Figure 13 (when time is $t^2$, $t \in [0, 20]$)

From Figures 6 to 13, there are two noticeable facts. One is that better geography and social institution affects positively output. Compared between Figures 6 and 7, where, without losing generality, labor and capital employment is valued within the sets [1, 100] and [100, 1000] respectively for the case of the corporation $a$, and the other way around for the case of the corporation $b$, it is clear that the corporation $a$ achieves a higher output, 1.997 larger than 1.994. And the other one is that time specification matters. Given other factors, output of corporations $a$ and $b$ is higher when time is $t^2$.

More complete numerical results considering all the factors employment and factor inflows are given in the following tables, which exactly conclude that there can be production/economic convergence or divergence between these two corpora-

tions/countries besides what we have reached above.

### 4.4.1 Economic convergence

Assuming the parameters of domestic factors employment and factor inflows in both the corporations $a$ and $b$ are all constant. Suppose growth rates of employment of domestic labor, capital and technology, and employment of labor, capital and technology inflow of the corporations $a$ and $b$ are 2%, 4%, 10%, 3.33%, 12.5%, 10%, 10%, 40%, 5%, 40%, 25% and 40% on average per year respectively. Additionally, parameters $l_a$, $k_a$, $t_a$ and so on remaining to be 1, let $\alpha_{ageo} = \beta_{asoc} = 0.6$ and $\alpha_{bgeo} = \beta_{bsoc} = 0.4$, which further reflects the difference of both the corporations in their nature and the role of geography and social institution.

Table 1 (when time is $t$)

| | | | |
|---|---|---|---|
| $L = 100$ | The $10^{th}$ year $Y_a = 10$ | $L = 120$ | The $20^{th}$ year $Y_a = 20.001$ |
| $K = 200$ | | $K = 400$ | |
| $T = 400$ | | $T = 900$ | |
| $L_{in} = 10$ | | $L_{in} = 20$ | |
| $K_{in} = 20$ | | $K_{in} = 30$ | |
| $T_{in} = 40$ | | $T_{in} = 50$ | |
| $G = 6$ | | $G = 6$ | |
| $I = 7$ | | $I = 7$ | |

| | | | |
|---|---|---|---|
| $L = 1000$ | The $10^{th}$ year $Y_b = 2.0043$ | $L = 1400$ | The $20^{th}$ year $Y_b = 10$ |
| $K = 150$ | | $K = 200$ | |
| $T = 50$ | | $T = 100$ | |
| $L_{in} = 2$ | | $L_{in} = 10$ | |
| $K_{in} = 4$ | | $K_{in} = 20$ | |
| $T_{in} = 6$ | | $T_{in} = 30$ | |
| $G = 4$ | | $G = 4$ | |
| $I = 5$ | | $I = 5$ | |

Table 1' (when time is $t^2$)

| | | | |
|---|---|---|---|
| $L = 100$ | The $10^{th}$ year $Y_a = 9.9995$ | $L = 120$ | The $20^{th}$ year $Y_a = 20$ |
| $K = 200$ | | $K = 400$ | |
| $T = 400$ | | $T = 900$ | |
| $L_{in} = 10$ | | $L_{in} = 20$ | |
| $K_{in} = 20$ | | $K_{in} = 30$ | |
| $T_{in} = 40$ | | $T_{in} = 50$ | |
| $G = 6$ | | $G = 6$ | |
| $I = 7$ | | $I = 7$ | |

| | | | |
|---|---|---|---|
| $L = 1000$ | The $10^{th}$ year $Y_b = 2.0006$ | $L = 1400$ | The $20^{th}$ year $Y_b = 10$ |
| $K = 150$ | | $K = 200$ | |
| $T = 50$ | | $T = 100$ | |
| $L_{in} = 2$ | | $L_{in} = 10$ | |
| $K_{in} = 4$ | | $K_{in} = 20$ | |
| $T_{in} = 6$ | | $T_{in} = 30$ | |
| $G = 4$ | | $G = 4$ | |
| $I = 5$ | | $I = 5$ | |

### 4.4.2 Economic divergence

Assuming there is larger difference between the corporations $a$ and $b$ in the $10^{th}$ year, embodied by the difference in quantity of domestic factors employment and factor inflow, and different growth rates of domestic factors employment and factor inflow (for example, 25%, 15%, 90%, 55% and 25% on average for growth rate of capital, technology, and labor employment, and capital and technology inflow respectively for the corporation $a$. 50%, 130% and 490% on average for growth rate of capital and technology employment, and capital inflow respectively for the corporation $b$. Other assumptions are the same as in the case of economic convergence).

Table 2 (when time is $t$)

| | | | |
|---|---|---|---|
| $L = 100$ | The $10^{th}$ year $Y_a = 20.001$ | $L = 120$ | The $20^{th}$ year $Y_a = 100.001$ |
| $K = 2000$ | | $K = 7000$ | |
| $T = 4000$ | | $T = 10000$ | |
| $L_{in} = 100$ | | $L_{in} = 1000$ | |
| $K_{in} = 20$ | | $K_{in} = 110$ | |
| $T_{in} = 40$ | | $T_{in} = 100$ | |
| $G = 6$ | | $G = 6$ | |
| $I = 7$ | | $I = 7$ | |

| | | | |
|---|---|---|---|
| $L = 10000$ | The $10^{th}$ year $y_b = 2.0043$ | $L = 14000$ | The $20^{th}$ year $y_b = 10.002$ |
| $K = 150$ | | $K = 900$ | |
| $T = 50$ | | $T = 700$ | |
| $L_{in} = 2$ | | $L_{in} = 10$ | |
| $K_{in} = 4$ | | $K_{in} = 200$ | |
| $T_{in} = 6$ | | $T_{in} = 40$ | |
| $G = 4$ | | $G = 4$ | |
| $I = 5$ | | $I = 5$ | |

Table 2' (when time is $t^2$)

| | | | |
|---|---|---|---|
| $L = 100$ | The $10^{th}$ year $Y_a = 19.999$ | $L = 120$ | The $20^{th}$ year $Y_a = 100.01$ |
| $K = 2000$ | | $K = 7000$ | |
| $T = 4000$ | | $T = 10000$ | |
| $L_{in} = 100$ | | $L_{in} = 1000$ | |
| $K_{in} = 20$ | | $K_{in} = 110$ | |
| $T_{in} = 40$ | | $T_{in} = 100$ | |
| $G = 6$ | | $G = 6$ | |
| $I = 7$ | | $I = 7$ | |

| | | | |
|---|---|---|---|
| $L = 10000$ | The $10^{th}$ year $Y_b = 2.0006$ | $L = 14000$ | The $20^{th}$ year $Y_b = 10$ |
| $K = 150$ | | $K = 900$ | |
| $T = 50$ | | $T = 700$ | |
| $L_{in} = 2$ | | $L_{in} = 10$ | |
| $K_{in} = 4$ | | $K_{in} = 200$ | |
| $T_{in} = 6$ | | $T_{in} = 40$ | |
| $G = 4$ | | $G = 4$ | |
| $I = 5$ | | $I = 5$ | |

From the tables above, we at least have the following five findings.

1) From table 1, we can see aggregate production of the corporation $b$ in the $20^{th}$ year is five times of that in the $10^{th}$ year and leaps from one fifth of the production of the corporation $a$ to only one second when time is specified as $t$. Aggregate production of the corporation $a$ is 50 times of that of the corporation $b$ in the $10^{th}$ year, but only 23.51 times in the $20^{th}$ year. The production of the corporation $a$ in the $20^{th}$ year grows by 0.67 times of that in the $10^{th}$ year, while the production of the corporation $b$ grows by 2.5 times. When time is non-linear as the form of $t^2$, table 1' shows the corporation $b$ grows even faster while the corporation $a$ grows slower. Both tables 1 and 1' present the possibility of economic convergence.

2) When there exists larger difference from the initial stage in the $10^{th}$ year in average growth rates of factors employment and inflow in the corporations $a$ and $b$,

even $t$ is linear, we would have economic divergence easily. In table 2, it can be seen that the production of the corporation $a$ in the $20^{th}$ year rises by 3.165 times from the $10^{th}$ year, and the production of the corporation $b$ in the $20^{th}$ year only rises by 2.57 times of that from the $10^{th}$ year. What is more, the gap of the production between the two corporations is slightly widened. The evidence of economic divergence from table 2 can also be confirmed in table 2' and we do not detail it here.

3) Improvement of social institution and geography is certainly beneficial to help the corporation $b$ reduce the gap of production growth between the corporation $a$ and itself. For example, in table 1, if we change the values for $G$ and $I$ of the corporation $b$, making them equal to 6 and 7 respectively, given other variables, we would find production of the corporation $b$ becomes 10.002 in the $20^{th}$ year. The additional increase of $Y_b$ directly comes from improvement of $G$ and $I$. But their indirect effect on production growth through affecting domestic factors employment and factor inflows should not be neglected. In fact, the first two findings tell the preliminary state composed by domestic factors employment and factor inflow would have momentous effect on the process of production/economic changes of a corporation or country. However, the initial state can in no way be exogenous, which is an evolutionary result influenced by such factors as social institution and geography.

4) There exist local maximum values of production for both the corporations. For example, look at the case of the corporation $a$ in table 2, given other factors, when capital inflow equals 101, production of the corporation $a$ can reach 100.01. Further increase of capital inflow from 101 on, the quantity of production 100.01 would remain unchanged for the corporation $a$. The situation applies to the corporation $b$ too. The numerical finding accounts that the production of the corporations $a$ and $b$ can remain at a steady state for a period of time. This production equilibrium and therefore an induced trade one have nothing to do with factor price equalization.

5) Speed of tending to a local maximum value of production may be subject to the size of effect of time on production growth given domestic factors employment and factor inflow. When time is non-linear in the case where its exponent is larger than one, for example time is captured by $t^2$, the speed will be faster than time in the form of $t$. When we continue to increase the size of the exponent of $t$, like $t^3$, we can see the speed will be much faster. For example, still look at the case for the corporation

$a$ in table 2. If we suppose time is formed as $t^3$, when capital inflow is 99 given other variables, production of the corporation $a$ is 99.007 and its counterpart when time is $t^2$ is 98.998 accordingly. The implication is that convergence or divergence rate can be faster depending on whether a country can win the initiative in international competition.

## 4.5 Policy implications

From the chapter, we have known free migration may or may not contribute to production/economic convergence between the two developed and developing countries. Convergence or not may need to depend on the difference of preliminary situations of employment and factor inflow in both countries, which is obviously related with non-economic elements. Albeit free factor movement is not a sufficient condition for convergence, it at least appears to be a potential way to get rid of disadvantages in international economic activities for a developing corporation or country. According to the trade pattern drawn by traditional trade theory, it is never possible for developing countries get dynamic gains from free trade such that their inferior trade status can change to a favorable side through time. That is to say, participating in free commodities trade is not competent for developing countries to catch up with developed ones.

