Horizontal multinational firms, vertical multinational firms and domestic investment

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Abstract
We construct a dynamic general equilibrium model with 2 countries, horizontal and vertical multinational activity and endogenous domestic and foreign investment. It is found that horizontal multinational activity always leads to a complementary relationship between domestic and foreign investment. Vertical multinational activity, in contrast, leads to a substitutional or complementary relationship between domestic and foreign investment, depending on the values of model parameters. We test the theoretical implications with a panel of U.S. multinationals and find empirical support.

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Keywords: Horizontal multinational firms, vertical multinational firms, domestic investments, neoclassical growth model
1 Introduction

Rising multinational activity has raised important questions about how foreign direct investment (FDI) affects domestic capital formation. Recent empirical evidence for the U.S. (Desai et al., 2005a) shows that the pessimists may be wrong as there seems to be a complementarity relationship between foreign and domestic capital expenditures, rather than a substitutional relationship.

Intuitively, a distinction between the motives for FDI is crucial for understanding the relation between domestic and foreign capital expenditures. While horizontal multinationals invest abroad as to serve new markets, vertical multinationals invest in order to reduce the cost of production. Therefore, the aggregate finding of foreign and domestic investments being complements may be rather distinct for either of the two types of multinationals.

Our paper intends to contribute to the debate by building a general equilibrium model, which extends Markusen’s (2002) Knowledge-Capital model of the multinational firm by endogenous domestic and foreign investment. Afterwards, we test the theoretical implications with U.S. data on the operations of multinational firms. Our theoretical and empirical implications show the importance of the motive for FDI in explaining the link between domestic and foreign capital expenditures.

The empirical literature on the link between domestic and foreign investment has started with Feldstein (1995) who found a negative correlation between FDI and domestic investment in a sample of OECD countries, suggesting that outward FDI reduces domestic investment. More recently, Desai et al. (2005a) redid his analysis on a subsample of domestic investment and FDI by examining domestic and foreign capital expenditures of U.S. multinationals. Instead of a negative relation between domestic and foreign capital expenditures, they find a positive and significant link between the two variables. One possible explanation they put forward is that the USA may be different from other OECD countries. By finding substitutability of domestic and foreign investment for German data while confirming complementarity for U.S. data, Herzer and Schrooten (2008) find some evidence for this explanation. A second explanation they put forward relates to the activities of multinational firms which are different from the activities of the average firm. A third explanation relates to the composition of FDI and domestic investment in both samples in the sense that aggregate FDI data contain financing flows whereas the data for multinationals are restricted to capital expenditures. In a pooled panel of U.S. multinationals with more than 2,000 observations and period fixed effects, Desai et al. (2005b) find that a 10% increase in foreign investment increases domestic investments by approximately 2%, confirming the aggregate results.

We test the implications of our theoretical model in an econometric analysis using a U.S.
panel of foreign and domestic investments at the sector level over the period 1999–2005. In order to test the implications from the theoretical model, we test whether the link between domestic and foreign investment is different for horizontal and vertical multinationals. The results of our panel with random and fixed sector effects confirm the findings by Desai et al. (2005b) for the sign of foreign investment. As to account for persistence in domestic investment we take lagged domestic investment as an explanatory variable in a dynamic panel model.

As to distinguish between horizontal and vertical multinationals, we follow empirical evidence by Hanson et al. (2001) and assume that firms in the manufacturing sectors are mainly vertical multinationals while multinationals operating in the other sectors are mainly horizontal. We find that complementarity relation between domestic and foreign investment remains for horizontal multinationals, but find a substitution relation for vertical multinationals. If we further refine the link between domestic and foreign investments, the econometric results show that the substitution effect for vertical MNE is moderated if the factor shares of the intermediate goods are more equal and if the shares of the intermediate goods in final goods production are more equal. This result is also predicted by the theoretical model.

This paper is organized as follows. Section 2 describes the theoretical model. Section 3 performs a comparative steady state analysis of the theoretical model and derives empirically testable predictions. Section 4 tests the predictions of the theoretical model. Section 5 concludes.

2 Basic model

This paper analyzes a general equilibrium model, which is a dynamic extension of the Knowledge–Capital model by Markusen (2002). The model consists of two countries, a home country $H$ and a foreign country $F$.

The representative household in each country consumes several varieties of a differentiated good $X$ and a homogeneous good $Z$. Good $X$ is produced by multinational firms.

It is assumed that households aggregate the varieties of good $X$ according to a CES–function like in Dixit and Stiglitz (1977). Furthermore, it is assumed that the number of firms in sector $X$ is sufficiently large so that the market for good $X$ is characterized by large–group monopolistic competition (e.g., Markusen and Venables, 2000). Sector $Z$ firms behave perfectly competitively.

The home country $H$ and the foreign country $F$ are endowed with two factors of production, labor $L$ and capital $K$. Both factors are mobile between sectors but immobile between countries.
Both factors are used for the following production activities: first, labor and capital are used to produce the homogeneous final good $Z$. Second, labor and capital are used to produce two intermediate goods $v_1$ and $v_2$; both intermediate goods are assembled to give a unique variety of the differentiated final good $X$.

Each country’s labor endowment is constant over time. Each country’s capital endowment, in contrast, is determined endogenously via the Ramsey growth model and therefore flexible in the long–run. Relative factor endowments are therefore flexible in the long–run as well.

Due to this dynamic extension of Markusen’s (2002) Knowledge–Capital model the firm regime has to be determined exogenously. In the first regime, only horizontal multinational firms are active. In the second regime, only vertical multinational firms are active.

The reason for the exogenous determination of the firm regime is the following: in the dynamic setup of this paper a unique causal relationship between the firm regime and the countries’ relative factor endowments is missing. On the one hand, the firm regime influences relative factor demands and, therefore, relative factor prices in each country. Relative factor prices, in turn, influence the investment behavior of households, which finally determines the countries’ relative factor endowments in the steady state.\(^1\) On the other hand, the countries’ relative factor endowments influence relative factor prices, which determine the firm regime.\(^2\)

Two different general steady state equilibria accordingly exist in this dynamic setup. First, a general equilibrium with horizontal multinational firms and the corresponding relative factor endowments in the steady state. Second, a general equilibrium with vertical multinational firms and the corresponding relative factor endowments in the steady state. This paper accordingly determines the firm regime exogenously. Afterwards, the countries’ corresponding relative factor endowments in the steady state are derived.

In the first firm regime with only horizontal multinational firms, each firm has two production plants, one in country $H$ and one in country $F$. Both production plants produce both intermediate goods $v_1$ and $v_2$. In the second firm regime with only vertical multinational firms, each firm has also two production plants, one in country $H$ and one in country $F$. However, each production plant produces only one of the two intermediate goods $v_1$ and $v_2$.\(^3\)

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1. The result that a country’s relative factor endowment in the steady state of a Ramsey growth model depends on the firms’ technologies, the household’s time discount rate and the capital depreciation rate is originally derived by Baxter (1992).
2. The influence of the countries’ relative factor endowments on the firm regime is explained by the Knowledge–Capital model by Markusen (2002). Note that the Knowledge–Capital model is a static model, i.e. the relative factor endowments are exogenously given and not influenced by the firm regime.
3. Note that the definition of horizontal and vertical multinational firms in this paper differs from the definition in the Knowledge–Capital model by Markusen (2002). No intermediate goods exist in the Knowledge–Capital model. Horizontal multinational firms in the Knowledge–Capital model produce the final good directly with labor and capital in both countries; headquarter services are only produced in one country, but are used for both production plants. Vertical multinational firms in the Knowledge–Capital model produce the final
Both horizontal and vertical multinational firms produce with economies of scale, which are due to the existence of fixed production costs.

Several assumptions are necessary in order to get straightforward analytical results. First, both countries are completely identical with respect to technology parameters and preference parameters. The only exception is the income share households spend on the varieties of good $X$ and on good $Z$, which is allowed to differ between countries. Second, international trade of both intermediate goods, the varieties of good $X$ and good $Z$ is assumed to be costless. Third, this paper assumes that either only horizontal multinational firms or only vertical multinational firms are active. Fourth, this paper assumes a ranking of the factor intensities of all 4 goods, which is in line with previous empirical studies. Finally, the model only considers the countries’ steady states; therefore, the time index is included only when necessary.

In order to analyze whether domestic and foreign capital expenditures are complements or substitutes, the steady state of the world will be disturbed by a variety of exogenous shocks. If the capital stocks of both countries move into the same direction due to the exogenous shock, domestic and foreign capital expenditures are complements. If the capital stocks of both countries move into different directions due to the exogenous shock, domestic and foreign capital expenditures are substitutes.

The following subsections separately describe the ingredients into the dynamic general equilibrium model. Subsection 2.1 describes the production side of both countries, subsection 2.2 describes the dynamic structure of the model, subsection 2.3 derives factor price equalization between both countries in the steady state, subsection 2.4 defines horizontal and vertical multinational firms and subsection 2.5 describes the demand side of both countries. Subsections 2.6 and 2.7 describe two additional conditions which have to hold in each period of the steady state: first, the free entry condition into the multinational firms’ sector and, second, the trade balance equation.

2.1 Production

Both countries have the same production technologies for producing intermediate goods and final goods.

The homogeneous good $Z$ is produced according to the following Cobb–Douglas production function directly with labor and capital in one country only; headquarter services are produced in the other country and are exported to the production plant. The additional separation of the production process into 2 intermediate goods like in this paper takes into account that vertical multinational firms in general never separate the entire production process from the headquarter services, but only the most labor intensive part of the production process (e.g., UNCTAD, 1998).
tion function:

\[ Z = \frac{L^\beta \cdot K^{1-\beta}}{\beta^\beta \cdot (1-\beta)^{1-\beta}}; \]  

(1)

since good Z represents the average outside good, its factor shares are assumed to be ‘average’ as well. Therefore, \( \beta \) will be set equal to 0.5 during the comparative steady state analysis in section 3. The per unit cost function which is dual to the production function in equation (1) is given by:

\[ c_Z (w_i, r_i) = w_i^\beta \cdot r_i^{1-\beta}. \]  

(2)

Since sector Z firms behave perfectly competitively, they sell their good at price \( p_Z = c_Z \).

Intermediate goods \( v_1 \) and \( v_2 \) are produced according to the following Cobb–Douglas production functions:

\[ v_1 = \frac{L^{\phi_1} \cdot K^{1-\phi_1}}{\phi_1^{\phi_1} \cdot (1-\phi_1)^{1-\phi_1}}, \quad \text{with} \quad 0 \leq \phi_1 \leq 0.5, \]  

(3)

\[ v_2 = \frac{L^{\phi_2} \cdot K^{1-\phi_2}}{\phi_2^{\phi_2} \cdot (1-\phi_2)^{1-\phi_2}}, \quad \text{with} \quad \phi_2 = 1 - \phi_1; \]  

(4)

note that intermediate good \( v_1 \) is assumed to be more \textit{capital} intensive than the outside good \( Z \), while intermediate good \( v_2 \) is assumed to be more \textit{labor} intensive than the outside good \( Z \). These assumptions on \( \phi_1 \) and \( \phi_2 \) therefore consider the empirical fact that multinational firms, if they are vertical, relocate the most \textit{labor} intensive production activities to the foreign country, while they keep the more capital intensive production activities at home (Blomström and Kokko, 1997; Hummels et al., 1998).\footnote{The assumption that \( \phi_2 \) exactly equals \( 1 - \phi_1 \) simplifies calculations, but is not crucial for the final results.}

The marginal cost functions which are dual to the production functions in equations (3) and (4) are given by:

\[ c_{v_1} (w_i, r_i) = w_i^{\phi_1} \cdot r_i^{1-\phi_1} \quad \text{and} \quad c_{v_2} (w_i, r_i) = w_i^{\phi_2} \cdot r_i^{1-\phi_2}, \quad i = H, F. \]  

(5)

The variables \( w_i \) and \( r_i \) stand for the price per unit labor and the capital rental rate in country \( i \).