We are also aware from the above text, that making optimal use of international factor movement is another prerequisite of realizing the maximum of total profit in a country. But, making policies independently by every single corporation for hiring optimal quantity of factor inflow is simply not possible in the regimes of concurrent system of a country, which has to meet uncountable governmental and institutional intervention and measures against free market behavior. Therefore, second-best policies could be more attractive and feasible than optimal ones when coping with international factor movement.

Grounded from the model, what policy implications can be drawn then? We conclude four points applicable to both developed and developing countries:

### 4.5.1 Adopting scientific policies in introducing international productive factors

Freer factor movement is a trend of international economic integration. During the process of global economic integration, degree of freedom of factor movement, can be viewed as a barometer of degree of economic integration.

The model accounts that, to both developed and developing countries advancing in returns to productive factors, social welfare, and property protection and market risk is eliminated continuously, labor inflow will not do harm to employment of domestic labor. That is because it would not decrease the employment level in the host country. To capital and technology movement, on the contrary, it would be negatively correlated with the local capital and technology employment.

So the chapter suggests that it may be not scientific that quite a few countries adopt indiscernible policies of encouraging capital and technology inflow while setting limits and controls on labor movement in their foreign trade, foreign capital or immigration policies. The model implies that more reasonable policies of introduction of international productive factors should be based on a more solid comparative study of economic and social situation in the countries involved. If both the country exporting productive factors and the one importing productive factors are improving in the elements we designate above, introduction of labor would be more beneficial to these countries.

### 4.5.2 Creating good conditions to avail international productive factors

The above text shows it is a weighty alternative for developing countries to introduce labor actively from developed countries rather than adopt capital or technology unilaterally. The disadvantage of doing so has already been shown in the chapter two[77]. The realistic picture is not beautiful, however. Labor and capital from developed countries seems not to be interested in moving to developing countries, and developed countries are not always ready to transfer even some obsolete technology to

[77]Of course, if it was easier to obtain from developed countries than innovate by developing countries themselves, it would be another case (see Su, 1999). Similar views can be found in Krugman (1990).

the developing ones[78]. Developed countries have more or less strategically oriented restrictions on exports to or imports from developing ones[79] and much more severe restrictions on factor outflows to the latter.

Introducing labor more does not mean less attention in moving in of capital and technology. Our argument is that developing countries should grasp how to raise their attractiveness to international productive factors. One spellbound policy for these countries from the chapter is resorting to their potential and incentive to improve their social institution or environment, more details given in the next point.

Because of geometric growth of technological innovation and information release in the times of knowledge economy[80], speed and content of economic development is becoming essentially different from traditional economic period. Developing countries need to be cautious about the new situation and fasten their pace in following up in economic development, social progress and betterment of other issues. Though there would be stronger and stronger challenges, they have also been provided equally external access to employing international resources and international assistance for their purpose.

### 4.5.3 Striving for a better social environment

Social environment is formed due to or apparent embodiment of statutorily stipulated or implicitly recognized social institution. A better social environment is substantive for social development besides economic one. Social development is a

[78]To reluctance of capital flowing to developing countries, Lucas (1990) views it as the result of two economic reasons in substance, one is human capital differential, and the other is return differential of capital between rich and poor countries. The non-economic reason, i.e., political risk is argued to be inadequate. However, Lucas (1990) owes the inadequacy to no evidence of a capital-labor ratio equalized by capital movement in the situation without political risk (or "in the two centuries before 1945" in its text). From the chapter, Lucas's argument is simply unconvincing. Capital movement, as other factors do, is not necessarily accompanyed with equalization of factor price or capital-labor ratios when both economic and non-economic elements are taken into account at the same time.

[79]The reason may be a natural result of dynamics of growth, of trade, and of the political economy of protection (see Deardorff, 2000).

[80]The non-linearity specification of time above-mentioned mimics the urgency endowed by swifter development of information and technology.

more complex concept than economic development. It contains at least such elements as development of habitation environment, humanistic environment, legal environment and institutional environment.

Social development may not be uphold without economic growth and development, but it will definitely have non-ignorable counter-effect on the latter. In the model, though social institution does not affect production directly, it does have effect on the performance of economic growth[81] and factor inflow. It affects speed of economic convergence and even lead to divergence. A country with a poorer social environment may not absorb deserved amount of factor inflow even if the factor payment is the same or higher than that of a country with a better one.

Fairness, equality, democracy, humanity, justice, transparency and so on should be treated seriously in most developing countries. Action to ameliorate these elements constitutes the key of a better off social surroundings. A country, especially a developing one, should work hard for a better social environment brought by improvement of these institutional elements rather than economic objects only.

### 4.5.4 Improving fairer welfare distribution between developed and developing countries

Improving fairer welfare distribution between developed and developing countries is still a long-lasting task only if developing countries are far behind developed countries in economic development

The endogenous factor supply implies that the world production will increase all the time without boundary in the long run, which is a direct reason from the perspective of supply side that permits the possibility of continuous divergence. As a matter of fact, economic divergence between developed and some developing countries has been enlarging in an absolute term in the recent years.

Promoting international welfare distribution is a track of helping bridge the gap of income and economic development between developed and developing countries. It may involve objection from domestic interest groups of different countries and international political struggle. Therefore, besides governments, relevant interna-

[81] Improvement of social institution leads to improvement of social development directly, while providing a more favorable social environment for economic growth indirectly.

tional organizations and non-governmental organizations should play an active role in contributing to this undertaking which concerns the habitability of the whole world in the future.

Prejudice, resentment, estrangement or hostility due to ideological, religion or political difference should be abandoned. This may be a non-economic premise of effectively conducting helping work to the poor countries. Meanwhile, sustainable economic growth in developed and developing countries fixes the financial basis. These two conditions are not converse to each other. Smooth international redistribution is more possible when the world is in a better economic condition and there is less antagonism among countries.

## 4.6 Conclusion

In response to theoretical paucity about factor movement, the chapter makes its contribution with a study in the relationship between MNCs and factor movement (i.e., labor migration, capital movement and technology flow). The theoretical model given in the chapter is a novel effort of integrating both economic and non-economic elements. Though we do not have a close-formed solution to the model, we have accomplished to find out new evidence around the topics in factor movement, domestic employment, production/economic convergence, and social institution.

The chapter equips these long-standing problems in the academia with new insights. When freely mobile factors are allowed, their impact on domestic factors employment contrasts to normal conception. Analysis about production/economic convergence reveals free factor movement is not a sufficient condition for developing countries to catch up with their developed counterparts.

The core research results of the chapter are concluded as follows:

- Labor inflow may have a positive effect on the local labor employment, which is valid for both the developed and developing corporations or countries cases, if only returns to productive factors, social welfare, and property protection are improving and market risk is falling all the time in both countries.

- Free international factor movement still can not guarantee production convergence between MNCs and thus economic convergence between countries, since

non-economic factors can create difference in factors employment and inflow large enough to cause divergence.

- A country (especially an underdeveloped one) should strive for a better social environment rather than economic objects only.

The side results of the chapter are in relation with the basic international trade theory problems. The chapter argues: when non-economic factors are considered,

- a general equilibrium of international trade is not necessarily accompanied with factor price equalization;
- free mobility of factor movement may not lead to factor price equalization;
- and a multi-cone equilibrium does not need to exist in groups of countries.

In the end, among others, a continuing research based on the chapter would provide a numerical study making use of the complete theoretical specification of $\varepsilon$ and $\theta$. Accordingly, there leaves a spacious room for empirical work too.

# Appendix A

$$
\begin{aligned}
(22)\ d\Pi_{d_d} = \ & (1)\ \beta_{d1}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \beta_{d2}(p_{Q_{d_{f1}}}Q_{d_{f1}} \\
& -p_{I_{d_{f1}}}\eta I_d - p_{L_{d_{f1}}}\gamma L_d)dz_1 + (\beta_d - \beta_{d1} - \beta_{d2})(p_{Q_{d_{f2}}}Q_{d_{f2}} \\
& -p_{I_{d_{f2}}}I_d - p_{L_{d_{f2}}}L_d)dz_2 \quad \text{(FDI)}
\end{aligned}
$$

$$
\begin{aligned}
& (2)\ \beta_{d3}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \beta_{d4}(p_{E_{d_{f1}}}E_{d_{f1}} - \\
& p_{I_{E_{d_{f1}}}}I_d - p_{L_{E_{d_{f1}}}}L_d)dz_1 + (\beta_d - \beta_{d3} - \beta_{d4})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d \\
& -p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Export)}
\end{aligned}
$$

$$
\begin{aligned}
& (3)\ \beta_{d5}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \beta_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}} - p_{I_{d_{f1}}}\eta I_d - \\
& p_{L_{d_{f1}}}\gamma L_d)dz_1 + \ (\beta_d - \beta_{d5} - \phi_{d6})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d \\
& -p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Mixed I)}
\end{aligned}
$$

$$
\begin{aligned}
& (4)\ \beta_{d7}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \beta_{d8}(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d \\
& -p_{L_{E_{d_{f1}}}}L_d)dz_1 + (\beta_d - \beta_{d7} - \beta_{d8})(p_{Q_{d_{f2}}}Q_{d_{f2}} - p_{I_{d_{f2}}}I_d \\
& -p_{L_{d_{f2}}}L_d)dz_2 \quad \text{(Mixed II)}
\end{aligned}
$$

$$
\begin{aligned}
(23)\ d\Pi_{d_{f1}} = \ & (1)\ \phi_{d1}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi_{d2}(p_{Q_{d_{f1}}}Q_{d_{f1}} - \\
& p_{I_{d_{f1}}}\eta I_d - p_{L_{d_{f1}}}\gamma L_d)dz_1 + (\phi_d - \phi_{d1} - \phi_{d2})(p_{Q_{d_{f2}}}Q_{d_{f2}} - \\
& p_{I_{d_{f2}}}I_d - p_{L_{d_{f2}}}L_d)dz_2 \quad \text{(FDI)}
\end{aligned}
$$

$$
\begin{aligned}
& (2)\ \phi_{d3}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi_{d4}(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d \\
& -p_{L_{E_{d_{f1}}}}L_d)dz_1 + (\phi_d - \phi_{d3} - \phi_{d4})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d \\
& -p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Export)}
\end{aligned}
$$

$$
\begin{aligned}
& (3)\ \phi_{d5}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}} - p_{I_{d_{f1}}}\eta I_d \\
& -p_{L_{d_{f1}}}\gamma L_d)dz_1 + \ (\phi_d - \phi_{d5} - \phi_{d6})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d \\
& -p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Mixed I)}
\end{aligned}
$$

$$
\begin{aligned}
& (4)\ \phi_{d7}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi_{d8}(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d - \\
& p_{L_{E_{d_{f1}}}}L_d)dz_1 + (\phi_d - \phi_{d7} - \phi_{d8})(p_{Q_{d_{f2}}}Q_{d_{f2}} - p_{I_{d_{f2}}}I_d \\
& -p_{L_{d_{f2}}}L_d)dz_2 \quad \text{(Mixed II)}
\end{aligned}
$$