Intermediate goods \( v_1 \) and \( v_2 \) are assembled to a unique variety of the differentiated final good \( X \) according to the following Cobb–Douglas production function:

\[ X = \frac{(v_1)^\alpha \cdot (v_2)^{1-\alpha}}{\alpha^\alpha \cdot (1-\alpha)^{1-\alpha}}, \quad \text{with} \quad 0 \leq \alpha \leq 1. \]  

(6)

The per unit cost function which is dual to the production function in equation (6) is given by:\footnote{If the firm has a horizontal organization of its production, i.e. intermediate goods \( v_1 \) and \( v_2 \) are produced in the same country, the per unit cost function simplifies to \( c_X (w_i, r_i) = w_i^{\phi_1 \cdot \alpha + \phi_2 \cdot (1-\alpha)} \cdot r_i^{\alpha \cdot (1-\phi_1) + (1-\phi_2) \cdot (1-\alpha)}. \)}

\[ c_X (w_i, w_j, r_i, r_j) = c_{v_1}^\alpha \cdot c_{v_2}^{1-\alpha} = w_i^{\phi_1 \cdot \alpha} \cdot w_j^{\phi_2 \cdot (1-\alpha)} \cdot r_i^{\alpha \cdot (1-\phi_1)} \cdot r_j^{(1-\phi_2) \cdot (1-\alpha)}, \quad i, j = H, F. \]  

(7)
2.2 Dynamic structure

The model is extended to a Ramsey growth setup. Including the time index \( t \), utility in a single period \( t \) in country \( i \), \( i = H, F \), is given by the following Cobb–Douglas function:

\[
U_{i,t} = X_{i,t}^{\gamma_i} Z_{i,t}^{1-\gamma_i}, \quad 0 < \gamma_i < 1, \tag{8}
\]

where \( X_{i,t} \) denotes a CES–aggregate of all consumed varieties of good \( X \) in period \( t \) in country \( i \) and \( Z_{i,t} \) the consumption of good \( Z \) in period \( t \) in country \( i \).

Country \( i \)'s capital stock \( K_{i,t} \) in period \( t \) is determined endogenously via the investment decision by country \( i \)'s representative household. It is assumed that only good \( Z \) is used for investment. The household chooses the consumption and investment level in each period such that lifetime utility \( V \) is maximized. If \( \rho \) denotes the time discount rate, lifetime utility of the households is given by: \(^6\)

\[
V_i = \sum_{t=0}^{\infty} \frac{1}{(1+\rho)^t} \cdot u(U_{i,t}), \tag{9}
\]

where \( u \) represents the household’s instantaneous utility function.

If \( \delta \) stands for the per–period depreciation rate for capital, investment into the country’s capital stock in period \( t \) of the steady state is given by: \(^7\)

\[
I_{i,t} = K_{i,t+1} - (1-\delta) \cdot K_{i,t}. \tag{10}
\]

\( I_{i,t} \) denotes the amount of good \( Z \), which is invested in period \( t \). Equation (10) implies that one unit of good \( Z \), which is invested in period \( t \), leads to one unit of capital in period \( t+1 \).

It is assumed that the country’s household and sector \( Z \)–firms behave perfectly competitively. The household owns the production factors and lends them out to firms for production purposes. The steady state of the economy is then described by several necessary first order conditions. \(^8\) Four of these necessary first order conditions already determine the country’s factor price ratio in the steady state:

\[
r_{i,t} + (1-\delta) \cdot p_{Z,i,t} = p_{K,i,t} \tag{11}
\]

\[
r_{i,t} = p_{Z,i,t} \cdot \left( \frac{1-\beta}{\beta} \cdot \frac{K_{Z,i,t}}{K_{Z,t,t}} \right)^\beta \tag{12}
\]

\[
w_{i,t} = p_{Z,i,t} \cdot \left( \frac{\beta}{1-\beta} \cdot \frac{K_{Z,i,t}}{L_{Z,i,t}} \right)^{1-\beta} \tag{13}
\]

\[
\frac{p_{K,i,t+1}}{1+\rho} = p_{Z,i,t} \tag{14}
\]

\(^6\)All parameters with a country index are assumed to be identical across countries.

\(^7\)Note that the country’s labor endowment is assumed to be constant over time. Investment in the steady state therefore only compensates for depreciation.

where \( p_{K,i,t} \) denotes the price per unit capital in country \( i \) period \( t \) and \( L_{Z,i,t} \) and \( K_{Z,i,t} \) the labor and capital input in sector \( Z \) of country \( i \) in period \( t \).

Equation (11) is the arbitrage condition for the household’s capital lending behavior: households are only willing to lend out capital to firms if the capital rental rate \( r_{i,t} \) plus the value of the remaining unit of capital in period \( t+1 \), which is given by \((1 - \delta) \cdot p_{Z,i,t}\), equals the price per unit capital today.

Equations (12) and (13) are the usual conditions for a profit maximizing factor input choice by firms.

Equation (14) denotes the Euler equation, which describes the dynamically optimizing behavior of a household: the household chooses the investment level such that, in the steady state, the discounted value of a unit capital in \( t+1 \) equals the value of a unit of good \( Z \) in \( t \).

The time index \( t \) is omitted from now on since only the steady state is considered in the following.

Substituting equation (14) into equation (11) leads to \( r_{i} + (1 - \delta) \cdot p_{Z,i} = (1 + \rho) \cdot p_{Z,i} \), which can be simplified to \( \frac{r_{i}}{p_{Z,i}} = \rho + \delta \).

Substituting \( \frac{r_{i}}{p_{Z,i}} = \rho + \delta \) into equation (12) and solving for \( \frac{K_{Z,i}}{L_{Z,i}} \) results in \( \frac{K_{Z,i}}{L_{Z,i}} = \frac{1 - \beta}{\beta} \cdot \left( \frac{1}{\rho + \delta} \right)^{1/\beta} \).

Substituting \( \frac{K_{Z,i}}{L_{Z,i}} = \frac{1 - \beta}{\beta} \cdot \left( \frac{1}{\rho + \delta} \right)^{1/\beta} \) into equation (13) results in \( \frac{w_{i}}{p_{Z,i}} = (\rho + \delta)^{(\beta - 1)/\beta} \).

Dividing \( \frac{w_{i}}{p_{Z,i}} \) by \( \frac{r_{i}}{p_{Z,i}} \) gives:

\[
\frac{w_{i}}{r_{i}} = (\rho + \delta)^{-1/\beta}.
\] (15)

The further analysis simplifies considerably since, in this dynamic setup, the factor price ration in the steady state is already determined by the parameters \( \rho, \delta \) and \( \beta \). Therefore, in this dynamic setup, it is not necessary to take the factor market equilibrium conditions to determine the factor price ration in the steady state.\(^9\)

Instead, the factor price ratio from equation (15) can be substituted into the factor market equilibrium conditions. The factor market equilibrium conditions can then be used to solve for the steady state capital stock, which is \textit{endogenous} in this dynamic setup. Furthermore, section 3 shows that the factor market equilibrium conditions can be used to solve for the number of multinational firms in the steady state.

Most importantly, section 3 shows that the factor market equilibrium conditions are \textit{linear} in the steady state capital stock and the number of firms, i.e. the factor market equilibrium conditions can be solved analytically for these two variables.

\(^9\)Note that the factor market equilibrium conditions are \textit{non-linear} in factor prices if, e.g., Cobb–Douglas production technologies are used. Therefore, in a \textit{static} setup, in which the equilibrium factor price ratio has to be determined by the factor market equilibrium conditions, analytical solutions are typically not available.
2.3 Factor price equalization in the steady state

The assumption of identical technologies and preferences in both countries implies that the parameters $\rho$, $\delta$ and $\beta$ are identical in both countries, i.e. $\frac{w_H}{r_H} = \frac{w_F}{r_F}$ due to equation (15). Furthermore, costless trade of good $Z$ between countries leads to:

\[
p_{Z,H} = w_H^\beta \cdot r_H^{1-\beta} = w_F^\beta \cdot r_F^{1-\beta} = p_{Z,F}
\]

(16)

\[
\Longleftrightarrow \left( \frac{w_H}{r_H} \right)^\beta \cdot r_H = \left( \frac{w_F}{r_F} \right)^\beta \cdot r_F.
\]

(17)

Since $\frac{w_H}{r_H} = \frac{w_F}{r_F}$ in the steady state, equation (17) implies that $r_H = r_F$ in the steady state. If the capital rental rate is identical, the price per unit labor must be identical in both countries in the steady state as well. The factor prices are therefore written without a country index in the following.

The per unit costs for a variety of good $X$ can accordingly be written as:

\[
c_X = w^\xi \cdot r^{1-\xi}, \quad \text{with} \quad \xi = \phi_1 \cdot \alpha + \phi_2 \cdot (1 - \alpha).
\]

(18)

2.4 Horizontal versus vertical multinational firms

2.4.1 Horizontal multinational firms

A single horizontal multinational firm with headquarters in country $i$, $i = H, F$, has two production plants, one in country $H$ and one in country $F$. Each production plant produces both intermediate goods $v_1$ and $v_2$ and assembles them to a unique variety of good $X$. Since each production plant produces a unique variety of good $X$, the final output of each production plant is sold domestically and exported to the other country.

Note that a single horizontal multinational firm sells two unique varieties of good $X$ since it owns two production plants.

Chart 1 of figure 1 illustrates the allocation of production activities across countries for horizontal multinational firms. The arrows from headquarter services (HQS) to both production plants (PP) indicate that headquarter services are produced in one country, but supplied to the production plants in both countries.

2.4.2 Vertical multinational firms

A single vertical multinational firm with headquarters in country $i$, $i = H, F$, has two production plants as well, one in country $H$ and one in country $F$. However, each production plant produces only either intermediate good $v_1$ or intermediate good $v_2$. Since vertical multinational firms typically have an identical allocation of production activities across countries
(e.g., Markusen, 2002), it is assumed that intermediate good \( v_1 \) is \emph{only} produced by production plants from country \( H \) and intermediate good \( v_2 \) is \emph{only} produced by production plants from country \( F \).

Therefore, the production plants in country \( H \) import intermediate good \( v_2 \) and the production plants in country \( F \) import intermediate good \( v_1 \). Each production plant then assembles both intermediate goods to a \emph{unique} variety of good \( X \). Since each production plant produces a \emph{unique} variety of good \( X \), each production plant sells its variety both domestically and to the other country.

Note again that a \emph{single} vertical multinational firm sells \emph{two} unique varieties of good \( X \) since it owns \emph{two} production plants.

Charts 2 and 3 of figure 1 illustrate the allocation of production activities across countries for vertical multinational firms.

\subsection{Demand}

The household’s utility in country \( i \) in a single period of the steady state is given by:

\[
U_i = X_i^{\gamma_i} \cdot Z_i^{1-\gamma_i}, \quad 0 \leq \gamma_i \leq 1, \quad (19)
\]

with \( X_i = \left((N_H + N_F) \cdot X_{ii}^{(\sigma-1)/\sigma} + (N_H + N_F) \cdot X_{ji}^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)}, \quad \sigma > 1 \)

and \( Z_i = Z_{ii} + Z_{ji} \).

\( N_H \) and \( N_F \) stand for the number of multinational firms with headquarters in country \( H \) and \( F \); note that these firms are either horizontal or vertical multinational firms. \( X_{ii} \) stands for the supply of a production plant from country \( i \) to country \( i \). \( X_{ji} \) stands for the supply of a production plant from country \( j \) to country \( i \). Similarly, \( Z_{ii} \) stands for the supply of good \( Z \) from country \( i \) to country \( i \) and \( Z_{ji} \) stands for the supply of good \( Z \) from country \( j \) to country \( i \).

It is assumed that the sum \( N_H + N_F \) is sufficiently large so that the market for good \( X \) is characterized by large-group monopolistic competition. Profit maximizing sector \( X \) firms then supply their unique varieties of good \( X \) at price \( p_X = \frac{\sigma}{\sigma-1} \cdot c_X \). Since factor prices are identical in both countries in the steady state, \( c_X \) does not have a country index.