$$(24)\ d\Pi_{d_{f2}} = \begin{array}{c} (1)\ \theta_{d1}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \theta_{d2}(p_{Q_{d_{f1}}}Q_{d_{f1}} - \\ p_{I_{d_{f1}}}\eta I_d - p_{L_{d_{f1}}}\gamma L_d)dz_1 + (1 - \beta_d - \phi_d - \theta_{d1} - \\ \theta_{d2})(p_{Q_{d_{f2}}}Q_{d_{f2}} - p_{I_{d_{f2}}}I_d - p_{L_{d_{f2}}}L_d)dz_2 \quad \text{(FDI)} \end{array}$$

$$\begin{array}{c} (2)\ \theta_{d3}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \theta_{d4}(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d \\ -p_{L_{E_{d_{f1}}}}L_d)dz_1 + (1 - \beta_d - \phi_d - \theta_{d3} - \theta_{d4})(p_{E_{d_{f2}}}E_{d_{f2}} - \\ p_{I_{E_{d_{f2}}}}I_d - p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Export)} \end{array}$$

$$\begin{array}{c} (3)\ \theta_{d5}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \theta_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}} - p_{I_{d_{f1}}}\eta I_d - \\ p_{L_{d_{f1}}}\gamma L_d)dz_1 + \ (1 - \beta_d - \phi_d - \theta_{d5} - \theta_{d6})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d \\ -p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Mixed I)} \end{array}$$

$$\begin{array}{c} (4)\ \theta_{d7}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \theta_{d8}(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d - \\ p_{L_{E_{d_{f1}}}}L_d)dz_1 + (1 - \beta_d - \phi_d - \theta_{d7} - \theta_{d8})(p_{Q_{d_{f2}}}Q_{d_{f2}} - p_{I_{d_{f2}}}I_d \\ -p_{L_{d_{f2}}}L_d)dz_2 \quad \text{(Mixed II)} \end{array}$$

$$(25)\ d\Pi_{f1_d} = \begin{array}{c} (1)\ \beta_{f11}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \beta_{f12}(p_{Q_{f1_d}}Q_{f1_d} \\ -p_{I_{f1_d}}I_d - p_{L_{f1_d}}L_d)dz_1 + (\beta_{f1} - \beta_{f11} - \beta_{f12})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} \\ -p_{I_{f1_{f2}}}I_d - p_{L_{f1_{f2}}}L_d)dz_2 \quad \text{(FDI)} \end{array}$$

$$\begin{array}{c} (2)\ \beta_{f13}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \beta_{f14}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}\eta I_d \\ -p_{L_{E_{f1_d}}}\gamma L_d)dz_1 + (\beta_{f1} - \beta_{f13} - \beta_{f14})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}\eta I_d \\ -p_{L_{E_{f1_{f2}}}}\gamma L_d)dz_2 \quad \text{(Export)} \end{array}$$

$$\begin{array}{c} (3)\ \beta_{f15}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \beta_{f16}(p_{Q_{f1_d}}Q_{f1_d} - p_{I_{f1_d}}I_d - \\ p_{L_{f1_d}}L_d)dz_1 + \ (\beta_{f1} - \beta_{f15} - \beta_{f16})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}\eta I_d \\ -p_{L_{E_{f1_{f2}}}}\gamma L_d)dz_2 \quad \text{(Mixed I)} \end{array}$$

$$\begin{array}{c} (4)\ \beta_{f17}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \beta_{f18}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}\eta I_d \\ -p_{L_{E_{f1_d}}}\gamma L_d)dz_1 + (\beta_{f1} - \beta_{f17} - \beta_{f18})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} - p_{I_{f1_{f2}}}I_d \\ -p_{L_{f1_{f2}}}L_d)dz_2 \quad \text{(Mixed II)} \end{array}$$

$$(26)\ d\Pi_{f1_{f1}} = \begin{array}{c} (1)\ \phi_{f11}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \phi_{f12}(p_{Q_{f1_d}}Q_{f1_d} \\ -p_{I_{f1_d}}I_d - p_{L_{f1_d}}L_d)dz_1 + (\phi_{f1} - \phi_{f11} - \phi_{f12})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} \\ -p_{I_{f1_{f2}}}I_d - p_{L_{f1_{f2}}}L_d)dz_2 \quad \text{(FDI)} \end{array}$$

$$(2)\ \phi_{f13}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \phi_{f14}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}\eta I_d$$
$$-p_{L_{E_{f1_d}}}\gamma L_d)dz_1 + (\phi_{f1} - \phi_{f13} - \phi_{f14})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}\eta I_d$$
$$-p_{L_{E_{f1_{f2}}}}\gamma L_d)dz_2 \quad \text{(Export)}$$

$$(3)\ \phi_{f15}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \phi_{f16}(p_{Q_{f1_d}}Q_{f1_d} - p_{I_{f1_d}}I_d$$
$$-p_{L_{f1_d}}L_d)dz_1 + \ (\phi_{f1} - \phi_{f15} - \phi_{f16})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}\eta I_d$$
$$-p_{L_{E_{f1_{f2}}}}\gamma L_d)dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \phi_{f17}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \phi_{f18}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}\eta I_d -$$
$$p_{L_{E_{f1_d}}}\gamma L_d)dz_1 + (\phi_{f1} - \phi_{f17} - \phi_{f18})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} - p_{I_{f1_{f2}}}I_d$$
$$-p_{L_{f1_{f2}}}L_d)dz_2 \quad \text{(Mixed II)}$$

$$(27)\ d\Pi_{f1_{f2}} = \begin{array}{c}(1)\ \theta_{f11}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \theta_{f12}(p_{Q_{f1_d}}Q_{f1_d} - p_{I_{f1_d}}I_d \\ -p_{L_{f1_d}}L_d)dz_1 + (1 - \beta_{f2} - \phi_{f2} - \theta_{f11} - \theta_{f12})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} \\ -p_{I_{f1_{f2}}}I_d - p_{L_{f1_{f2}}}L_d)dz_2 \quad \text{(FDI)}\end{array}$$

$$(2)\ \theta_{f13}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \theta_{f14}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}\eta I_d -$$
$$p_{L_{E_{f1_d}}}\gamma L_d)dz_1 + (1 - \beta_{f2} - \phi_{f2} - \theta_{f13} - \theta_{f14})(p_{E_{f1_{f2}}}E_{f1_{f2}} -$$
$$p_{I_{E_{f1_{f2}}}}\eta I_d - p_{L_{E_{f1_{f2}}}}\gamma L_d)dz_2 \quad \text{(Export)}$$

$$(3)\ \theta_{f15}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \theta_{f16}(p_{Q_{f1_d}}Q_{f1_d} - p_{I_{f1_d}}I_d -$$
$$p_{L_{f1_d}}L_d)dz_1 + \ (1 - \beta_{f2} - \phi_{f2} - \theta_{f15} - \theta_{f16})(p_{E_{f1_{f2}}}E_{f1_{f2}} -$$
$$p_{I_{E_{f1_{f2}}}}\eta I_d - p_{L_{E_{f1_{f2}}}}\gamma L_d)dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \theta_{f17}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}\eta I_d - p_{L_{f1}}\gamma L_d)dt + \theta_{f18}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}\eta I_d$$
$$-p_{L_{E_{f1_d}}}\gamma L_d)dz_1 + (1 - \beta_{f2} - \phi_{f2} - \theta_{f17} - \theta_{f18})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} -$$
$$p_{I_{f1_{f2}}}I_d - p_{L_{f1_{f2}}}L_d)dz_2 \quad \text{(Mixed II)}$$

$$(28)\ d\Pi_{f2_d} = \begin{array}{c}(1)\ \beta_{f21}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \beta_{f22}(p_{Q_{f2_d}}Q_{f2_d} - \\ p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + (\beta_{f2} - \beta_{f21} - \beta_{f22})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} - p_{I_{f2_{f1}}}\eta I_d \\ -p_{L_{f2_{f1}}}\gamma L_d)dz_2 \quad \text{(FDI)}\end{array}$$

$$(2)\ \beta_{f23}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \beta_{f24}(p_{E_{f2_d}}E_{f2_d} - p_{I_{E_{f2_d}}}I_d$$
$$-p_{L_{E_{f2_d}}}L_d)dz_1 + (\beta_{f2} - \beta_{f23} - \beta_{f24})(p_{E_{f2_{f1}}}E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}}I_d$$
$$-p_{L_{E_{f2_{f1}}}}L_d)dz_2 \quad \text{(Export)}$$

$$(3)\ \beta_{f25}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \beta_{f26}(p_{Q_{f2_d}}Q_{f2_d} - p_{I_{f2_d}}I_d$$
$$-p_{L_{f2_d}}L_d)dz_1 + \ (\beta_{f2} - \beta_{f25} - \beta_{f26})(p_{E_{f2_{f1}}}E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}}I_d$$
$$-p_{L_{E_{f2_{f1}}}}L_d)dz_2 \ \ \text{(Mixed I)}$$

$$(4)\ \beta_{f27}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \beta_{f28}(p_{E_{f2_d}}E_{f2_d} -$$
$$p_{I_{E_{f2_d}}}I_d - p_{L_{E_{f2_d}}}L_d)dz_1 + (\beta_{f2} - \beta_{f27} - \beta_{f28})(p_{Q_{f2_{f1}}}Q_{f2_{f1}}$$
$$-p_{I_{f2_{f1}}}\eta I_d - p_{L_{f2_{f1}}}\gamma L_d)dz_2 \ \ \text{(Mixed II)}$$

$$(29)\ d\Pi_{f2_{f1}} = \begin{array}{c}(1)\ \phi_{f21}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \phi_{f22}(p_{Q_{f2_d}}Q_{f2_d} - \\ p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + (\phi_{f2} - \phi_{f21} - \phi_{f22})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} \\ -p_{I_{f2_{f1}}}\eta I_d - p_{L_{f2_{f1}}}\gamma L_d)dz_2 \ \ \text{(FDI)}\end{array}$$

$$(2)\ \phi_{f23}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \phi_{f24}(p_{E_{f2_d}}E_{f2_d} -$$
$$p_{I_{E_{f2_d}}}I_d - p_{L_{E_{f2_d}}}L_d)dz_1 + (\phi_{f2} - \phi_{f23} - \phi_{f24})(p_{E_{f2_{f1}}}E_{f2_{f1}}$$
$$-p_{I_{E_{f2_{f1}}}}I_d - p_{L_{E_{f2_{f1}}}}L_d)dz_2 \ \ \text{(Export)}$$

$$(3)\ \phi_{f25}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \phi_{f26}(p_{Q_{f2_d}}Q_{f2_d} -$$
$$p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + \ (\phi_{f2} - \phi_{f25} - \phi_{f26})(p_{E_{f2_{f1}}}E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}}I_d$$
$$-p_{L_{E_{f2_{f1}}}}L_d)dz_2 \ \ \text{(Mixed I)}$$

$$(4)\ \phi_{f27}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \phi_{f28}(p_{E_{f2_d}}E_{f2_d} -$$
$$p_{I_{E_{f2_d}}}I_d - p_{L_{E_{f2_d}}}L_d)dz_1 + (\phi_{f2} - \phi_{f27} - \phi_{f28})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} - p_{I_{f2_{f1}}}\eta I_d$$
$$-p_{L_{f2_{f1}}}\gamma L_d)dz_2 \ \ \text{(Mixed II)}$$

$$(30)\ d\Pi_{f2_{f2}} = \begin{array}{c}(1)\ \theta_{f21}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \ \theta_{f22}(p_{Q_{f2_d}}Q_{f2_d} - \\ p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + (1 - \beta_{f2} - \phi_{f2} - \ \theta_{f21} - \\ \theta_{f22})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} - p_{I_{f2_{f1}}}\eta I_d - p_{L_{f2_{f1}}}\gamma L_d)dz_2 \ \ \text{(FDI)}\end{array}$$

$$(2)\ \theta_{f23}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \ \theta_{f24}(p_{E_{f2_d}}E_{f2_d} -$$
$$p_{I_{E_{f2_d}}}I_d - p_{L_{E_{f2_d}}}L_d)dz_1 + (1 - \beta_{f2} - \phi_{f2} - \ \theta_{f23} - \ \theta_{f24})(p_{E_{f2_{f1}}}E_{f2_{f1}} -$$
$$p_{I_{E_{f2_{f1}}}}I_d - p_{L_{E_{f2_{f1}}}}L_d)dz_2 \ \ \text{(Export)}$$

$$(3)\ \theta_{f25}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}I_d - p_{L_{f2}}L_d)dt + \theta_{f26}(p_{Q_{f2_d}}Q_{f2_d} -$$
$$p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + \ (\ -\ \theta_{f25} - \ \theta_{f26})(p_{E_{f2_{f1}}}E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}}I_d$$
$$-p_{L_{E_{f2_{f1}}}}L_d)dz_2 \ \ \text{(Mixed I)}$$

$$(4)\ \theta_{f27}(p_{Q_{f2}}Q_{f2}-p_{I_{f2}}I_d-p_{L_{f2}}L_d)dt+\ \theta_{f28}(p_{E_{f2_d}}E_{f2_d}-$$
$$p_{I_{E_{f2_d}}}I_d-p_{L_{E_{f2_d}}}L_d)dz_1+(1-\beta_{f2}-\phi_{f2}-\ \theta_{f27}-\ \theta_{f28})(p_{Q_{f2_{f1}}}Q_{f2_{f1}}$$
$$-p_{I_{f2_{f1}}}\eta I_d-p_{L_{f2_{f1}}}\gamma L_d)dz_2\quad\text{(Mixed II)}$$

$$(37')\ \Pi^2_{d_{f1}}=\tfrac{1}{12}\sqrt{6}\sqrt{M_{d_{f1}}}-$$
$$\frac{1}{12}\sqrt{-\frac{\begin{array}{c}6\sqrt[3]{12}\sqrt{M_{d_{f1}}}\left(\sqrt[3]{\left(\left(9n^2_{d_{f1}}+\sqrt{\left(-768v^3_{d_{f1}}m_{d_{f1}}+81n^4_{d_{f1}}\right)}\right)m_{d_{f1}}\right)}\right)^2+\\ 24\left(\sqrt[3]{12}\right)^2\sqrt{M_{d_{f1}}}v_{d_{f1}}m_{d_{f1}}+\\ 72n_{d_{f1}}\sqrt{6}\sqrt[3]{\left(\left(9n^2_{d_{f1}}+\sqrt{\left(-768v^3_{d_{f1}}m_{d_{f1}}+81n^4_{d_{f1}}\right)}\right)m_{d_{f1}}\right)}\end{array}}{m_{d_{f1}}\sqrt[3]{\left(\left(9n^2_{d_{f1}}+\sqrt{\left(-768v^3_{d_{f1}}m_{d_{f1}}+81n^4_{d_{f1}}\right)}\right)m_{d_{f1}}\right)}\sqrt{M_{d_{f1}}}}}$$

$$(37'')\ \Pi^3_{d_{f1}}=-\tfrac{1}{12}\sqrt{6}\sqrt{M_{d_{f1}}}+$$
$$\frac{1}{12}\sqrt{-\frac{\begin{array}{c}6\sqrt[3]{12}\sqrt{M_{d_{f1}}}\left(\sqrt[3]{\left(\left(9n^2_{d_{f1}}+\sqrt{\left(-768v^3_{d_{f1}}m_{d_{f1}}+81n^4_{d_{f1}}\right)}\right)m_{d_{f1}}\right)}\right)^2+\\ 24\left(\sqrt[3]{12}\right)^2\sqrt{M_{d_{f1}}}v_{d_{f1}}m_{d_{f1}}+\\ 72n_{d_{f1}}\sqrt{6}\sqrt[3]{\left(\left(9n^2_{d_{f1}}+\sqrt{\left(-768v^3_{d_{f1}}m_{d_{f1}}+81n^4_{d_{f1}}\right)}\right)m_{d_{f1}}\right)}\end{array}}{m_{d_{f1}}\sqrt[3]{\left(\left(9n^2_{d_{f1}}+\sqrt{\left(-768v^3_{d_{f1}}m_{d_{f1}}+81n^4_{d_{f1}}\right)}\right)m_{d_{f1}}\right)}\sqrt{M_{d_{f1}}}}}$$

$$(37''')\ \Pi^4_{d_{f1}}=-\tfrac{1}{12}\sqrt{6}\sqrt{M}$$
$$-\frac{1}{12}\sqrt{-\frac{\begin{array}{c}6\sqrt[3]{12}\sqrt{M}\left(\sqrt[3]{\left(\left(9n^2+\sqrt{(-768v^3m+81n^4)}\right)m\right)}\right)^2+\\ 24\left(\sqrt[3]{12}\right)^2\sqrt{M}vm+72n\sqrt{6}\sqrt[3]{\left(\left(9n^2+\sqrt{(-768v^3m+81n^4)}\right)m\right)}\end{array}}{m\sqrt[3]{\left(\left(9n^2+\sqrt{(-768v^3m+81n^4)}\right)m\right)}\sqrt{M}}}$$

$$(44)\ d\Pi_{d_d}=\begin{array}{c}(1)\ \beta'_{d1}(p_{Q_d}Q_d-p_{I_d}I_d-p_{L_d}L_d)dt+\beta'_{d2}(p_{Q_{d_{f1}}}Q_{d_{f1}}-\\ p_{I_{d_{f1}}}I_d-p_{L_{d_{f1}}}L_d)dz_1+(\beta_d-\beta'_{d1}-\beta'_{d2})(p_{Q_{d_{f2}}}Q_{d_{f2}}\\ -p_{I_{d_{f2}}}I_d\tfrac{1}{\eta'}-p_{L_{d_{f2}}}L_d\tfrac{1}{\gamma'})dz_2\quad\text{(FDI)}\end{array}$$

$$(2)\ \beta'_{d3}(p_{Q_d}Q_d-p_{I_d}I_d-p_{L_d}L_d)dt+\beta'_{d4}(p_{E_{d_{f1}}}E_{d_{f1}}-p_{I_{E_{d_{f1}}}}I_d$$
$$-p_{L_{E_{d_{f1}}}}L_d)dz_1+(\beta_d-\beta'_{d3}-\beta'_{d4})(p_{E_{d_{f2}}}E_{d_{f2}}-p_{I_{E_{d_{f2}}}}I_d-p_{L_{E_{d_{f2}}}}L_d$$
$$-sE_{d_{f2}}-mE_{d_{f2}})dz_2\quad\text{(Export)}$$

$$(3)\ \beta'_{d5}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \beta'_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}} - p_{I_{d_{f1}}}I_d$$
$$-p_{L_{d_{f1}}}L_d)dz_1 + \ (\beta_d - \beta'_{d5} - \beta'_{d6})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d - p_{L_{E_{d_{f2}}}}L_d$$
$$-sE_{d_{f2}} - mE_{d_{f2}})dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \beta'_{d7}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \beta'_{d8}(p_{E_{d_{f1}}}E_{d_{f1}} -$$
$$p_{I_{E_{d_{f1}}}}I_d - p_{L_{E_{d_{f1}}}}L_d)dz_1 + (\beta_d - \beta'_{d7} - \beta'_{d8})(p_{Q_{d_{f2}}}Q_{d_{f2}}$$
$$-p_{I_{d_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{d_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(Mixed II)}$$

$$(45)\ d\Pi_{d_{f1}} = \begin{array}{c}(1)\ \phi'_{d1}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi'_{d2}(p_{Q_{d_{f1}}}Q_{d_{f1}} - \\ p_{I_{d_{f1}}}I_d - p_{L_{d_{f1}}}L_d)dz_1 + (\phi_d - \phi'_{d1} - \phi'_{d2})(p_{Q_{d_{f2}}}Q_{d_{f2}} \\ -p_{I_{d_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{d_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(FDI)}\end{array}$$

$$(2)\ \phi'_{d3}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi'_{d4}(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d$$
$$-p_{L_{E_{d_{f1}}}}L_d)dz_1 + (\phi_d - \phi'_{d3} - \phi'_{d4})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d -$$
$$p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Export)}$$

$$(3)\ \phi'_{d5}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi'_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}} - p_{I_{d_{f1}}}I_d$$
$$-p_{L_{d_{f1}}}L_d)dz_1 + \ (\phi_d - \phi'_{d5} - \phi'_{d6})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d$$
$$-p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \phi'_{d7}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi'_{d8}(p_{E_{d_{f1}}}E_{d_{f1}} -$$
$$p_{I_{E_{d_{f1}}}}I_d - p_{L_{E_{d_{f1}}}}L_d)dz_1 + (\phi_d - \phi'_{d7} - \phi'_{d8})(p_{Q_{d_{f2}}}Q_{d_{f2}}$$
$$-p_{I_{d_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{d_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(Mixed II)}$$

$$(46)\ d\Pi_{d_{f2}} = \begin{array}{c}(1)\ \theta'_{d1}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \phi'_{d2}(p_{Q_{d_{f1}}}Q_{d_{f1}} - \\ p_{I_{d_{f1}}}I_d - p_{L_{d_{f1}}}L_d)dz_1 + (1 - \beta_d - \phi_d - \phi'_{d1} - \\ \phi'_{d2})(p_{Q_{d_{f2}}}Q_{d_{f2}} - p_{I_{d_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{d_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(FDI)}\end{array}$$

$$(2)\ \theta'_{d3}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \theta'_{d4}(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d$$
$$-p_{L_{E_{d_{f1}}}}L_d)dz_1 + (1 - \beta_d - \phi_d - \theta'_{d3} - \theta'_{d4})(p_{E_{d_{f2}}}E_{d_{f2}}$$
$$-p_{I_{E_{d_{f2}}}}I_d - p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Export)}$$