The price index which is dual to the CES-aggregate \( X_i \) is then given by:

\[
P = (N_H + N_F)^{1/(1-\sigma)} \cdot \frac{\sigma}{\sigma-1} \cdot w^\xi \cdot r^{1-\xi} \cdot 2^{1/(1-\sigma)}. \quad (20)
\]

If

\[
M_i = L_i \cdot w + K_i \cdot r \quad (21)
\]

9
denotes aggregate factor income of country \( i \), \( i = H, F \), the supply = demand–conditions result as

\[
X_{ii} = p^{-\sigma} \cdot P^{\sigma - 1} \cdot M_i \cdot \gamma_i = \left( \frac{\sigma}{\sigma - 1} \cdot w^\xi \cdot r^{1 - \xi} \right)^{-\sigma} \cdot \frac{\left( \frac{\sigma}{\sigma - 1} \cdot w^\xi \cdot r^{1 - \xi} \right)^{\sigma - 1}}{2 \cdot (N_H + N_F)} \cdot M_i \cdot \gamma_i
\]

\[
= \gamma_i \cdot \frac{\sigma - 1}{\sigma} \cdot \frac{1}{w^\xi \cdot r^{1 - \xi}} \cdot \frac{M_i}{2 \cdot (N_H + N_F)}, \quad i = H, F; \quad (22)
\]

and, similarly,

\[
X_{ij} = \gamma_j \cdot \frac{\sigma - 1}{\sigma} \cdot \frac{1}{w^\xi \cdot r^{1 - \xi}} \cdot \frac{M_j}{2 \cdot (N_H + N_F)}, \quad i, j = H, F, \quad i \neq j. \quad (23)
\]

Note that the left–hand sides of equations (22) and (23) denote the supply of a single production plant from country \( i \) to country \( i \) or \( j \). The right–hand sides of equations (22) and (23) accordingly denote the demand in country \( i \) or \( j \) for a unique variety which is produced by a production plant from country \( i \).

The supply = demand–condition for good \( Z \) and country \( i \) can be derived as:

\[
Z_{ii} + Z_{ji} = \frac{M_i}{p_Z} \cdot (1 - \gamma_i), \quad i, j = H, F, \quad i \neq j. \quad (24)
\]

### 2.6 Free entry condition

If entry into sector \( X \) is unrestricted, the free entry condition for sector \( X \) has to hold in each period of the steady state. The free entry condition equalizes total markup revenue of a single sector \( X \) firm with total fixed costs of this firm. The free entry condition of a single multinational firm is given by:

\[
(p_X - c_X) \cdot (X_{HH} + X_{HF} + X_{FF} + X_{FH}) = r \cdot (F_{HQS+PP} + F_{PP}), \quad (25)
\]

where the left–hand side of equation (25) denotes total markup revenue of a single multinational firm and the right–hand side of equation (25) denotes total fixed costs of this firm.

\( p_X - c_X \) stands for the markup revenue per unit of good \( X \) sales. The sum \( X_{HH} + X_{HF} \) denotes total sales of the firm’s production plant in country \( H \) and the sum \( X_{FF} + X_{FH} \) denotes total sales of the firm’s production plant in country \( F \). \( F_{HQS+PP} \) stands for the fixed capital input in the country of the firm’s headquarters. \( F_{HQS+PP} \) is used for running the entire firm, i.e. for producing headquarters services (HQs), and for maintaining the production plant (PP) in the country of the firm’s headquarters. \( F_{PP} \) stands for the fixed capital input in the host country. \( F_{PP} \) is used for maintaining the production plant in the host country. The term \( r \cdot (F_{HQS+PP} + F_{PP}) \) accordingly denotes total fixed capital expenditures of a single firm.
Since $F_{PP}$ only includes the fixed capital input for maintaining a production plant, whereas $F_{HQS+PP}$ additionally includes the fixed capital input for producing headquarter services, $F_{HQS+PP} > F_{PP}$ is assumed for the comparative steady state analysis in section 3.

Substituting the expressions for $X_{HH}$, $X_{HF}$, $X_{FF}$ and $X_{FH}$ (cf. equations (22) and (23)) into equation (25) and considering that $p_X = \frac{\sigma - 1}{\sigma - 1} \cdot c_X = \frac{\sigma - 1}{\sigma - 1} \cdot w^\xi \cdot r^{1-\xi}$ leads to the following simplification of the free entry condition:

$$
\frac{(L_H \cdot w_H + K_H \cdot r_H) \cdot \gamma_H + (L_F \cdot w_F + K_F \cdot r_F) \cdot \gamma_F}{\sigma \cdot (N_H + N_F)} = r \cdot (F_{HQS+PP} + F_{PP}). \quad (26)
$$

### 2.7 Trade balance equation

The trade pattern between countries depends on whether horizontal or vertical multinational firms are active. In the regime with horizontal multinational firms, countries only trade the varieties of the differentiated good $X$ and good $Z$.\(^{10}\) In the regime with vertical multinational firms, countries additionally trade intermediate goods $v_1$ and $v_2$.\(^{11}\)

The trade balance equation is therefore derived separately for either firm regime.

#### 2.7.1 Trade balance equation with horizontal multinational firms

Trade between country $H$ and country $F$ is balanced if the value of exports equals the value of imports, i.e. if the following holds:

$$
Z_{HF} \cdot p_Z + (N_H + N_F) \cdot X_{HF} \cdot p_X = Z_{FH} \cdot p_Z + (N_H + N_F) \cdot X_{FH} \cdot p_X. \quad (27)
$$

The left-hand side (right-hand side) of equation (27) denotes the value of country $H$’s exports (imports). Since $X_{HF}$ and $X_{FH}$ stand for exports of a single production plant from country $H$ and $F$, the quantities $X_{HF}$ and $X_{FH}$ have to be multiplied by $N_H + N_F$. The sum $N_H + N_F$ denotes the total number of firms, which own a production plant in both countries.

Considering that country $H$’s imports of good $Z$ are country $F$’s exports of good $Z$, $Z_{HF}$ can be set equal to zero and $Z_{HF}$ is allowed to be negative. Substituting the expressions for $X_{HF}$ and $X_{FH}$ (cf. equation (23)) into equation (27) and considering $p_Z = w^\beta \cdot r^{1-\beta}$ and $p_X = \frac{\sigma - 1}{\sigma - 1} \cdot w^\xi \cdot r^{1-\xi}$ leads to the following expressions for the trade balance equation:

$$
Z_{HF} = \frac{(L_H \cdot w + K_H \cdot r) \cdot \gamma_H - (L_F \cdot w + K_F \cdot r) \cdot \gamma_F}{2 \cdot w^\beta \cdot r^{1-\beta}}. \quad (28)
$$

\(^{10}\)Note that the varieties of good $X$ are traded even between completely identical countries due to the Dixit–Stiglitz formulation of the preferences for good $X$ (e.g., Markusen and Venables, 2000). Good $Z$ is only traded if trade in the varieties of good $X$ is not balanced.

\(^{11}\)Strictly speaking, intermediate goods $v_1$ and $v_2$ are traded within the firm. However, production of intermediate goods leads to factor income, which leads to demand for final goods in the country of production. Trade of intermediate goods therefore has to be considered as well in the trade balance equation.
2.7.2 Trade balance equation with vertical multinational firms

Trade of intermediate goods between countries has to be considered as well.

Country $H$’s imports of intermediate good $v_2$ are equal to:

$$\frac{\partial c_X}{\partial c_{v_2}} \cdot (X_{HH} + X_{HF}) \cdot (N_H + N_F).$$  \hfill (29)

$\frac{\partial c_X}{\partial c_{v_2}}$ denotes the input of intermediate good $v_2$ per unit of good $X$ due to Shephard’s Lemma. $(X_{HH} + X_{HF}) \cdot (N_H + N_F)$ denotes total production of good $X$ in country $H$. Considering equations (5) and (7), $\frac{\partial c_X}{\partial c_{v_2}}$ can be calculated as:

$$\frac{\partial c_X}{\partial c_{v_2}} = (1 - \alpha) \cdot \left( \frac{c_{v_2}}{c_{v_1}} \right)^{\alpha} = (1 - \alpha) \cdot \left( \frac{w_H^{\phi_1} \cdot r_H^{1-\phi_1}}{w_F^{\phi_2} \cdot r_F^{1-\phi_2}} \right)^{\alpha} = (1 - \alpha) \cdot \left( \frac{w}{r} \right)^{\alpha(\phi_1-\phi_2)},$$  \hfill (30)

where the last equality uses the fact that factor prices are identical in both countries in the steady state with free trade.

Similarly, country $F$’s imports of intermediate good $v_1$ are equal to:

$$\frac{\partial c_X}{\partial c_{v_1}} \cdot (X_{FF} + X_{FH}) \cdot (N_H + N_F).$$  \hfill (31)

Again, $\frac{\partial c_X}{\partial c_{v_1}}$ denotes the input of intermediate good $v_1$ per unit of good $X$ due to Shephard’s Lemma and $(X_{FF} + X_{FH}) \cdot (N_H + N_F)$ denotes total production of good $X$ in country $F$. Considering equations (5) and (7), $\frac{\partial c_X}{\partial c_{v_1}}$ results as:

$$\frac{\partial c_X}{\partial c_{v_1}} = \alpha \cdot \left( \frac{c_{v_2}}{c_{v_1}} \right)^{1-\alpha} = \alpha \cdot \left( \frac{w_F^{\phi_2} \cdot r_F^{1-\phi_2}}{w_H^{\phi_1} \cdot r_H^{1-\phi_1}} \right)^{1-\alpha} = \alpha \cdot \left( \frac{w}{r} \right)^{(1-\alpha)(\phi_2-\phi_1)},$$  \hfill (32)

where the last equality again uses the fact that factor prices are identical in both countries in the steady state with free trade.

The trade balance equation in the regime with vertical multinational firms accordingly results as follows:

$$Z_{HF} \cdot p_Z + \left( \alpha \cdot \left( \frac{w}{r} \right)^{(1-\alpha)(\phi_2-\phi_1)} \cdot (X_{FF} + X_{FH}) \cdot w_F^{\phi_2} \cdot r_F^{1-\phi_2} + X_{HF} \cdot p_X \right) \cdot (N_H + N_F) = Z_{FH} \cdot p_Z + \left( 1 - \alpha \right) \cdot \left( \frac{w}{r} \right)^{\alpha(\phi_1-\phi_2)} \cdot (X_{HH} + X_{HF}) \cdot w_H^{\phi_1} \cdot r_H^{1-\phi_1} + X_{FH} \cdot p_X \right) \cdot (N_H + N_F).$$  \hfill (33)

Again, $Z_{FH}$ is set equal to zero and $Z_{HF}$ is allowed to be negative since country $H$’s imports of good $Z$ are equal to country $F$’s exports of good $Z$. Substituting the expressions for $X_{HH}$,
X_{FF}, X_{HF} and X_{FH} into equation (33) and considering $p_Z = w^\beta \cdot r^{1-\beta}$ and $p_X = \frac{\sigma}{\sigma - 1} \cdot w^\xi \cdot r^{1-\xi}$ leads to the following expression for the trade balance equation:

$$Z_{HF} = \frac{\sigma - 1}{\sigma} \cdot \frac{L_H \cdot w + K_H \cdot r \cdot \gamma_H + (L_F \cdot w + K_F \cdot r) \cdot \gamma_F \cdot (1 - 2 \cdot \alpha)}{2 \cdot w^\beta \cdot r^{1-\beta}} + \frac{(L_H \cdot w + K_H \cdot r) \cdot \gamma_H - (L_F \cdot w + K_F \cdot r) \cdot \gamma_F}{2 \cdot w^\beta \cdot r^{1-\beta}}. \quad (34)$$

3 General steady state equilibrium

The general steady state equilibrium for this 2-country world is characterized by:

- the condition $\frac{w}{r} = (\rho + \delta)^{-1/\beta}$ since countries are in their steady state
- the free entry condition for sector $X$
- the trade balance equation
- 2 factor market equilibrium conditions for each country.

The condition $\frac{w}{r} = (\rho + \delta)^{-1/\beta}$, the free entry condition for sector $X$ and the trade balance equation can be substituted into the 2 factor market equilibrium conditions for each country. The general steady state equilibrium for this 2-country world can then be represented by a system of 4 equations, which are linear in 4 variables. The 4 variables are the numbers of multinational firms $N_H$ and $N_F$ and the countries’ capital endowments $K_H$ and $K_F$ in the steady state.

If $N_H$, $N_F$, $K_H$ and $K_F$ are known and if one production factor, e.g., labor in country $H$, is chosen as the numéraire good, all quantity variables and relative prices of the model can then be derived immediately:

- the relative price of capital follows from equation (15).
- The relative prices of intermediate goods $v_1$ and $v_2$ follow from equation (5).
- The relative prices of the final goods $Z$ and $X$ follow from equations (2) and (18). Aggregate factor income in both countries follows from equation (21). Demand for the varieties of good $X$ follows from equations (22) and (23). Aggregate demand for good $Z$ follows from equation (24). Trade in the varieties of good $X$ follows from equation (23). Trade in good $Z$ follows from equations (28) and (34). Trade in intermediate goods $v_1$ and $v_2$ in the regime with vertical multinational activity follows from equations (29) and (31). Finally, utility of either country follows from substituting the consumed quantities into equation (19).

Since horizontal and vertical multinational firms have different production patterns, the factor market equilibrium conditions differ between both firm regimes. Therefore, the general steady state equilibrium is derived separately for both firm regimes.
In order to simplify the setup of the general steady state equilibrium, the capital depreciation rate \( \delta \) is normalized to zero. Since each country’s labor endowment is assumed to be constant over time, investment in the steady state is therefore equal to zero. If a persistent exogenous shock in the comparative steady state analysis shifts the country to a new steady state with a larger (smaller) capital stock, investment is temporarily positive (negative).

### 3.1 Horizontal multinational firms

Horizontal multinational firms produce both intermediate goods \( v_1 \) and \( v_2 \) in each production plant. The per unit costs of good \( X \) accordingly result as:

\[
c_X(w_i, r_i) = w_i^{\phi_1 \cdot \alpha} \cdot w_i^{\phi_2 \cdot (1-\alpha)} \cdot r_i^{(1-\phi_1) \cdot \alpha} \cdot r_i^{(1-\phi_2) \cdot (1-\alpha)} = w^{\xi} \cdot r^{1-\xi},
\]

with \( \xi = \phi_1 \cdot \alpha + \phi_2 \cdot (1-\alpha) \).

Applying Shephard’s Lemma, the factor input coefficients for labor and capital, \( a^X_L(w,r) \) and \( a^X_K(w,r) \), are given by:

\[
a^X_L(w,r) = \frac{\partial c_X(w,r)}{\partial w} = \xi \cdot \left( \frac{r}{w} \right)^{1-\xi} \quad (36)
\]

\[
a^X_K(w,r) = \frac{\partial c_X(w,r)}{\partial r} = (1-\xi) \cdot \left( \frac{w}{r} \right)^{\xi}. \quad (37)
\]

The corresponding factor input coefficients for good \( Z \) are given by:

\[
a^Z_L(w,r) = \frac{\partial c_Z(w,r)}{\partial w} = \beta \cdot \left( \frac{r}{w} \right)^{1-\beta} \quad (38)
\]

\[
a^Z_K(w,r) = \frac{\partial c_Z(w,r)}{\partial r} = (1-\beta) \cdot \left( \frac{w}{r} \right)^{\beta}. \quad (39)
\]

\( a^X_L(w,r), a^X_K(w,r), a^Z_L(w,r) \) and \( a^Z_K(w,r) \) are used to derive the factor market equilibrium conditions for either country. Note that \( N_H \) and \( N_F \) stand for the mass of active horizontal multinational firms and \( X_{HH}, X_{HF}, X_{FF} \) and \( X_{FH} \) stand for the supply of a single horizontal multinational firm:

**equilibrium on labor market country H:**

\[
\xi \cdot \left( \frac{r}{w} \right)^{1-\xi} \cdot (X_{HH} + X_{HF}) \cdot (N_H + N_F) + \beta \cdot \left( \frac{r}{w} \right)^{1-\beta} \cdot (Z_{HH} + Z_{HF}) = L_H \quad (40)
\]

**equilibrium on capital market country H:**

\[
(1-\xi) \cdot \left( \frac{w}{r} \right)^{\xi} \cdot (N_H + N_F) \cdot (X_{HH} + X_{HF}) + N_H \cdot F_{HQS+PP} + N_F \cdot F_{PP} + (1-\beta) \cdot \left( \frac{w}{r} \right)^{\beta} \cdot (Z_{HH} + Z_{HF}) = K_H \quad (41)
\]
factor market equilibrium conditions:
\[ \xi \cdot \left( \frac{r}{w} \right)^{1-\xi} \cdot (X_{FF} + X_{FH}) \cdot (N_H + N_F) + \beta \cdot \left( \frac{r}{w} \right)^{1-\beta} \cdot Z_{FF} = L_F \] (42)

Substituting the expressions for the factor market equilibrium conditions, considering the free entry condition (equation (26)) and the trade balance equation (equation (28)) leads to the following simplification of the shift in favor of good \( X \) disturbed by 4 different exogenous shocks. The first shock is a symmetric demand shift in favor of good \( X \) in both countries, i.e. \( d\gamma_H = d\gamma_F > 0 \). The second shock is a demand shift in favor of good \( X \) only in country \( H \), i.e. \( d\gamma_H > 0 \) and \( d\gamma_F = 0 \). The third shock is a symmetric increase in population size in both countries, i.e. \( dL_H = dL_F > 0 \). The fourth

\[ \xi \cdot \left( \frac{r}{w} \right)^{1-\xi} \cdot (X_{FF} + X_{FH}) \cdot (N_H + N_F) + \beta \cdot \left( \frac{r}{w} \right)^{1-\beta} \cdot Z_{FF} = L_F \]

\[ (1 - \xi) \cdot \left( \frac{w}{r} \right)^{\xi} \cdot (N_H + N_F) \cdot (X_{FF} + X_{FH}) + N_H \cdot F_{PP} + N_F \cdot F_{HQS+PP} + (1 - \beta) \cdot \left( \frac{w}{r} \right)^{\beta} \cdot Z_{FF} = K_F. \] (43)
shock is an increase in population size only in country $H$, i.e. $dL_H > 0$ and $dL_F = 0$. Note that these 4 shocks are the only relevant ones.  

If the capital stocks of both countries, $K_H$ and $K_F$, move into the same direction due to the exogenous shock, domestic and foreign investment are complements. If the capital stocks $K_H$ and $K_F$ move into opposite directions due to the exogenous shock, domestic and foreign investment are substitutes.

Based on the comparative steady state analysis, which is relegated to appendix A, we can derive the following hypotheses on the relationship between $K_H$ and $K_F$ if multinational activity is horizontal:

**H1:** In the case of

- a symmetric demand shift $\left( d\gamma_H = d\gamma_F > 0 \right)$
- an asymmetric demand shift $\left( d\gamma_H > 0 \text{ and } d\gamma_F = 0 \right)$
- a symmetric increase in population size $\left( dL_H = dL_F > 0 \right)$

domestic and foreign capital are complements with $dK_H = dK_F$.

**H2:** In the case of an asymmetric increase in population size $\left( dL_H > 0 \text{ and } dL_F = 0 \right)$

domestic and foreign capital are complements with $dK_H = \Phi \cdot dK_F$ and $\Phi > 0$.

**Proof:** See appendix A.

### 3.2 Vertical multinational firms

Vertical multinational firms produce intermediate good $v_1$ in their production plant in country $H$ and intermediate good $v_2$ in their production plant in country $F$. The per unit costs of good $X$ accordingly result as:

$$c_X \left( w_H, w_F, r_H, r_F \right) = w_H^{\phi_1 - \alpha} \cdot w_F^{\phi_2 (1-\alpha)} \cdot r_H^{\gamma_1 - \alpha} \cdot r_F^{\gamma_2 (1-\alpha)}. \tag{48}$$

In the case of an asymmetric shock in the production technologies, countries completely specialize in the production of either good $X$ or good $Z$ (cf. Baxter, 1992). However, if there is complete specialization in production, no horizontal multinational firms, which produce good $X$ in both countries, do exist. In the case of an asymmetric shock in the elasticity of substitution $\sigma$, the model is not analytically solvable any more. The reason is as follows: if $\sigma$ differs between countries, equation (26) becomes

$$\left( \frac{\gamma_H \cdot M_H}{\sigma_H} + \gamma_F \cdot M_F / \sigma_F \right) \cdot (N_H + N_F)^{-1} = r \cdot (F_{HQS+PR} + F_{PR})$$

However, the sum $X_{ii} + X_{ij}$ in the factor market equilibrium conditions equals

$$\left( \frac{\sigma_H - 1}{\sigma_H} \cdot \gamma_H \cdot M_H + \frac{\sigma_F - 1}{\sigma_F} \cdot \gamma_F \cdot M_F \right) \cdot (N_H + N_F)^{-1} \text{ if } \sigma \text{ differs between countries. Therefore, } X_{ii} + X_{ij} \text{ in the factor market equilibrium conditions cannot be substituted by } r \cdot (F_{HQS+PR} + F_{PR}) \cdot (\sigma - 1) \text{ from equation (26) if } \sigma \text{ differs between countries. However, this substitution is necessary to get the factor market equilibrium conditions linear in } N_H \text{ and } N_F \text{ like in equations (44)--(47).}$$
Applying Shephard’s Lemma and considering factor price equalization in the steady state, the factor input coefficients for labor and capital, $a^X_{L,i}(w_H, w_F, r_H, r_F)$ and $a^X_{K,i}(w_H, w_F, r_H, r_F)$, $i = H, F$, are given by:

\[
\begin{align*}
    a^X_{LH}(w_H, w_F, r_H, r_F) & = \frac{\partial c_X(w_H, w_F, r_H, r_F)}{\partial w_H} \\
    & = \phi_1 \cdot \alpha \cdot w_H^{\phi_1 \cdot \alpha - 1} \cdot w_F^{\phi_2 - (1 - \alpha)} \cdot r_H^{(1 - \phi_1) \cdot \alpha} \cdot r_F^{(1 - \phi_2) \cdot (1 - \alpha)} \\
    & = \phi_1 \cdot \alpha \cdot \left(\frac{r}{w}\right)^{1 - \xi}, \text{ with } \xi = \phi_1 \cdot \alpha + \phi_2 \cdot (1 - \alpha) \\
\end{align*}
\]

(49)

\[
\begin{align*}
    a^X_{KH}(w_H, w_F, r_H, r_F) & = \frac{\partial c_X(w_H, w_F, r_H, r_F)}{\partial r_H} \\
    & = (1 - \phi_1) \cdot \alpha \cdot w_H^{\phi_1 \cdot \alpha} \cdot w_F^{\phi_2 - (1 - \alpha)} \cdot r_H^{(1 - \phi_1) \cdot \alpha - 1} \cdot r_F^{(1 - \phi_2) \cdot (1 - \alpha)} \\
    & = (1 - \phi_1) \cdot \alpha \cdot \left(\frac{w}{r}\right)^{1 - \xi} \\
\end{align*}
\]

(50)

\[
\begin{align*}
    a^X_{LF}(w_H, w_F, r_H, r_F) & = \frac{\partial c_X(w_H, w_F, r_H, r_F)}{\partial w_F} \\
    & = \phi_2 \cdot (1 - \alpha) \cdot w_H^{\phi_1 \cdot \alpha} \cdot w_F^{\phi_2 - (1 - \alpha) - 1} \cdot r_H^{(1 - \phi_1) \cdot \alpha} \cdot r_F^{(1 - \phi_2) \cdot (1 - \alpha)} \\
    & = \phi_2 \cdot (1 - \alpha) \cdot \left(\frac{r}{w}\right)^{1 - \xi} \\
\end{align*}
\]

(51)

\[
\begin{align*}
    a^X_{KF}(w_H, w_F, r_H, r_F) & = \frac{\partial c_X(w_H, w_F, r_H, r_F)}{\partial r_F} \\
    & = (1 - \phi_2) \cdot (1 - \alpha) \cdot w_H^{\phi_1 \cdot \alpha} \cdot w_F^{\phi_2 - (1 - \alpha)} \cdot r_H^{(1 - \phi_1) \cdot \alpha} \cdot r_F^{(1 - \phi_2) \cdot (1 - \alpha) - 1} \\
    & = (1 - \phi_2) \cdot (1 - \alpha) \cdot \left(\frac{w}{r}\right)^{1 - \xi}. \\
\end{align*}
\]

(52)

Note that $a^X_{L,i}(w_H, w_F, r_H, r_F)$ and $a^X_{K,i}(w_H, w_F, r_H, r_F)$ stand for the amount of labor and capital per unit of good $X$.