$$(3)\ \theta'_{d5}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \theta'_{d6}(p_{Q_{d_{f1}}}Q_{d_{f1}} -$$
$$p_{I_{d_{f1}}}I_d - p_{L_{d_{f1}}}L_d)dz_1 + \ (1 - \beta_d - \phi_d - \theta'_{d5} -$$
$$\theta'_{d6})(p_{E_{d_{f2}}}E_{d_{f2}} - p_{I_{E_{d_{f2}}}}I_d - p_{L_{E_{d_{f2}}}}L_d)dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \theta'_{d7}(p_{Q_d}Q_d - p_{I_d}I_d - p_{L_d}L_d)dt + \theta'_{d8}(p_{E_{d_{f1}}}E_{d_{f1}} - p_{I_{E_{d_{f1}}}}I_d$$
$$-p_{L_{E_{d_{f1}}}}L_d)dz_1 + (1 - \beta_d - \phi_d - \theta'_{d7} - \theta'_{d8})(p_{Q_{d_{f2}}}Q_{d_{f2}} -$$
$$p_{I_{d_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{d_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(Mixed II)}$$

$$(47)\ d\Pi_{f1_d} = \begin{array}{c}(1)\ \beta'_{f11}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \beta'_{f12}(p_{Q_{f1_d}}Q_{f1_d} - \\ p_{I_{f1_d}}I_d - p_{L_{f1_d}}L_d)dz_1 + (\beta_{f1} - \beta'_{f11} - \beta'_{f12})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} - p_{I_{f1_{f2}}}I_d\tfrac{1}{\eta'} \\ -p_{L_{f1_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(FDI)}\end{array}$$

$$(2)\ \beta'_{f13}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \beta'_{f14}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}I_d$$
$$-p_{L_{E_{f1_d}}}L_d)dz_1 + (\beta_{f1} - \beta'_{f13} - \beta'_{f14})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}I_d -$$
$$p_{L_{E_{f1_{f2}}}}L_d)dz_2 \quad \text{(Export)}$$

$$(3)\ \beta'_{f15}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \beta'_{f16}(p_{Q_{f1_d}}Q_{f1_d} -$$
$$p_{I_{f1_d}}I_d - p_{L_{f1_d}}L_d)dz_1 + \ (\beta_{f1} - \beta'_{f15} - \beta'_{f16})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}I_d -$$
$$p_{L_{E_{f1_{f2}}}}L_d)dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \beta'_{f17}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \beta'_{f18}(p_{E_{f1_d}}E_{f1_d} -$$
$$p_{I_{E_{f1_d}}}I_d - p_{L_{E_{f1_d}}}L_d)dz_1 + (\beta_{f1} - \beta'_{f17} - \beta'_{f18})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} - p_{I_{f1_{f2}}}I_d\tfrac{1}{\eta'}$$
$$-p_{L_{f1_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(Mixed II)}$$

$$(48)\ d\Pi_{f1_{f1}} = \begin{array}{c}(1)\ \phi'_{f11}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \phi'_{f12}(p_{Q_{f1_d}}Q_{f1_d} - \\ p_{I_{f1_d}}I_d - p_{L_{f1_d}}L_d)dz_1 + (\phi_{f1} - \phi'_{f11} - \phi'_{f12})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} \\ -p_{I_{f1_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{f1_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(FDI)}\end{array}$$

$$(2)\ \phi'_{f13}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \phi'_{f14}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}I_d$$
$$-p_{L_{E_{f1_d}}}L_d)dz_1 + (\phi_{f1} - \phi'_{f13} - \phi'_{f14})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}I_d -$$
$$p_{L_{E_{f1_{f2}}}}L_d)dz_2 \quad \text{(Export)}$$

$$(3)\ \phi'_{f15}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \phi'_{f16}(p_{Q_{f1_d}}Q_{f1_d} - p_{I_{f1_d}}I_d$$
$$-p_{L_{f1_d}}L_d)dz_1 + \ (\phi_{f1} - \phi'_{f15} - \phi'_{f16})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}I_d$$
$$-p_{L_{E_{f1_{f2}}}}L_d)dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \phi'_{f17}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \phi'_{f18}(p_{E_{f1_d}}E_{f1_d} -$$
$$p_{I_{E_{f1_d}}}I_d - p_{L_{E_{f1_d}}}L_d)dz_1 + (\phi_{f1} - \phi'_{f17} - \phi'_{f18})(p_{Q_{f1_{f2}}}Q_{f1_{f2}}$$
$$-p_{I_{f1_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{f1_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(Mixed II)}$$

$$(49)\ d\Pi_{f1_{f2}} = \begin{array}{c}(1)\ \theta'_{f11}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \theta'_{f12}(p_{Q_{f1_d}}Q_{f1_d} - \\ p_{I_{f1_d}}I_d - p_{L_{f1_d}}L_d)dz_1 + (1 - \beta_{f1} - \phi_{f1} - \theta'_{f11} - \\ \theta'_{f12})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} - p_{I_{f1_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{f1_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(FDI)}\end{array}$$

$$\begin{array}{c}(2)\ \theta'_{f13}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \theta'_{f14}(p_{E_{f1_d}}E_{f1_d} - \\ p_{I_{E_{f1_d}}}I_d - p_{L_{E_{f1_d}}}L_d)dz_1 + (1 - \beta_{f1} - \phi_{f1} - \theta'_{f13} - \\ \theta'_{f14})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}I_d - p_{L_{E_{f1_{f2}}}}L_d)dz_2 \quad \text{(Export)}\end{array}$$

$$\begin{array}{c}(3)\ \theta'_{f15}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \theta'_{f16}(p_{Q_{f1_d}}Q_{f1_d} - p_{I_{f1_d}}I_d \\ -p_{L_{f1_d}}L_d)dz_1 + (1 - \beta_{f1} - \phi_{f1} - \theta'_{f15} - \theta'_{f16})(p_{E_{f1_{f2}}}E_{f1_{f2}} - p_{I_{E_{f1_{f2}}}}I_d - \\ p_{L_{E_{f1_{f2}}}}L_d)dz_2 \quad \text{(Mixed I)}\end{array}$$

$$\begin{array}{c}(4)\ \theta'_{f17}(p_{Q_{f1}}Q_{f1} - p_{I_{f1}}I_d - p_{L_{f1}}L_d)dt + \theta'_{f18}(p_{E_{f1_d}}E_{f1_d} - p_{I_{E_{f1_d}}}I_d \\ -p_{L_{E_{f1_d}}}L_d)dz_1 + (1 - \beta_{f1} - \phi_{f1} - \theta'_{f17} - \theta'_{f18})(p_{Q_{f1_{f2}}}Q_{f1_{f2}} - \\ p_{I_{f1_{f2}}}I_d\tfrac{1}{\eta'} - p_{L_{f1_{f2}}}L_d\tfrac{1}{\gamma'})dz_2 \quad \text{(Mixed II)}\end{array}$$

$$(50)\ d\Pi_{f2_d} = \begin{array}{c}(1)\ \beta'_{f21}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \\ \beta'_{f22}(p_{Q_{f2_d}}Q_{f2_d} - p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + (\beta_{f2} - \\ \beta'_{f21} - \beta'_{f22})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} - p_{I_{f2_{f1}}}I_d - p_{L_{f2_{f1}}}L_d)dz_2 \quad \text{(FDI)}\end{array}$$

$$\begin{array}{c}(2)\ \beta'_{f23}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \beta'_{f24}(p_{E_{f2_d}}E_{f2_d} - \\ p_{I_{E_{f2_d}}}\tfrac{1}{\eta'}I_d - p_{L_{E_{f2_d}}}\tfrac{1}{\gamma'}L_d)dz_1 + (\beta_{f2} - \beta'_{f23} - \beta'_{f24})(p_{E_{f2_{f1}}}E_{f2_{f1}} \\ -p_{I_{E_{f2_{f1}}}}\tfrac{1}{\eta'}I_d - p_{L_{E_{f2_{f1}}}}\tfrac{1}{\gamma'}L_d)dz_2 \quad \text{(Export)}\end{array}$$

$$\begin{array}{c}(3)\beta'_{f25}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \beta'_{f26}(p_{Q_{f2_d}}Q_{f2_d} - \\ p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + (\beta_{f2} - \beta'_{f25} - \beta'_{f26})(p_{E_{f2_{f1}}}E_{f2_{f1}} - \\ p_{I_{E_{f2_{f1}}}}\tfrac{1}{\eta'}I_d - p_{L_{E_{f2_{f1}}}}\tfrac{1}{\gamma'}L_d)dz_2 \quad \text{(Mixed I)}\end{array}$$

$$\begin{array}{c}(4)\ \beta'_{f27}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \beta'_{f28}(p_{E_{f2_d}}E_{f2_d} - \\ p_{I_{E_{f2_d}}}\tfrac{1}{\eta'}I_d - p_{L_{E_{f2_d}}}\tfrac{1}{\gamma'}L_d)dz_1 + (\beta_{f2} - \beta'_{f27} - \beta'_{f28})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} - \\ p_{I_{f2_{f1}}}I_d - p_{L_{f2_{f1}}}L_d)dz_2 \quad \text{(Mixed II)}\end{array}$$

$$(51)\ d\Pi_{f2_{f1}} = \begin{array}{c}(1)\ \phi'_{f21}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \\ \phi'_{f22}(p_{Q_{f2_d}}Q_{f2_d} - p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + (\phi_{f2} - \phi'_{f21} \\ -\phi'_{f22})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} - p_{I_{f2_{f1}}}I_d - p_{L_{f2_{f1}}}L_d)dz_2 \quad \text{(FDI)}\end{array}$$

$$(2)\ \phi'_{f23}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \phi'_{f24}(p_{E_{f2_d}}E_{f2_d} - p_{I_{E_{f2_d}}}\tfrac{1}{\eta'}I_d$$
$$-p_{L_{E_{f2_d}}}\tfrac{1}{\gamma'}L_d)dz_1 + (\phi_{f2} - \phi'_{f23} - \phi'_{f24})(p_{E_{f2_{f1}}}E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}}\tfrac{1}{\eta'}I_d$$
$$-p_{L_{E_{f2_{f1}}}}\tfrac{1}{\gamma'}L_d)dz_2 \quad \text{(Export)}$$

$$(3)\phi'_{f25}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \phi'_{f26}(p_{Q_{f2_d}}Q_{f2_d} - p_{I_{f2_d}}I_d$$
$$-p_{L_{f2_d}}L_d)dz_1 + \ (\phi_{f2} - \phi'_{f25} - \phi'_{f26})(p_{E_{f2_{f1}}}E_{f2_{f1}} - p_{I_{E_{f2_{f1}}}}\tfrac{1}{\eta'}I_d$$
$$-p_{L_{E_{f2_{f1}}}}\tfrac{1}{\gamma'}L_d)dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \phi'_{f27}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \phi'_{f28}(p_{E_{f2_d}}E_{f2_d} - p_{I_{E_{f2_d}}}\tfrac{1}{\eta'}I_d$$
$$-p_{L_{E_{f2_d}}}\tfrac{1}{\gamma'}L_d)dz_1 + (\phi_{f2} - \phi'_{f27} - \phi'_{f28})(p_{Q_{f2_{f1}}}Q_{f2_{f1}}$$
$$-p_{I_{f2_{f1}}}I_d - p_{L_{f2_{f1}}}L_d)dz_2 \quad \text{(Mixed II)}$$

$$(52)\ d\Pi_{f2_{f2}} = \begin{array}{c}(1)\ \theta'_{f21}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\frac{1}{\eta'}I_d - p_{L_{f2}}\frac{1}{\gamma'}L_d)dt + \\ \theta'_{f22}(p_{Q_{f2_d}}Q_{f2_d} - p_{I_{f2_d}}I_d - p_{L_{f2_d}}L_d)dz_1 + (1 - \beta_{f2} - \phi_{f2} \\ -\theta'_{f21} - \theta'_{f22})(p_{Q_{f2_{f1}}}Q_{f2_{f1}} - p_{I_{f2_{f1}}}I_d - p_{L_{f2_{f1}}}L_d)dz_2 \quad \text{(FDI)}\end{array}$$

$$(2)\ \theta'_{f23}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \theta'_{f24}(p_{E_{f2_d}}E_{f2_d} - p_{I_{E_{f2_d}}}\tfrac{1}{\eta'}I_d$$
$$-p_{L_{E_{f2_d}}}\tfrac{1}{\gamma'}L_d)dz_1 + (1 - \beta_{f2} - \phi_{f2} - \theta'_{f23} - \theta'_{f24})(p_{E_{f2_{f1}}}E_{f2_{f1}}$$
$$-p_{I_{E_{f2_{f1}}}}\tfrac{1}{\eta'}I_d - p_{L_{E_{f2_{f1}}}}\tfrac{1}{\gamma'}L_d)dz_2 \quad \text{(Export)}$$

$$(3)\theta'_{f25}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \theta'_{f26}(p_{Q_{f2_d}}Q_{f2_d} - p_{I_{f2_d}}I_d$$
$$-p_{L_{f2_d}}L_d)dz_1 + \ (1 - \beta_{f2} - \phi_{f2} - \theta'_{f25} - \theta'_{f26})(p_{E_{f2_{f1}}}E_{f2_{f1}}$$
$$-p_{I_{E_{f2_{f1}}}}\tfrac{1}{\eta'}I_d - p_{L_{E_{f2_{f1}}}}\tfrac{1}{\gamma'}L_d)dz_2 \quad \text{(Mixed I)}$$

$$(4)\ \theta'_{f27}(p_{Q_{f2}}Q_{f2} - p_{I_{f2}}\tfrac{1}{\eta'}I_d - p_{L_{f2}}\tfrac{1}{\gamma'}L_d)dt + \theta'_{f28}(p_{E_{f2_d}}E_{f2_d} - p_{I_{E_{f2_d}}}\tfrac{1}{\eta'}I_d$$
$$-p_{L_{E_{f2_d}}}\tfrac{1}{\gamma'}L_d)dz_1 + (1 - \beta_{f2} - \phi_{f2} - \theta'_{f27} - \theta'_{f28})(p_{Q_{f2_{f1}}}Q_{f2_{f1}}$$
$$-p_{I_{f2_{f1}}}I_d - p_{L_{f2_{f1}}}L_d)dz_2 \quad \text{(Mixed II)}$$

# Appendix B

$$\Gamma_4 = \frac{\hat{w}_{K_{a/b}}^{x_{11}-\frac{x_{11}x_4x_{15}}{x_9(x_3-x_{15})}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}}\hat{T}_a^{1+\frac{x_{15}}{x_3-x_{15}}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}}\hat{Pn}_{a/b}^{\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16}}}{D^F\hat{R}_{a/b}^{x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})}}\hat{K}_a^{1-\frac{x_4x_{15}}{x_9(x_3-x_{15})}}}t^B \quad (23)$$

$$\Gamma_5 = \frac{\hat{w}_{T_{a/b}}^{x_{17}}\hat{w}_{K_{a/b}}^{\frac{x_{11}^2x_4x_{15}}{x_9(x_3-x_{15})}\frac{x_{14}}{A}}\hat{K}_a^{(1-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}}\hat{R}_{a/b}^{(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}}}{D^{x_{13}-F\frac{x_{14}}{A}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}\hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_{14}}{A}+1}\hat{Pn}_{a/b}^{x_{16}+(\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16})\frac{x_{14}}{A}}}$$
$$t^{x_{18}-\frac{B}{A}x_{14}} \quad (24)$$

$$\Gamma_6 = \frac{\hat{w}_{K_{a/b}}^{x_{11}-(x_{11}-\frac{x_{11}x_4x_{15}}{x_3-x_{15}})\frac{x_{14}}{A}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_8}{A}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{Pn}_{a/b}^{x_{16}+\frac{x_{16}x_{15}}{x_3-x_{15}}\frac{x_8}{A}}}{D^{x_7-F\frac{x_8}{A}}\hat{R}_{a/b}^{x_{10}-(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}\hat{K}_a^{(1-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}}$$
$$t^{x_{12}-\frac{B}{A}x_8} \quad (25)$$

$$\Gamma_7 = \frac{\hat{w}_{K_{a/b}}^{x_{11}-(x_{11}-\frac{x_{11}x_4x_{15}}{x_3-x_{15}})\frac{x_8}{A}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_8}{A}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{Pn}_{a/b}^{x_{16}+\frac{x_{16}x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_8}{A}}}{D^{x_7-F\frac{x_8}{A}}\hat{R}_{a/b}^{x_{10}-(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}}$$
$$t^{x_{12}-\frac{B}{A}x_8} \quad (26)$$

$$\Gamma_8 = \frac{\hat{w}_{T_{a/b}}^{x_{17}}\hat{w}_{K_{a/b}}^{\frac{x_{11}^2x_4x_{15}}{x_9(x_3-x_{15})}\frac{x_{14}}{A}}\hat{R}_{a/b}^{(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}}\hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}}{D^{x_{13}-F\frac{x_{14}}{A}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}\hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_{14}}{A}+1}\hat{Pn}_{a/b}^{x_{16}+(\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16})\frac{x_{14}}{A}}}$$
$$t^{x_{18}-\frac{B}{A}x_{14}} \quad (27)$$

$$\Gamma_9 = \frac{\hat{w}_{K_{a/b}}^{x_{11}-(x_{11}-\frac{x_{11}x_4x_{15}}{x_3-x_{15}})\frac{x_8}{A}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_8}{A}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{Pn}_{a/b}^{x_{16}+\frac{x_{16}x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_8}{A}}}{D^{x_7-F\frac{x_8}{A}}\hat{R}_{a/b}^{x_{10}-(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}}$$
$$t^{x_{12}-\frac{B}{A}x_8} \quad (28)$$

$$\Gamma_{10} = \frac{\hat{w}_{K_{a/b}}^{x_{11}-\frac{x_{11}x_4x_{15}}{x_9(x_3-x_{15})}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}}\hat{Pn}_{a/b}^{\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16}}}{D^F\hat{R}_{a/b}^{x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})}}\hat{K}_a^{1-\frac{x_4x_{15}}{x_9(x_3-x_{15})}}\hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}}}t^B \quad (29)$$

$$\Gamma_{11} = \frac{\hat{w}_{T_{a/b}}^{x_{17}}\hat{w}_{K_{a/b}}^{\frac{x_{11}^2x_4x_{15}}{x_9(x_3-x_{15})}\frac{x_{14}}{A}}\hat{K}_a^{(1-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}}\hat{R}_{a/b}^{(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}}\hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}}{D^{x_{13}-F\frac{x_{14}}{A}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}\hat{Pn}_{a/b}^{x_{16}+(\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16})\frac{x_{14}}{A}}}$$
$$t^{x_{18}-\frac{B}{A}x_{14}} \quad (30)$$

$$\Gamma_{12} = \frac{\hat{w}_{K_{a/b}}^{x_{11}-(x_{11}-\frac{x_{11}x_4x_{15}}{x_3-x_{15}})\frac{x_8}{A}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{Pn}_{a/b}^{x_6+\frac{x_6x_{15}}{x_3-x_{15}}\frac{x_8}{A}}\hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_8}{A}}}{D^{x_7-F\frac{x_8}{A}}\hat{R}_{a/b}^{x_{10}-(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}\hat{K}_a^{1-(1-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}}t^{x_{12}-\frac{B}{A}x_8} \quad (31)$$

$$\Gamma_{13} = \frac{\hat{w}_{K_{a/b}}^{x_{11}-\frac{x_{11}x_4x_{15}}{x_9(x_3-x_{15})}}\hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}}\hat{T}_a^{1+\frac{x_{15}}{x_3-x_{15}}}\hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}}\hat{Pn}_{a/b}^{\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16}}}{D^F\hat{R}_{a/b}^{x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})}}\hat{K}_a^{1-\frac{x_4x_{15}}{x_9(x_3-x_{15})}}}t^B \quad (32)$$

$$\Gamma_{14} = \frac{\hat{w}_{T_{a/b}}^{x_{17}} \hat{w}_{K_{a/b}}^{\frac{x_{11}^2 x_4 x_{15}}{x_9(x_3-x_{15})}\frac{x_{14}}{A}} \hat{K}_a^{(1-\frac{x_4 x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}} \hat{R}_{a/b}^{(x_{10}-\frac{x_4 x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}}}{D^{x_{13}-F\frac{x_{14}}{A}} \hat{W}_{a/b}^{\frac{x_5 x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}} \hat{w}_{L_{a/b}}^{\frac{x_2 x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}} \hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_{14}}{A}+1} \hat{P}n_{a/b}^{x_{16}+(\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16})\frac{x_{14}}{A}}} t^{x_{18}-\frac{B}{A}x_{14}} \quad (33)$$

$$\Gamma_{15} = \frac{\hat{w}_{K_{a/b}}^{x_{11}-(x_{11}-\frac{x_{11}x_4x_{15}}{x_3-x_{15}})\frac{x_8}{A}} \hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_8}{A}} \hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{P}n_{a/b}^{x_{16}+\frac{x_{16}x_{15}}{x_3-x_{15}}\frac{x_8}{A}}}{D^{x_7-F\frac{x_8}{A}} \hat{R}_{a/b}^{x_{10}-(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}} \hat{K}_a^{1-(1-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}} t^{x_{12}-\frac{B}{A}x_8} \quad (34)$$

$$\Gamma_{16} = \frac{\hat{w}_{K_{a/b}}^{x_{11}-\frac{x_{11}x_4x_{15}}{x_9(x_3-x_{15})}} \hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}} \hat{T}_a^{1+\frac{x_{15}}{x_3-x_{15}}} \hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}} \hat{P}n_{a/b}^{\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16}}}{D^F \hat{R}_{a/b}^{x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}}} t^B \quad (35)$$

$$\Gamma_{17} = \frac{\hat{w}_{T_{a/b}}^{x_{17}} \hat{w}_{K_{a/b}}^{\frac{x_{11}^2 x_4 x_{15}}{x_9(x_3-x_{15})}\frac{x_{14}}{A}} \hat{R}_{a/b}^{(x_{10}-\frac{x_4 x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}}{D^{x_{13}-F\frac{x_{14}}{A}} \hat{W}_{a/b}^{\frac{x_5 x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}} \hat{w}_{L_{a/b}}^{\frac{x_2 x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}} \hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_{14}}{A}+1} \hat{P}n_{a/b}^{x_{16}+(\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16})\frac{x_{14}}{A}}} t^{x_{18}-\frac{B}{A}x_{14}} \quad (36)$$