The corresponding factor input coefficients for good $Z$ are again given by:

\[
\begin{align*}
    a^Z_{L}(w, r) & = \frac{\partial c_Z(w, r)}{\partial w} = \beta \cdot \left(\frac{r}{w}\right)^{1 - \beta} \\
\end{align*}
\]

(53)

\[
\begin{align*}
    a^Z_{K}(w, r) & = \frac{\partial c_Z(w, r)}{\partial r} = (1 - \beta) \cdot \left(\frac{w}{r}\right)\beta. \\
\end{align*}
\]

(54)

Equations (49)–(54) are used to derive the factor market equilibrium conditions for either country. $N_H$ and $N_F$ stand for the mass of active vertical multinational firms and $X_{HH}$, $X_{HF}$, $X_{FF}$, $X_{FH}$ stand for the supply of a single vertical multinational firm:

**Equilibrium on labor market country $H$:**

\[
\phi_1 \cdot \alpha \cdot \left(\frac{r}{w}\right)^{1 - \xi} \cdot (X_{HH} + X_{HF}) \cdot (N_H + N_F) + \beta \cdot \left(\frac{r}{w}\right)^{1 - \beta} \cdot (Z_{HH} + Z_{HF}) = L_H
\]

(55)

\textsuperscript{13}Alternatively, the labor and capital input per unit of intermediate goods $v_1$ and $v_2$ could be derived. If these factor input coefficients are multiplied by the input of $v_1$ and $v_2$ per unit of good $X$, the resulting input of labor and capital per unit of good $X$ would be as derived by equations (48)–(51).
equilibrium on capital market country $H$:

\[
(1 - \phi_1) \cdot \alpha \cdot \left(\frac{w}{r}\right)^\xi \cdot (N_H + N_F) \cdot (X_{HH} + X_{HF}) + N_H \cdot F_{HQS+PP} + N_F \cdot F_{PP} + (1 - \beta) \cdot \left(\frac{w}{r}\right)^\beta \cdot (Z_{HH} + Z_{HF}) = K_H \quad (56)
\]

equilibrium on labor market country $F$:

\[
\phi_2 \cdot (1 - \alpha) \cdot \left(\frac{r}{w}\right)^{1-\xi} \cdot (X_{FF} + X_{FH}) \cdot (N_H + N_F) + \beta \cdot \left(\frac{r}{w}\right)^{1-\beta} \cdot Z_{FF} = L_F \quad (57)
\]

equilibrium on capital market country $F$:

\[
(1 - \phi_2) \cdot (1 - \alpha) \cdot \left(\frac{w}{r}\right)^\xi \cdot (N_H + N_F) \cdot (X_{FF} + X_{FH}) + N_H \cdot F_{PP} + N_F \cdot F_{HQS+PP} + (1 - \beta) \cdot \left(\frac{w}{r}\right)^\beta \cdot Z_{FF} = K_F. \quad (58)
\]

Substituting the expressions for $X_{HH}, X_{HF}, X_{FF}$ and $X_{FH}$ (equations (22) and (23)) into the factor market equilibrium conditions, considering the free entry condition (equation (26)) and the trade balance equation (equation (34)) leads to the following simplification of the factor market equilibrium conditions:

\[
(1 - \phi_1) \cdot \alpha \cdot \frac{\sigma - 1}{2} \cdot \frac{r}{w} \cdot (F_{HQS+PP} + F_{PP}) \cdot (N_H + N_F)
+ \left(\frac{L_H + \frac{r}{w} \cdot K_H}{w}\right) \cdot \beta \cdot \left(1 - \frac{\gamma_H}{2} \cdot \frac{2 \cdot \alpha \cdot (\sigma - 1) + 1}{\sigma}\right)
+ \left(\frac{L_F + \frac{r}{w} \cdot K_F}{w}\right) \cdot \beta \cdot \frac{\gamma_F}{2} \cdot \frac{2 \cdot \alpha \cdot (\sigma - 1) - 1}{\sigma} = \frac{r}{w} \cdot K_H \quad (59)
\]

\[
(1 - \phi_1) \cdot \alpha \cdot \frac{\sigma - 1}{2} \cdot \frac{r}{w} \cdot (F_{HQS+PP} + F_{PP}) \cdot (N_H + N_F) + N_H \cdot \frac{r}{w} \cdot F_{HQS+PP} + N_F \cdot \frac{r}{w} \cdot F_{PP}
+ \left(\frac{L_H + \frac{r}{w} \cdot K_H}{w}\right) \cdot (1 - \beta) \cdot \left(1 - \frac{\gamma_H}{2} \cdot \frac{2 \cdot \alpha \cdot (\sigma - 1) + 1}{\sigma}\right)
+ \left(\frac{L_F + \frac{r}{w} \cdot K_F}{w}\right) \cdot (1 - \beta) \cdot \frac{\gamma_F}{2} \cdot \frac{2 \cdot \alpha \cdot (\sigma - 1) - 1}{\sigma} = \frac{r}{w} \cdot K_H \quad (60)
\]

\[
\phi_2 \cdot (1 - \alpha) \cdot \frac{\sigma - 1}{2} \cdot \frac{r}{w} \cdot (F_{HQS+PP} + F_{PP}) \cdot (N_H + N_F)
+ \left(\frac{L_H + \frac{r}{w} \cdot K_H}{w}\right) \cdot \beta \cdot \frac{\gamma_H}{2} \cdot \frac{1 - 2 \cdot \alpha - 2 \cdot \sigma \cdot (1 - \alpha)}{\sigma}
+ \left(\frac{L_F + \frac{r}{w} \cdot K_F}{w}\right) \cdot \beta \cdot \left(1 - \frac{\gamma_F}{2} \cdot \frac{2 \cdot \alpha - 1 + 2 \cdot \sigma \cdot (1 - \alpha)}{\sigma}\right) = L_F \quad (61)
\]

\[
(1 - \phi_2) \cdot (1 - \alpha) \cdot \frac{\sigma - 1}{2} \cdot \frac{r}{w} \cdot (F_{HQS+PP} + F_{PP}) \cdot (N_H + N_F) + N_F \cdot \frac{r}{w} \cdot F_{HQS+PP} + N_H \cdot \frac{r}{w} \cdot F_{PP}
\]
Again, since the factor price ratio $\frac{r}{w}$ is fixed by the model parameters $\rho$, $\delta$ and $\beta$ (cf. equation (15)), equations (59)–(62) are linear in the 4 variables $N_H$, $N_F$, $K_H$ and $K_F$.

The steady state in the 2–country world with vertical multinational activity is described by equations (59)–(62). In order to analyze whether vertical multinational activity leads to a different relationship between the capital stocks $K_H$ and $K_F$, the steady state with vertical multinational activity is disturbed by the same 4 exogenous shocks as before.

The comparative steady state analysis for vertical multinational activity is relegated to appendix B. The relationship between the capital stocks $K_H$ and $K_F$ in the regime with vertical multinational activity is summarized by hypotheses H3–H5:

**H3:** In the case of

- a symmetric demand shift $\left( d\gamma_H = d\gamma_F > 0 \right)$;
- an asymmetric demand shift $\left( d\gamma_H > 0 \text{ and } d\gamma_F = 0 \right)$

domestic and foreign capital are substitutes, i.e. $dK_H = \Psi \cdot dK_F$, with $\Psi < 0$, if:

- the labor share of the intermediate good which is produced in country $H$ $\left( \phi_1 \right)$ is sufficiently small;
- the share of intermediate good $v_1$ in final goods production $\left( \alpha \right)$ is sufficiently large.

If $\phi_1$ is not sufficiently small and if $\alpha$ is not sufficiently large, domestic and foreign capital are complements, i.e. $\Psi > 0$.

**H4:** In the case of an asymmetric increase in country size $\left( dL_H > 0 \text{ and } dL_F = 0 \right)$

domestic and foreign capital are substitutes, i.e. $dK_H = \Theta \cdot dK_F$, with $\Theta < 0$, if:

- the labor share of the intermediate good which is produced in country $H$ $\left( \phi_1 \right)$ is sufficiently small;
- the share of intermediate good $v_1$ in final goods production $\left( \alpha \right)$ is sufficiently large.

If $\phi_1$ is not sufficiently small and if $\alpha$ is not sufficiently large, domestic and foreign capital are complements, i.e. $\Theta > 0$. 
**H5:** In the case of a symmetric increase in country size \( dL_H = dL_F > 0 \) domestic and foreign capital are complements, i.e. \( dK_H = \Delta \cdot dK_F \), with \( \Delta > 0 \), for all possible values of \( \phi_1 \) and \( \alpha \).

**Proof:** See appendix B.

Figure 2 summarizes the results of our comparative steady state analysis for both firm regimes.

### 4 Empirical model

Data for the empirical analysis are taken from the website of the Bureau of Economic Analysis (BEA). We constructed a panel with 42 sectors (see table A1 of the appendix), and 7 years (1999–2005). The BEA data divides the operations of multinational companies into the operation of the American parent company and its foreign affiliate(s). For the data of the foreign affiliates, the BEA allows to choose between data for majority-owned foreign affiliates only or all foreign affiliates, where the latter are defined as outward foreign direct investment with ownership or control by the parent firm of at least 10%.\(^{14}\) We have chosen to use the data for all these foreign affiliates. As initial year, 1999 is chosen as the BEA switched from SIC to the NAICS classification in that year. For the year 2005, sales of the foreign affiliates in our sample cover 90% of the total sales of all foreign affiliates.

In order to test the previously derived hypotheses, we construct four variables at the sector level: (i) Domestic Investment, defined as domestic capital expenditures of U.S. parent companies as part of total value added of U.S. parent companies; (ii) Foreign Investment, defined as foreign capital expenditures of U.S. parent companies as part of total value added of U.S. parent companies; (iii) Labor Share, defined as the compensation of U.S. parent companies as part of total value added of U.S. parent companies; (iv) Share Intermediate, defined as one minus the imports of goods shipped to U.S. parents from foreign affiliates as part of the value added of U.S. parent companies. The last two variables are proxies for \( \alpha \) and \( \phi_1 \), respectively, as defined previously. As to test differences in the relationship between domestic and foreign investment between horizontal and vertical MNEs, we make the assumption that MNEs in the manufacturing sectors are mainly vertical, while MNEs in other sectors are mainly horizontal.\(^{15}\) The mean of Share Intermediate, as shown in table A2 of the appendix, indicates that trade in intermediates is almost absent in the non-manufacturing industries, while imports of intermediates from affiliates constitutes around 19% of the value

---

\(^{14}\)A more complete description of the BEA data on the operations of U.S. multinational companies can be found in Slaughter (2000).

\(^{15}\)The manufacturing sectors have a NAICS code starting with 3 in table A1 of the appendix.
added of U.S. parent firms. Therefore, the distinction between manufacturing and non-
manufacturing seems to capture the main difference between horizontal and vertical MNEs
remarkably well.

4.1 Empirical results

We test the implications of the theoretical model in an econometric model using a U.S. panel
of foreign and domestic investments at the sector level over the period 1999–2005. The re-
sults of our panel with random and fixed sector effects confirm the findings by Desai et al.
(2005b) for the estimated sign of foreign investment. Table 1 (columns 1 and 2) shows that
the estimated coefficient is equal to 0.10 with random and with fixed effects. Column 3 shows
that accounting for a common autoregressive term in the disturbances (estimated at a value
of 0.6) decreases the estimated coefficient in the random effects model to 0.09. As there is
strong autocorrelation in the disturbances, in column 4, we include lagged domestic capital
expenditures in the panel and use the Arellano–Bond GMM estimation of the parameters
in the dynamic model. The estimate of 0.378 for the lagged coefficient of domestic invest-
ment and the estimate of 0.065 for domestic capital investments imply a response of 0.10 in
the steady state (0.065/(1 – 0.378)). The Arellano–Bond test statistics for autocorrelation
indicates that the dynamic model is well specified.