$$\Gamma_{18} = \frac{\hat{w}_{K_{a/b}}^{x_{11}-(x_{11}-\frac{x_{11}x_4x_{15}}{x_3-x_{15}})\frac{x_8}{A}} \hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{T}_a^{(1+\frac{x_{15}}{x_3-x_{15}})\frac{x_8}{A}} \hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{P}n_{a/b}^{x_{16}+\frac{x_{16}x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_8}{A}}}{D^{x_7-F\frac{x_8}{A}} \hat{R}_{a/b}^{x_{10}-(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}}$$
$$t^{x_{12}-\frac{B}{A}x_8} \quad (37)$$

$$\Gamma_{19} = \frac{\hat{w}_{K_{a/b}}^{x_{11}-\frac{x_{11}x_4x_{15}}{x_9(x_3-x_{15})}} \hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}} \hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}} \hat{P}n_{a/b}^{\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16}}}{D^F \hat{R}_{a/b}^{x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})}} \hat{K}_a^{1-\frac{x_4x_{15}}{x_9(x_3-x_{15})}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}}} t^B \quad (38)$$

$$\Gamma_{20} = \frac{\hat{w}_{T_{a/b}}^{x_{17}} \hat{w}_{K_{a/b}}^{\frac{x_{11}^2 x_4 x_{15}}{x_9(x_3-x_{15})}\frac{x_{14}}{A}} \hat{K}_a^{(1-\frac{x_4 x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}} \hat{R}_{a/b}^{(x_{10}-\frac{x_4 x_{15}}{x_9(x_3-x_{15})})\frac{x_{14}}{A}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}}}{D^{x_{13}-F\frac{x_{14}}{A}} \hat{W}_{a/b}^{\frac{x_5 x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}} \hat{w}_{L_{a/b}}^{\frac{x_2 x_{15}}{x_3-x_{15}}\frac{x_{14}}{A}} \hat{P}n_{a/b}^{x_{16}+(\frac{x_{16}x_{15}}{x_3-x_{15}}+x_{16})\frac{x_{14}}{A}}} t^{x_{18}-\frac{B}{A}x_{14}} \quad (39)$$

$$\Gamma_{21} = \frac{\hat{w}_{K_{a/b}}^{x_{11}-(x_{11}-\frac{x_{11}x_4x_{15}}{x_3-x_{15}})\frac{x_8}{A}} \hat{W}_{a/b}^{\frac{x_5x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{w}_{L_{a/b}}^{\frac{x_2x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{P}n_{a/b}^{x_{16}+\frac{x_{16}x_{15}}{x_3-x_{15}}\frac{x_8}{A}} \hat{L}_a^{\frac{x_{15}}{x_3-x_{15}}\frac{x_8}{A}}}{D^{x_7-F\frac{x_8}{A}} \hat{R}_{a/b}^{x_{10}-(x_{10}-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}} \hat{K}_a^{1-(1-\frac{x_4x_{15}}{x_9(x_3-x_{15})})\frac{x_8}{A}}} t^{x_{12}-\frac{B}{A}x_8} \quad (40)$$

$$L_b = \Big(\frac{\hat{w}_{K_{b/a}}^{x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}} \hat{T}_b^{1+\frac{x'_{15}}{x'_3-x'_{15}}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}} \hat{P}n_{b/a}^{\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x_{16}}}{D^{F'} \hat{R}_{b/a}^{x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{K}_b^{1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}}} t^{B'}\Big)^{\frac{1}{A'}} \quad (41)$$

$$K_b = \Big(\frac{\hat{w}_{T_{b/a}}^{x'_{17}} \hat{w}_{K_{b/a}}^{\frac{x_{11}^{2'} x'_4 x'_{15}}{x'_9(x'_3-x'_{15})}\frac{x'_{14}}{A'}} \hat{K}_b^{(1-\frac{x'_4 x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{R}_{b/a}^{(x'_{10}-\frac{x'_4 x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}}}{D^{x'_{13}-F'\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5 x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2 x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{T}_a^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}+1} \hat{P}n_{b/a}^{x'_{16}+(\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16})\frac{x'_{14}}{A'}}}$$
$$t^{x'_{18}-\frac{B'}{A'}x'_{14}}\Big)^{\frac{1}{x'_{15}}} \quad (42)$$

$$T_b = \Big(\frac{\hat{w}_{K_{a/b}}^{x'_{11}-(x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{P}n_{b/a}^{x'_{16}+\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}}}{D^{x'_7-F'\frac{x'_8}{A'}} \hat{R}_{b/a}^{x'_{10}-(x'_{10}-\frac{x'_4x'_{15}}{x_9(x_3-x_{15})})\frac{x'_8}{A'}} \hat{K}_b^{(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}}}$$

$$t^{x'_{12}-\frac{B'}{A'}x'_8})^{\frac{1}{x'_9}} \quad (43)$$

$$\frac{dL_b}{d\hat{L}_b} = \frac{1}{A'}L_b^{A'(\frac{1}{A'}-1)}(-\frac{x'_{15}}{x_{\prime 3}-x'_{15}})\hat{L}_b^{-\frac{x'_{15}}{x'_3-x'_{15}}-1}\Gamma'_{13} \quad (44)$$

$$\frac{dK_b}{d\hat{L}_b} = \frac{1}{x'_{15}}K_b^{x'_{15}(\frac{1}{x'_{15}}-1)}\frac{x'_{15}x'_{14}}{(x'_3-x'_{15})A'}\hat{L}_b^{\frac{x'_{15}x'_{14}}{(x'_3-x'_{15})A'}-1}\Gamma'_{14} \quad (45)$$

$$\frac{dT_b}{d\hat{L}_b} = \frac{1}{x'_9}T_b^{x'_9(\frac{1}{x'_9}-1)}\frac{x'_{15}x'_8}{(x'_3-x'_{15})A'}\hat{L}_b^{\frac{x'_{15}x'_8}{(x'_3-x'_{15})A'}-1}\Gamma'_{15} \quad (46)$$

$$\frac{dL_b}{d\hat{K}_b} = \frac{1}{A'}L_b^{A'(\frac{1}{A'}-1)}(\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}-1)\hat{K}_b^{\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}-2}\Gamma'_{16} \quad (47)$$

$$\frac{dK_b}{d\hat{K}_b} = \frac{1}{x'_{15}}K_b^{x'_{15}(\frac{1}{x'_{15}}-1)}(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}\hat{K}_b^{(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}-1}\Gamma'_{17} \quad (48)$$

$$\frac{dT_b}{d\hat{K}_b} = \frac{1}{x'_9}T_b^{x'_9(\frac{1}{x'_9}-1)}((1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}-1)\hat{K}_b^{(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}-2}\Gamma'_{18} \quad (49)$$

$$\frac{dL_b}{d\hat{T}_b} = \frac{1}{A'}L_b^{A'(\frac{1}{A'}-1)}(1+\frac{x'_{15}}{x'_3-x'_{15}})\hat{T}_b^{\frac{x'_{15}}{x'_3-x'_{15}}}\Gamma'_{19} \quad (50)$$

$$\frac{dK_b}{d\hat{T}_b} = \frac{1}{x'_{15}}K_b^{x'_{15}(\frac{1}{x'_{15}}-1)}(-(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}-1)\hat{T}_b^{-(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}-2}\Gamma'_{20} \quad (51)$$

$$\frac{dT_b}{d\hat{T}_b} = \frac{1}{x'_9}T_b^{x'_9(\frac{1}{x'_9}-1)}(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}\hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}-1}\Gamma'_{21} \quad (52)$$

$$A' = x'_8 - x'_4 - \frac{x'_4x'_{15}}{x'_3-x'_{15}} - \frac{x'_8}{x'_9}\frac{x'_4x'_{15}}{x'_3-x'_{15}} \quad (53)$$

$$B' = x'_{12} - x'_{18} + \frac{(x'_6-x'_{18})x'_{15}}{x'_3-x'_{15}} - \frac{x'_{12}}{x'_9}\frac{x'_4x'_{15}}{x'_3-x'_{15}} \quad (54)$$

$$F' = x'_7 - x'_{13} + \frac{x'_{15}(x'_1-x'_{13})}{x'_7-x'_{13}} - \frac{x'_7}{x'_9}\frac{x'_4x'_{15}}{x'_3-x'_{15}} \quad (55)$$

$$\Gamma'_4 = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}}\hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}}\hat{T}_b^{1+\frac{x'_{15}}{x'_3-x'_{15}}}\hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}}\hat{P}n_{b/a}^{\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16}}}{D^{F'}\hat{R}_{b/a}^{x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}}\hat{K}_b^{1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}}}t^{B'} \quad (56)$$

$$\Gamma'_5 = \frac{\hat{w}_{T_{b/a}}^{x'_{17}}\hat{w}_{K_{b/a}}^{\frac{2'x'_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}\frac{x'_{14}}{A'}}\hat{K}_b^{(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}}\hat{R}_{b/a}^{(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}}}{D^{x'_{13}-F'\frac{x'_{14}}{A'}}\hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}}\hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}}\hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}+1}\hat{P}n_{b/a}^{x'_{16}+(\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16})\frac{x'_{14}}{A'}}}$$
$$t^{x'_{18}-\frac{B'}{A'}x'_{14}} \quad (57)$$

$$\Gamma'_6 = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-(x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x_8}{A}} \hat{P}n_{b/a}^{x'_{16}+\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}}}{D^{x'_7-F'\frac{x'_8}{A'}} \hat{R}_{b/a}^{x'_{10}-(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}} \hat{K}_b^{(1-\frac{x'_4x'_{15}}{x_9(x'_3-x'_{15})})\frac{x'_8}{A'}}} t^{x'_{12}-\frac{B'}{A'}x'_8} \quad (58)$$

$$\Gamma'_7 = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-(x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x_8}{A}} \hat{P}n_{b/a}^{x'_{16}+\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}}}{D^{x'_7-F'\frac{x'_8}{A'}} \hat{R}_{b/a}^{x'_{10}-(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}}} t^{x'_{12}-\frac{B'}{A'}x'_8} \quad (59)$$

$$\Gamma'_8 = \frac{\hat{w}_{T_{b/a}}^{x'_{17}} \hat{w}_{K_{b/a}}^{\frac{x'^2_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}\frac{x'_{14}}{A'}} \hat{R}_{b/a}^{(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}}}{D^{x'_{13}-F'\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}+1} \hat{P}n_{b/a}^{x'_{16}+(\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16})\frac{x'_{14}}{A'}}} t^{x'_{18}-\frac{B'}{A'}x'_{14}} \quad (60)$$

$$\Gamma'_9 = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-(x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x_8}{A}} \hat{P}n_{b/a}^{x'_{16}+\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}}}{D^{x'_7-F'\frac{x'_8}{A'}} \hat{R}_{b/a}^{x'_{10}-(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}}} t^{x'_{12}-\frac{B'}{A'}x'_8} \quad (61)$$

$$\Gamma'_{10} = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}} \hat{P}n_{b/a}^{\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16}}}{D^{F'} \hat{R}_{b/a}^{x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{K}_b^{1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}}} t^{B'} \quad (62)$$

$$\Gamma'_{11} = \frac{\hat{w}_{T_{b/a}}^{x'_{17}} \hat{w}_{K_{b/a}}^{\frac{x'^2_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}\frac{x'_{14}}{A'}} \hat{K}_b^{(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{R}_{b/a}^{(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}}}{D^{x'_{13}-F'\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{P}n_{b/a}^{x'_{16}+(\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16})\frac{x'_{14}}{A'}}} t^{x'_{18}-\frac{B'}{A'}x'_{14}} \quad (63)$$

$$\Gamma'_{12} = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-(x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x_8}{A}} \hat{P}n_{b/a}^{x'_{16}+\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}}}{D^{x'_7-F'\frac{x'_8}{A'}} \hat{R}_{b/a}^{x'_{10}-(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}} \hat{K}_b^{1-(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}}} t^{x'_{12}-\frac{B'}{A'}x'_8} \quad (64)$$

$$\Gamma'_{13} = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}} \hat{T}_b^{1+\frac{x'_{15}}{x'_3-x'_{15}}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}} \hat{P}n_{b/a}^{\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16}}}{D^{F'} \hat{R}_{b/a}^{x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{K}_b^{1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}}} t^{B'} \quad (65)$$

$$\Gamma'_{14} = \frac{\hat{w}_{T_{b/a}}^{x'_{17}} \hat{w}_{K_{b/a}}^{\frac{x''_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}\frac{x'_{14}}{A'}} \hat{K}_b^{(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{R}_{b/a}^{(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}}}{D^{x'_{13}-F'\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}+1} \hat{P}n_{b/a}^{x'_{16}+(\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16})\frac{x'_{14}}{A'}}} t^{x'_{18}-\frac{B'}{A'}x'_{14}}$$

(66)

$$\Gamma'_{15} = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-(x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x_8}{A}} \hat{P}n_{b/a}^{x'_{16}+\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}}}{D^{x'_7-F'\frac{x'_8}{A'}} \hat{R}_{b/a}^{x'_{10}-(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}} \hat{K}_b^{1-(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}}} t^{x'_{12}-\frac{B'}{A'}x'_8} \quad (67)$$

$$\Gamma'_{16} = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}} \hat{T}_b^{1+\frac{x'_{15}}{x'_3-x'_{15}}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}} \hat{P}n_{b/a}^{\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16}}}{D^{F'} \hat{R}_{b/a}^{x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}}} t^{B'} \quad (68)$$

$$\Gamma'_{17} = \frac{\hat{w}_{T_{b/a}}^{x'_{17}} \hat{w}_{K_{b/a}}^{\frac{x''_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}\frac{x'_{14}}{A'}} \hat{R}_{b/a}^{(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}}}{D^{x'_{13}-F'\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}+1} \hat{P}n_{b/a}^{x'_{16}+(\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16})\frac{x'_{14}}{A'}}} t^{x'_{18}-\frac{B'}{A'}x'_{14}}$$

(69)

$$\Gamma'_{18} = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-(x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_3-x'_{15}})\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{T}_b^{(1+\frac{x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x_8}{A}} \hat{P}n_{b/a}^{x'_{16}+\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}}}{D^{x'_7-F'\frac{x'_8}{A'}} \hat{R}_{b/a}^{x'_{10}-(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}}}$$

$$t^{x'_{12}-\frac{B'}{A'}x'_8} \quad (70)$$

$$\Gamma'_{19} = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}} \hat{P}n_{a/b}^{\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16}}}{D^{F'} \hat{R}_{b/a}^{x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{K}_b^{1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}}} t^{B'} \quad (71)$$

$$\Gamma'_{20} = \frac{\hat{w}_{T_{b/a}}^{x'_{17}} \hat{w}_{K_{b/a}}^{\frac{x''_{11}x'_4x'_{15}}{x'_9(x'_3-x'_{15})}\frac{x'_{14}}{A'}} \hat{K}_b^{(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{R}_{b/a}^{(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_{14}}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}}}{D^{x'_{13}-F'\frac{x'_{14}}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x'_{14}}{A'}} \hat{P}n_{b/a}^{x'_{16}+(\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}+x'_{16})\frac{x'_{14}}{A'}}} t^{x'_{18}-\frac{B'}{A'}x'_{14}} \quad (72)$$

$$\Gamma'_{21} = \frac{\hat{w}_{K_{b/a}}^{x'_{11}-(x'_{11}-\frac{x'_{11}x'_4x'_{15}}{x'_3-x'_{15}})\frac{x'_8}{A'}} \hat{W}_{b/a}^{\frac{x'_5x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{w}_{L_{b/a}}^{\frac{x'_2x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{P}n_{b/a}^{x'_{16}+\frac{x'_{16}x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}} \hat{L}_b^{\frac{x'_{15}}{x'_3-x'_{15}}\frac{x'_8}{A'}}}{D^{x'_7-F'\frac{x'_8}{A'}} \hat{R}_{b/a}^{x'_{10}-(x'_{10}-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}} \hat{K}_b^{1-(1-\frac{x'_4x'_{15}}{x'_9(x'_3-x'_{15})})\frac{x'_8}{A'}}} t^{x'_{12}-\frac{B'}{A'}x'_8} \quad (73)$$

# Concluding remarks

Up to now, the dissertation should come to an end. In above, we have hammered at a number of significant theoretical topics as: (1) why would the intraindustry trade and intraindustry investment more likely take place between developed countries? (2) why shouldn't technological transfer be unconditionally thought to be beneficial to developing countries and why is research and development still a crucial means for developing countries to survive a long run development? (3) why would being a multinational corporation be more superior in terms of risk aversion? and (4) why is free factor movement and sound social environment instrumental for a developing country to catch up with its developed counterpart? These questions are not just worthy of remark theoretically, but significant in toiling for a flourishing economic and social development in developing countries and the world as a whole practically.

The study on why a corporation would like to keep technological leadership discloses an almost ignored problem, i.e., developing corporations and countries might benefit nothing from restricted technological transfer. The study stresses the importance of strengthening research and development in developing countries and free mobility of productive factors across the world. Though our worry at the very first beginning that technological transfer may not help developing corporations or countries raise their international competitiveness hits the point unfortunately, anyhow, it has clued to these developing entities why their gap with developed ones grew larger. We do hope it is never too late to improve economic buildup in developing countries and technological assistance from developed ones for a bright world henceforward.

A theoretical model of multi-factors production is devised for studying the relationship between multinational corporations and factor movement. Free factor movement is shown to be auxiliary to production growth of a corporation and economic convergence of a country. We find out particularly that inflow of labor rather than capital and technology has complementary effect on local employment of its counterpart, given returns to productive factors, social welfare, and property protection are progressing and market risk is descending all the time in the countries involved. The finding suggests that there is Pareto improvement area for a more

blessed production/economic performance of a corporation/country. Especially to a developing one, the information may appear to be more important. Optimizing social environment, and carrying out policies oriented on introducing relatively skillful professionals and experts from developed countries are imposing for its future economic and social development.

Pursuit of a higher generalization is another characteristics of the dissertation. It accommodates these forms of international economic exchange as intraindustry trade, intraindustry investment, interindustry trade and interindustry investment within a single model. It also provides intuition for other important trade phenomena like intrafirm trade. It is no doubt that the dissertation points out that traditional trade theory still has its power to interpret new phenomena of international trade, which is not necessarily the patent of the new trade theory. In addition, the dissertation develops a model to look into the relationship between market risk and business behavior of multinational corporations. In the corresponding chapter, one can see easily how a corporation may be affected by variously sourced market risks and why being a multinational can better plan for investment, labor employment and production in front of these risks. The theoretical model is general enough to study any kind of (economic or non-economic) risk, and is well ready to be extended.

As summed up in the Introduction, the major contribution of the dissertation is distributed in the following four academic fields: international trade theory, theory of multinational corporations, growth theory, and business and public policy studies. We can hereby see from the dissertation, microeconomic foundation and macroeconomic phenomena are closely tied. It is understandable, with abstraction of complexity, that the way of operating a corporation may be effectively ascribed to govern a country, since whether a country grows well leans upon whether corporations of the country performs well to a large extent. Perhaps, theory of public choice argues a country would need to deal with social, cultural and other non-economic problems besides economic ones such that their respective objectives may always contradict among one another. On the contrary, the dissertation has offered such a case that social environment and corporate behavior is compatible. That at least can be viewed as a theoretical mirror of that there realistically exists that a developed country not only has developed corporate economy, but also has developed

social environment.

The policy implications of the dissertation may be especially informative for less developed market economy countries such as China, and other similar transition economies. China is the second largest recipient of FDI in the world, but an indisputable fact is that most FDI happens among developed countries. Besides the fact that China is facing large scale capital outflow, even worse, its scientific and technological competitiveness is falling during recent years. The International Institute for Management Development (IMD) has downgraded China's ranking in world competitiveness for consecutive three years from 29 in 1999, 30 in 2000 to 33 in 2001 (see *World Competitiveness Yearbook 1999, 2000, 2001*). Despite its high growth rate in GDP, poor performance in its state-owned enterprises, relatively high market risk and lack of economic efficiency has thrown doubts on China's quality of economic development. External positive impact like joining the WTO is helpful in raising survival probability (or sustainability) of economic growth (growth in GDP per capita) and consumer welfare (see Schwalbach and Su, 2002), but internal endeavour of promoting education and research and development, reducing market risk, and improving social environment is the intrinsic way to achieve a healthier and more competitive economy. And all of this is exactly what the dissertation aims to account for.

Finally, all the four chapters are theoretical, suggesting that corresponding empirical studies can be followed up based on the idea and framework of the dissertation in our future work. However, a would-be difficulty is that relevant data such as those recording international factor movement and reflecting social institution are still insufficient. Certainly, theoretical extension is indispensable. For instance, a study where non-economic or interdisciplinary reasonings can be introduced in the chapter one and the chapter two, concrete anatomy of social institution in the chapter four, and unsymmetrical risk across countries in the chapter three.

It is notwithstanding that the four chapters are only a trivial endeavour for deeper and more precise understanding of the phenomena of multinational corporations, intraindustry trade, factor movement, market risk, economic growth, social development and other related economic and non-economic issues. We know realistic economic and business behavior is much more complicated than current theoretical

modeling technique can glean. An exerted academic endeavor along the spirit of the dissertation would be followed up by the author. Our wish would be best realized if the dissertation can play a role of turning up more further studies from other scholars and proper attention from countries concerned when stipulating economic policies and so forth.

As Marcel Proust said, "the real voyage of discovery is not in seeking new lands but in seeing with new eyes", I do hope the dissertation can provide such "new eyes" to the theory of multinational corporations.

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# Erklärung

Hiermit erkläre ich an Eides statt, die vorliegende Arbeit selbständig und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt zu haben. Die Personen, von denen ich Unterstützung erhalten habe, sind im Vorwort erwähnt.

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Berlin, den

Qi Su