The main novelty in the regressions is to allow for sector specific estimates of the coefficient
for foreign investment. Table 2 splits the sample in manufacturing and non–manufacturing
sectors and shows the regression results for both categories with random effects across sec-
tors and fixed time effects. The sign of the link between foreign investment and domestic
investment is opposite for the manufacturing and the non–manufacturing sectors. Includ-
ing lagged domestic investment as explanatory variable widens the gap between the two
estimates. While the sign is positive and significant from zero for the non–manufacturing
sectors, the sign is negative for the manufacturing sectors. Hence, under the assumption
that vertical MNEs are primarily active in manufacturing sectors and horizontal MNEs are
primarily active in non–manufacturing sectors, we can confirm our first hypothesis that there
is a positive relationship between domestic and foreign capital expenditures when MNEs are
horizontal while there is a possibility that foreign capital expenditures have a negative effect
on domestic capital formation when MNEs are vertical.

As a further test for differences in the link between domestic and foreign investment,
we include in table 3 interaction terms between foreign investment and (centralized) labor
share in a sector and between investment and the share of the intermediate good produced
by the U.S. parent. In line with the predictions from the theoretical model, the signs for
the interaction terms are negative for the manufacturing sectors. However, only the result for the share of intermediate goods is significant. The result indicates that manufacturing sectors with a relatively high labor share and a relatively high share of the intermediate good are characterized by a negative relationship between foreign and domestic investment. If the labor share and the share of the intermediate good are relatively low, however, there is a possibility that the sign for foreign investment becomes positive. An example of such a sector is petroleum and coal products where the average labor share over the sample period is 0.2 and the average share of the intermediate goods equals about 0.1. Calculating the centralized labor share and centralized share of intermediate good gives a coefficient of about 0.1 for foreign investment. As to check whether similar results can be obtained for non-manufacturing sectors, we include the same interactions in the regressions for the sample of non-manufacturing sectors. We find no convincing evidence that the interaction effects are significant for the non-manufacturing sectors. Furthermore, it appears impossible to find a sector where the sign for the foreign investment variable turns out to be negative.

5 Conclusions

Our paper has shown a clear distinction between horizontal and vertical multinationals in explaining the link between domestic and foreign capital expenditures. In the analytical general equilibrium model we derive a complementary relationship between domestic and foreign capital expenditures if multinational activity is horizontal. However, if multinational activity is vertical, the relationship between domestic and foreign capital expenditures is substitutional or complementary, depending on technology parameters.

We test out theoretical implications with a panel of U.S. multinationals and find empirical support. First, we find that horizontal multinational activity leads to a complementary relationship between domestic and foreign capital expenditures, irrespective of the values for relevant technology parameters. Second, we find a substitutional relationship between domestic and foreign capital expenditures if multinational activity is vertical. In order to refine our empirical results, we show that the empirical influence of relevant technology parameters on this substitutional link is as predicted by the theoretical model.
References


Becker, S.O. and M.A. Muendler (2006), The Effects of FDI on Worker Displacement, mimeo, University of Munich and UC San Diego.


Appendix A — Comparative steady state analysis for regime with horizontal multinational activity

The system of equations (44)–(47) is differentiated totally. Cramer’s Rule then leads to the following reaction of the capital stocks \( K_H \) and \( K_F \) to the exogenous shocks:

1 Symmetric demand shift \((d\gamma_H = d\gamma_F > 0)\):

\[
\frac{dK_F}{d\gamma_F} = \frac{\left( L_H + \frac{\zeta}{\omega} \cdot K_H + L_F + \frac{\zeta}{\omega} \cdot K_F \right) \cdot 2 \cdot \left[ 2 \cdot \xi + \sigma \cdot (1 - 2 \cdot \xi) \right]}{\frac{\zeta}{\omega} \cdot \left( \frac{1}{\gamma_H} - \frac{\alpha}{\gamma_H} \right) + (\sigma - 1) \cdot 2 \cdot \xi \cdot \left( \frac{\alpha}{\gamma_H} + 1 \right)}
\]

(63)

\[
\frac{dK_H}{d\gamma_H} = \frac{\left( L_H + \frac{\zeta}{\omega} \cdot K_H + L_F + \frac{\zeta}{\omega} \cdot K_F \right) \cdot 2 \cdot \left[ 2 \cdot \xi + \sigma \cdot (1 - 2 \cdot \xi) \right]}{\frac{\zeta}{\omega} \cdot \left( \frac{1}{\gamma_H} - \frac{\alpha}{\gamma_H} \right) + (\sigma - 1) \cdot 2 \cdot \xi \cdot \left( \frac{\alpha}{\gamma_H} + 1 \right)}
\]

(64)

If the preference parameters \( \gamma_H \) and \( \gamma_F \) do not differ too much \( i.e. \frac{\alpha}{\gamma_H} \leq 3 \) and if \( \xi \leq 0.5 \), both \( \frac{dK_F}{d\gamma_F} \) and \( \frac{dK_H}{d\gamma_H} \) are positive.

Irrespective of the exact values of \( \frac{\alpha}{\gamma_H} \) and \( \xi \), the relationship between \( K_H \) and \( K_F \) is always complementary. Dividing equations (63) and (64) by each other leads to:

\[
\frac{dK_F}{dK_H} = 1 \implies dK_F = dK_H.
\]

(65)

2 Asymmetric demand shift \((d\gamma_H > 0, d\gamma_F = 0)\):

\[
\frac{dK_F}{d\gamma_H} = \left( L_H + \frac{\zeta}{\omega} \cdot K_H \right) \cdot \left[ 2 \cdot \xi + \sigma \cdot (1 - 2 \cdot \xi) \right]
\]

(66)

\[
\frac{dK_H}{d\gamma_H} = \left( L_H + \frac{\zeta}{\omega} \cdot K_H \right) \cdot \left[ 2 \cdot \xi + \sigma \cdot (1 - 2 \cdot \xi) \right]
\]

(67)

Again, if \( \frac{\alpha}{\gamma_H} \leq 3 \) and \( \xi \leq 0.5 \), both \( \frac{dK_F}{d\gamma_H} \) and \( \frac{dK_H}{d\gamma_H} \) are positive. However, \( dK_H \) and \( dK_F \) are smaller if only \( \gamma_H \) increases.

Dividing equations (66) and (67) by each other shows that the relationship between \( K_H \) and \( K_F \) is complementary, irrespective of the exact values of \( \frac{\alpha}{\gamma_H} \) and \( \xi \):

\[
\frac{dK_F}{dK_H} = 1, \implies dK_F = dK_H.
\]

(68)

3 Symmetric increase in population size \((dL_H = dL_F > 0)\):

\[
\frac{dK_F}{dL_F} = \frac{2 \cdot (\sigma \cdot (3 - 2 \cdot \xi) + 2 \cdot \xi)}{\frac{\zeta}{\omega} \cdot \left[ \sigma \cdot 2 + (\sigma - 1) \cdot 4 \cdot \xi \right]}
\]

(69)

\[
\frac{dK_H}{dL_H} = \frac{2 \cdot (\sigma \cdot (3 - 2 \cdot \xi) + 2 \cdot \xi)}{\frac{\zeta}{\omega} \cdot \left[ \sigma \cdot 2 + (\sigma - 1) \cdot 4 \cdot \xi \right]}
\]

(70)
Hanson, 1996a, 1996b) supports shows that the relationship between produced more capital intensively than good \(K\) and \(dK\) both leads to \(dK\) is unambiguously positive since \(1 - 2 \cdot \phi_1 > 0\), i.e., intermediate good 1 is capital intensive relative to good Z. \(\frac{dK}{d\gamma_H}\) is positive (negative) if \(\phi_1\) is larger (smaller) than a threshold value \(\Theta\), i.e., if the following

\[
\frac{dK}{d\gamma_H} = \begin{cases} 
1 & \text{if } \phi_1 > \Theta \\
0 & \text{if } \phi_1 = \Theta \\
< 0 & \text{if } \phi_1 < \Theta 
\end{cases}
\]

Appendix B — Comparative steady state analysis for regime with vertical multinational activity

1 Symmetric demand shift \((d\gamma_H = d\gamma_F > 0)\):

The system of equations (59)–(62) is differentiated totally. Cramer’s Rule then leads to the following reaction of the capital stocks \(K_H\) and \(K_F\) to the change in \(\gamma_H\) and \(\gamma_F\):

\[
\frac{dK}{d\gamma_F} = \frac{2 \cdot \xi + \sigma \cdot (1 - 2 \cdot \xi)}{\frac{\sigma}{w} \cdot (\Psi_1 + \Psi_2 + \Psi_3) \cdot (M_H + M_F)^{-1}}
\]

\[
\frac{dK}{d\gamma_H} = \frac{2 \cdot \xi + \sigma \cdot (1 - 2 \cdot \xi)}{\frac{\sigma}{w} \cdot (\Psi_1 + \Psi_2 + \Psi_3) \cdot (M_H + M_F)^{-1}}
\]

with

\[
M_i = L_i + K_i \cdot \frac{w}{r}, \ i = H, F
\]

\[
\Psi_1 = 2 \cdot \sigma \cdot (1 + \sigma) + (\sigma + \alpha) \cdot \left(1 - \frac{\gamma_F}{\gamma_H}\right) > 0
\]

\[
\Psi_2 = (1 - \alpha) \cdot \left[2 \cdot \sigma - 1 \cdot \left(1 - \frac{\gamma_F}{\gamma_H}\right) + 2 \cdot \sigma \cdot (\sigma - 1)\right] > 0
\]

\[
\Psi_3 = (\sigma - 1) \cdot \left[2 \cdot \sigma - 1 \cdot \left(\frac{\gamma_F}{\gamma_H}\right) - 2 \cdot \phi_1 + 4 \cdot \phi_1 \cdot \sigma \cdot \alpha\right] > 0
\]
It can be shown that $\phi_1$ increases with $\sigma$ but not in sign. If $\phi_1$ is negative, intensive relative to good 0 is possible if $\frac{dK_F}{d\gamma_F} < 0$ is possible if $\phi_1$ is sufficiently small. However, $\Theta$ is negative if $\sigma$ is sufficiently small and if $\alpha$ is sufficiently large; if $\Theta$ is negative, $\frac{dK_F}{d\gamma_F} > 0$ results even if $\phi_1 = 0$.\footnote{The following partial derivatives can be calculated: $\frac{\partial \phi_1}{\partial \sigma} = \frac{(2\alpha - 3)\sigma^2 + (2\sigma - 1)(2 - 2\sigma)}{4(\alpha - 1)(\sigma - 1)^2\sigma^2} > 0$ and $\frac{\partial \phi_1}{\partial \alpha} = \frac{4(\sigma - 1)(\alpha - 1)\sigma}{4(\sigma - 1)(\sigma - 1)^2\sigma^2} < 0$. Furthermore, if $\alpha = 0.5$ and if $\sigma = 10$, for example, the threshold value $\Theta$ equals 0.389. If the factor share parameter $\phi_1$ is strictly smaller than 0.389, $\frac{dK_F}{d\gamma_F} < 0$ results. However, if $\alpha = 0.9$ and $\sigma \leq 7.5$, for example, the threshold value $\Theta$ is negative. Even if $\phi_1 = 0$, $\frac{dK_F}{d\gamma_F} > 0$ results.}

Dividing equations (76) and (77) by each other results in:

$$
\frac{dK_F}{dK_H} = \frac{4 \cdot \sigma \cdot \phi_1 \cdot (1 - \alpha) \cdot (\sigma - 1) + (1 - \alpha) \cdot 2 \cdot \sigma \cdot (2 - \sigma) - 1 + \sigma + 2 \cdot \alpha}{1 + \sigma - 2 \cdot \alpha + 4 \cdot \alpha \cdot \phi_1 \cdot \sigma + 2 \cdot \sigma^2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1)} \equiv \Upsilon
$$

and, finally, to $dK_F = \Upsilon \cdot dK_H$. (79)

It can be shown that $\Upsilon$ increases with $\phi_1$:

$$
\frac{\partial \Upsilon}{\partial \phi_1} = \frac{4 \cdot (\sigma - 1) \cdot \sigma \cdot [4 \cdot \alpha \cdot (\sigma - 1) \cdot (1 - \alpha) + \sigma + 1]}{[1 + \sigma - 2 \cdot \alpha + 4 \cdot \alpha \cdot \phi_1 \cdot \sigma + 2 \cdot \sigma^2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1)]^2} > 0.
$$

(80)

2 Asymmetric demand shift ($d\gamma_H > 0$, $d\gamma_F = 0$):

$$
\frac{dK_F}{d\gamma_H} = \frac{2 \cdot [4 \cdot \sigma \cdot (-1) \phi_1 + 1) \cdot (1 - \alpha) - 2^2 \cdot (1 - \alpha) \cdot (2 - 4 \cdot \phi_1) - 1 + \sigma + 2 \cdot \alpha]}{\psi_1 \cdot \Psi_2 + \psi_3 \cdot M_H^{-1}}
$$

(81)

$$
\frac{dK_H}{d\gamma_H} = \frac{2 \cdot [2 \cdot \alpha \cdot \sigma^2 \cdot (1 - 2 \cdot \phi_1) + 1 + \sigma - 2 \cdot \alpha + 4 \cdot \alpha \cdot \phi_1 \cdot \sigma]}{\psi_1 \cdot \Psi_2 + \psi_3 \cdot M_H^{-1}}
$$

(82)

$\frac{dK_F}{d\gamma_F}$ and $\frac{dK_H}{d\gamma_H}$ in the previous scenario differ from $\frac{dK_F}{d\gamma_H}$ and $\frac{dK_H}{d\gamma_H}$ in the current scenario only in magnitude, but not in sign. Therefore again, $\frac{dK_F}{d\gamma_H}$ is unambiguously positive since $1 - 2 \cdot \phi_1 > 0$, i.e., intermediate good 1 is capital intensive relative to good Z. $\frac{dK_F}{d\gamma_H}$ is positive (negative) if $\phi_1$ is larger (smaller) than a threshold value $\Theta$, i.e., if the following holds:

$$
\phi_1 > \left( < \right) \frac{1 - \sigma - 2 \cdot \alpha - (1 - \alpha) \cdot 2 \cdot \sigma \cdot (2 - \sigma)}{4 \cdot (1 - \alpha) \cdot (\sigma - 1)} \equiv \Theta.
$$

(83)

Since the threshold value $\Theta$ is strictly positive if $\sigma$ is sufficiently large and if $\alpha$ is sufficiently small, $\frac{dK_F}{d\gamma_H} < 0$ is possible if $\phi_1$ is sufficiently small. However, $\Theta$ is negative if $\sigma$ is sufficiently small and if $\alpha$ is sufficiently large; if $\Theta$ is negative, $\frac{dK_F}{d\gamma_H} > 0$ results even if $\phi_1 = 0$.

Dividing equations (81) and (82) by each other results in:

$$
\frac{dK_F}{dK_H} = \frac{4 \cdot \sigma \cdot \phi_1 \cdot (1 - \alpha) \cdot (\sigma - 1) + (1 - \alpha) \cdot 2 \cdot \sigma \cdot (2 - \sigma) - 1 + \sigma + 2 \cdot \alpha}{1 + \sigma - 2 \cdot \alpha + 4 \cdot \alpha \cdot \phi_1 \cdot \sigma + 2 \cdot \sigma^2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1)} \equiv \Lambda
$$

and, finally, to $dK_F = \Lambda \cdot dK_H$. (84)
Again, it can be shown that $\Lambda$ increases with $\phi_1$:

$$\frac{\partial \Lambda}{\partial \phi_1} = \frac{4 \cdot (\sigma - 1) \cdot \sigma \cdot \left[ 4 \cdot \alpha \cdot (\sigma - 1) \cdot (1 - \alpha) + \sigma + 1 \right]}{\left[ 1 + \sigma - 2 \cdot \alpha + 4 \cdot \alpha \cdot \phi_1 \cdot \sigma + 2 \cdot \sigma^2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) \right]^2} > 0.$$  \hfill (85)

3 Symmetric change increase in population size ($dL_H = dL_F > 0$):

$$\frac{dK_F}{dL_F} = \frac{\sigma^2 \cdot \left[ 2 \cdot \alpha - 1 + \phi_1 \cdot (6 - 4 \cdot \alpha) \right] + 4 \cdot \alpha \cdot (1 + \phi_1 \cdot \sigma) - 2 + 6 \cdot \sigma \cdot (1 - \alpha) + \sigma \cdot (3 - 6 \cdot \phi_1)}{\sigma \cdot \frac{3}{\sigma} \cdot \left[ 2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) \cdot (1 - \sigma) + 2 \cdot \sigma \cdot (1 - \phi_1) + 2 \cdot \phi_1 + \sigma - 1 \right]}.$$  \hfill (86)

$$\frac{dK_H}{dL_H} = \frac{\sigma^2 \cdot \left[ 2 \cdot (1 - \phi_1) + 2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) + 1 \right] + 2 + \sigma \cdot (1 + 2 \cdot \alpha) \cdot (1 + 2 \cdot \phi_1) - 4 \cdot \alpha}{\sigma \cdot \frac{3}{\sigma} \cdot \left[ 2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) \cdot (1 - \sigma) + 2 \cdot \sigma \cdot (1 - \phi_1) + 2 \cdot \phi_1 + \sigma - 1 \right]}.$$  \hfill (87)

Both $\frac{dK_F}{dL_F}$ and $\frac{dK_H}{dL_H}$ are positive if $\sigma > 1$, $0.5 \leq \alpha \leq 1$ and $0 \leq \phi_1 \leq 0.5$. Dividing equations (86) and (87) by each other results in:

$$\frac{dK_F}{dK_H} = \frac{\sigma^2 \cdot \left[ 2 \cdot (1 - \phi_1) + 2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) + 1 \right] + 2 + \sigma \cdot (1 + 2 \cdot \alpha) \cdot (1 + 2 \cdot \phi_1) - 4 \cdot \alpha}{\sigma \cdot \frac{3}{\sigma} \cdot \left[ 2 \cdot (1 - \phi_1) + 2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) + 1 \right] + 2 + \sigma \cdot (1 + 2 \cdot \alpha) \cdot (1 + 2 \cdot \phi_1) - 4 \cdot \alpha} \equiv \Delta$$

and, finally, to $dK_F = \Delta \cdot dK_H$.  \hfill (88)

It can be shown that $\Delta$ increases with $\phi_1$:

$$\frac{\partial \Delta}{\partial \phi_1} = \frac{8 \cdot \sigma \cdot (\sigma - 1) \cdot \left[ 4 \cdot \alpha \cdot (\sigma - 1) \cdot (1 - \alpha) + 3 \cdot \sigma + 2 \cdot \sigma^2 + 1 \right]}{\left( \sigma^2 \cdot \left[ 2 \cdot (1 - \phi_1) + 2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) + 1 \right] + 2 + \sigma \cdot (1 + 2 \cdot \alpha) \cdot (1 + 2 \cdot \phi_1) - 4 \cdot \alpha \right)^2} > 0.$$  \hfill (89)

4 Asymmetric increase in country size ($dL_H > 0$ and $dL_F = 0$):

$$\frac{dK_F}{dL_H} = -\frac{4 \cdot \sigma \cdot (\phi_1 - 1) \cdot (1 - \alpha) + \sigma^2 \cdot (1 - \alpha) \cdot (2 - 4 \cdot \phi_1) + 1 - \sigma - 2 \cdot \alpha}{\sigma \cdot \frac{3}{\sigma} \cdot \left[ 2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) \cdot (1 - \sigma) + 2 \cdot \sigma \cdot (1 - \phi_1) + 2 \cdot \phi_1 + \sigma - 1 \right]}.$$  \hfill (90)

$$\frac{dK_H}{dL_H} = \frac{\sigma^2 \cdot (3 - 2 \cdot \phi_1) + 2 \cdot \alpha \cdot (\sigma - 1) + 2 \cdot \phi_1 \cdot \sigma + 1}{\sigma \cdot \frac{3}{\sigma} \cdot \left[ 2 \cdot \alpha \cdot (1 - 2 \cdot \phi_1) \cdot (1 - \sigma) + 2 \cdot \sigma \cdot (1 - \phi_1) + 2 \cdot \phi_1 + \sigma - 1 \right]}.$$  \hfill (91)
\( \frac{dK_H}{dL_H} \) is positive since \( \phi_1 \leq 0.5 \), i.e. since intermediate good \( v_1 \) is capital intensive relative to good \( Z \). \( \frac{dK_F}{dL_H} \) is positive (negative) if \( \phi_1 \) is larger (smaller) than a threshold value \( \Theta \), i.e. if the following holds:

\[
\phi_1 > \left( < \right) \frac{1 - \sigma - 2 \cdot \alpha - (1 - \alpha) \cdot 2 \cdot \sigma \cdot (2 - \sigma)}{4 \cdot (1 - \alpha) \cdot (\sigma - 1)} \equiv \Theta. \tag{92}
\]

The threshold value \( \Theta \) is strictly positive if \( \sigma \) is sufficiently large and if \( \alpha \) is sufficiently small. However, \( \Theta \) is negative if \( \sigma \) is sufficiently small and if \( \alpha \) is sufficiently large; if \( \Theta \) is negative, \( \frac{dK_F}{dL_H} > 0 \) results even if \( \phi_1 = 0 \).

Dividing equations (90) and (91) by each other results in:

\[
\frac{dK_F}{dK_H} = \frac{-4 \cdot \sigma \cdot (\phi_1 - 1) \cdot (1 - \alpha) - \sigma^2 \cdot (1 - \alpha) \cdot (2 - 4 \cdot \phi_1) - 1 + \sigma + 2 \cdot \alpha}{\sigma^2 \cdot (3 - 2 \cdot \phi_1) + 2 \cdot \alpha \cdot (\sigma - 1) + 2 \cdot \phi_1 \cdot \sigma + 1} \equiv \Xi
\]

and, finally, to \( dK_F = \Xi \cdot dK_H \). \tag{93}

It can be shown that \( \Xi \) increases with \( \phi_1 \):

\[
\frac{\partial \Xi}{\partial \phi_1} = \frac{2 \cdot \sigma \cdot (\sigma - 1) \cdot \left[ 4 \cdot \sigma^2 \cdot (1 - \alpha) + 4 \cdot \sigma \cdot (1 - \alpha^2) - 4 \cdot \alpha + 1 + \sigma + 4 \cdot \alpha^2 \right]}{\left[ \sigma^2 \cdot (3 - 2 \cdot \phi_1) + 2 \cdot \alpha \cdot (\sigma - 1) + 2 \cdot \phi_1 \cdot \sigma + 1 \right]^2} > 0. \tag{94}
\]
Figure 1: allocation of production activities across countries

chart 1: horizontal multinational firms with headquarters in country \(i, j = H, F, i \neq j:\)

country \(i:\)

- **HQS**
- **PP:**
  - *production:* \(v_1 \& v_2\)
  - *assembly:* \(v_1 \& v_2 \rightarrow \text{variety of } X\)
  - *sales of output:* domestic market & exports

country \(j:\)

- **PP:**
  - *production:* \(v_1 \& v_2\)
  - *assembly:* \(v_1 \& v_2 \rightarrow \text{variety of } X\)
  - *sales of output:* domestic market & exports

chart 2: vertical multinational firms with headquarters in country \(H:\)

country \(H:\)

- **HQS**
- **PP:**
  - *production:* only \(v_1\)
  - *exports:* \(v_1\), *imports:* \(v_2\)
  - *assembly:* \(v_1 \& v_2 \rightarrow \text{variety of } X\)
  - *sales of output:* domestic market & exports

country \(F:\)

- **PP:**
  - *production:* only \(v_2\)
  - *exports:* \(v_2\), *imports:* \(v_1\)
  - *assembly:* \(v_1 \& v_2 \rightarrow \text{variety of } X\)
  - *sales of output:* domestic market & exports

chart 3: vertical multinational firms with headquarters in country \(F:\)

country \(H:\)

- **HQS**
- **PP:**
  - *production:* only \(v_1\)
  - *exports:* \(v_1\), *imports:* \(v_2\)
  - *assembly:* \(v_1 \& v_2 \rightarrow \text{variety of } X\)
  - *sales of output:* domestic market & exports

country \(F:\)

- **PP:**
  - *production:* only \(v_2\)
  - *exports:* \(v_2\), *imports:* \(v_1\)
  - *assembly:* \(v_1 \& v_2 \rightarrow \text{variety of } X\)
  - *sales of output:* domestic market & exports

Note: HQS = headquarter services; PP = production plant
**Figure 2: summary of comparative steady state results**

### Horizontal multinationals

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### Vertical multinationals

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<td>asymmetric demand shift</td>
<td>final good uses capital intensive intermediate good sufficiently intensively</td>
<td></td>
</tr>
<tr>
<td>asymmetric change in population size</td>
<td>all other relevant parameter constellations</td>
<td>complementary: $dK_F &gt; 0$ implies $dK_H &gt; 0$</td>
</tr>
<tr>
<td>symmetric change in population size</td>
<td>all relevant parameter constellations</td>
<td>complementary: $dK_F &gt; 0$ implies $dK_H &gt; 0$</td>
</tr>
</tbody>
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## TABLES

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Regression with random effects</th>
<th>Regression with fixed effects</th>
<th>Regression with random effects and common AR(1) term in errors.</th>
<th>Dynamic regression with random effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.165*** (0.014)</td>
<td>0.197*** (0.011)</td>
<td>0.166*** (0.011)</td>
<td>0.082*** (0.025)</td>
</tr>
<tr>
<td>Foreign Investment</td>
<td>0.104*** (0.014)</td>
<td>0.090*** (0.002)</td>
<td>0.089*** (0.010)</td>
<td>0.065*** (0.011)</td>
</tr>
<tr>
<td>Lagged Domestic Investment</td>
<td></td>
<td></td>
<td></td>
<td>0.378** (0.166)</td>
</tr>
<tr>
<td>Year_2000</td>
<td>-0.013 (0.017)</td>
<td>-0.014* (0.008)</td>
<td>0.013 (0.014)</td>
<td>0.019 (0.012)</td>
</tr>
<tr>
<td>Year_2001</td>
<td>0.010 (0.017)</td>
<td>0.009 (0.014)</td>
<td>0.010 (0.017)</td>
<td>0.053*** (0.014)</td>
</tr>
<tr>
<td>Year_2002</td>
<td>-0.028* (0.017)</td>
<td>-0.029 (0.019)</td>
<td>-0.028* (0.019)</td>
<td>0.011 (0.021)</td>
</tr>
<tr>
<td>Year_2003</td>
<td>-0.039** (0.017)</td>
<td>-0.040** (0.018)</td>
<td>-0.039** (0.020)</td>
<td>0.007 (0.021)</td>
</tr>
<tr>
<td>Year_2004</td>
<td>-0.071*** (0.014)</td>
<td>-0.072*** (0.018)</td>
<td>-0.071*** (0.020)</td>
<td>-0.016 (0.010)</td>
</tr>
<tr>
<td>Year_2005</td>
<td>-0.064*** (0.014)</td>
<td>-0.066*** (0.013)</td>
<td>-0.064*** (0.020)</td>
<td></td>
</tr>
<tr>
<td>Arellano-Bond AR(1) test</td>
<td></td>
<td></td>
<td></td>
<td>-3.02***</td>
</tr>
<tr>
<td>Arellano-Bond AR(2) test</td>
<td></td>
<td></td>
<td></td>
<td>0.031</td>
</tr>
<tr>
<td>N</td>
<td>294</td>
<td>294</td>
<td>294</td>
<td>210</td>
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</tbody>
</table>

Notes: The dependent variable is total domestic capital expenditures of U.S. multinational firms in a sector divided by total value added of the multinational firms in the sector. Foreign investment is defined as foreign capital expenditures of U.S. multinational firms in a sector divided by total value added of the multinational firms in the sector. Arellano-Bond statistics test the autocorrelation of the first difference of the residuals at order 1 and 2 and are (standard) normally distributed under the null. The model is rejected if evidence of autocorrelation is found at order 2. Standard errors that correct for clustering appear in parentheses. *** and * denote significance at the 1% and 10% level, respectively.
Table 2: Basic regression results for non-manufacturing and manufacturing sectors

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Non-Manufacturing</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Random Effects</td>
<td>Random Effects</td>
</tr>
<tr>
<td>Constant</td>
<td>0.183***</td>
<td>0.100**</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.038)</td>
</tr>
<tr>
<td>Foreign Investment</td>
<td>0.104***</td>
<td>0.065***</td>
</tr>
<tr>
<td></td>
<td>(0.013)</td>
<td>(0.013)</td>
</tr>
<tr>
<td>Lagged Domestic</td>
<td>0.407***</td>
<td>-1.89*</td>
</tr>
<tr>
<td>Investment</td>
<td>(0.167)</td>
<td></td>
</tr>
<tr>
<td>Arellano-Bond AR(1)</td>
<td>-1.21</td>
<td>-2.49**</td>
</tr>
<tr>
<td>test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arellano-Bond AR(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>test</td>
<td></td>
<td></td>
</tr>
<tr>
<td># Obs</td>
<td>154</td>
<td>110</td>
</tr>
</tbody>
</table>

Notes: The dependent variable is total domestic capital expenditures of U.S. multinational firms in a sector divided by total value added of the multinational firms in the sector. Foreign investment is defined as foreign capital expenditures of U.S. multinational firms in a sector divided by total value added of the multinational firms in the sector. Regressions include time fixed effects (not shown). Arellano-Bond statistics test the autocorrelation of the first difference of the residuals at order 1 and 2 and are (standard) normally distributed under the null. The model is rejected if evidence of autocorrelation is found at order 2. Standard errors that correct for clustering appear in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively.
Table 3: Regression results for non-manufacturing and manufacturing sectors with interaction effects.

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Non-Manufacturing</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Random Effects</td>
<td>Random Effects</td>
</tr>
<tr>
<td>Constant</td>
<td>0.176*** (0.021)</td>
<td>0.093*** (0.034)</td>
</tr>
<tr>
<td></td>
<td>0.157*** (0.011)</td>
<td>0.089*** (0.021)</td>
</tr>
<tr>
<td>Foreign Investment</td>
<td>0.152*** (0.046)</td>
<td>0.065*** (0.013)</td>
</tr>
<tr>
<td></td>
<td>-0.206** (0.102)</td>
<td>-0.328*** (0.124)</td>
</tr>
<tr>
<td>Lagged Domestic Investment</td>
<td>0.435*** (0.148)</td>
<td>0.444*** (0.107)</td>
</tr>
<tr>
<td>Foreign Investment * Centralized Labor Share (φ₁ - φᵣ)</td>
<td>-0.001 (0.022)</td>
<td>0.063 (0.038)</td>
</tr>
<tr>
<td></td>
<td>-0.722 (0.641)</td>
<td>-1.154 (0.743)</td>
</tr>
<tr>
<td>Foreign Investment * Share Intermediate (α₁ - αᵣ)</td>
<td>-3.770* (2.237)</td>
<td>-2.050 (2.579)</td>
</tr>
<tr>
<td></td>
<td>-1.500*** (0.390)</td>
<td>-1.409** (0.554)</td>
</tr>
<tr>
<td>Arellano-Bond AR(1) test</td>
<td>-1.59</td>
<td>-2.29**</td>
</tr>
<tr>
<td>Arellano-Bond AR(2) test</td>
<td>0.90</td>
<td>0.51</td>
</tr>
<tr>
<td>N</td>
<td>154</td>
<td>110</td>
</tr>
</tbody>
</table>

Notes: The dependent variable is total domestic capital expenditures of U.S. multinational firms in a sector divided by total value added of the multinational firms in the sector. Foreign investment is defined as foreign capital expenditures of U.S. multinational firms in a sector divided by total value added of the multinational firms in the sector. Regressions include time fixed effects (not shown). Arellano-Bond statistics test the autocorrelation of the first difference of the residuals at order 1 and 2 and are (standard) normally distributed under the null. The model is rejected if evidence of autocorrelation is found at order 2. Standard errors that correct for clustering appear in parentheses. **, ** and * denote significance at the 1%, 5% and 10% level, respectively.
Appendix tables

Table A1: Industries in the panel

<table>
<thead>
<tr>
<th>NAICS 2002 code</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Agriculture, forestry, fishing, and hunting</td>
</tr>
<tr>
<td>211</td>
<td>Oil and Gas Extraction</td>
</tr>
<tr>
<td>212</td>
<td>Other mining</td>
</tr>
<tr>
<td>23</td>
<td>Construction</td>
</tr>
<tr>
<td>311</td>
<td>Food</td>
</tr>
<tr>
<td>324</td>
<td>Petroleum and coal products</td>
</tr>
<tr>
<td>3251</td>
<td>Basic chemicals</td>
</tr>
<tr>
<td>3252</td>
<td>Resins and synthetic rubber, fibers, and filaments</td>
</tr>
<tr>
<td>3254</td>
<td>Pharmaceuticals and medicines</td>
</tr>
<tr>
<td>3256</td>
<td>Soap, cleaning compounds, and toilet preparations</td>
</tr>
<tr>
<td>3259</td>
<td>Other Chemicals</td>
</tr>
<tr>
<td>331</td>
<td>Primary metals</td>
</tr>
<tr>
<td>332</td>
<td>Fabricated metal products</td>
</tr>
<tr>
<td>3331</td>
<td>Agriculture, construction, and mining machinery</td>
</tr>
<tr>
<td>3332</td>
<td>Industrial machinery</td>
</tr>
<tr>
<td>3339</td>
<td>Other machinery</td>
</tr>
<tr>
<td>3341</td>
<td>Computers and peripheral equipment</td>
</tr>
<tr>
<td>3342</td>
<td>Communications equipment</td>
</tr>
<tr>
<td>3343</td>
<td>Audio and video equipment</td>
</tr>
<tr>
<td>3344</td>
<td>Semiconductors and other electronic components</td>
</tr>
<tr>
<td>3345</td>
<td>Navigational, measuring, and other instruments</td>
</tr>
<tr>
<td>335</td>
<td>Electrical equipment, appliances, and components</td>
</tr>
<tr>
<td>3361-3363</td>
<td>Motor vehicles, bodies and trailers, and parts</td>
</tr>
<tr>
<td>3364-3369</td>
<td>Other Transportation equipment</td>
</tr>
<tr>
<td>42</td>
<td>Wholesale trade</td>
</tr>
<tr>
<td>44-45</td>
<td>Retail trade</td>
</tr>
<tr>
<td>48-49</td>
<td>Transportation and warehousing</td>
</tr>
<tr>
<td>51</td>
<td>Information</td>
</tr>
<tr>
<td>5231</td>
<td>Securities, commodity contracts, and other intermediation and related activities</td>
</tr>
<tr>
<td>5232-5239</td>
<td>Other finance, except depository institutions</td>
</tr>
<tr>
<td>524</td>
<td>Insurance carriers and related activities</td>
</tr>
<tr>
<td>531</td>
<td>Real estate</td>
</tr>
<tr>
<td>532</td>
<td>Rental and leasing (except real estate)</td>
</tr>
<tr>
<td>5413</td>
<td>Architectural, engineering, and related services</td>
</tr>
<tr>
<td>5415</td>
<td>Computer systems design and related services</td>
</tr>
<tr>
<td>5416</td>
<td>Management, scientific, and technical consulting</td>
</tr>
<tr>
<td>5419</td>
<td>Other Professional, Technical and Scientific Services</td>
</tr>
<tr>
<td>56</td>
<td>Administration, support, and waste management</td>
</tr>
<tr>
<td>62</td>
<td>Health care and social assistance</td>
</tr>
<tr>
<td>721</td>
<td>Accommodation</td>
</tr>
<tr>
<td>722</td>
<td>Food services and drinking places</td>
</tr>
<tr>
<td>81</td>
<td>Miscellaneous services</td>
</tr>
</tbody>
</table>
Table A2: descriptive statistics of variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Whole Sample (N=294)</th>
<th>Manufacturing (N=140)</th>
<th>Non-manufacturing (N=150)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
</tr>
<tr>
<td>Domestic Investment</td>
<td>Domestic capital expenditures / Value added of US parent companies</td>
<td>0.18</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>Foreign Investment</td>
<td>Foreign capital expenditures / Value added of US parent companies</td>
<td>0.10</td>
<td>0.43</td>
<td>0.05</td>
</tr>
<tr>
<td>Share Intermediate</td>
<td>1 - Imports from foreign affiliates / Value added of US parent companies</td>
<td>0.90</td>
<td>0.18</td>
<td>0.81</td>
</tr>
<tr>
<td>Labor share</td>
<td>Compensation of employees of US parent companies / Value added of US parent companies</td>
<td>0.67</td>
<td>0.26</td>
<td>0.64</td>
</tr>
</tbody>
</table>