A.1 Aggregation

This section of the Web Appendix presents the aggregation of intermediate goods as inputs of the aggregate production function. Note that the fixed costs to enter different markets that are used below are the versions with scale effect corrections, as presented in Section 2.5.1.

Intermediate good $l$ can be renamed as good $a$. Only goods with marginal cost $a \leq a_{iit}$ are counted when aggregating the intermediate goods. Equation (3) can be rewritten in the form of (25):

$$Y_{it} = A_i L_i^{1-\alpha} \int_0^{N_{it}} X_{li}^\alpha \, dl = 1 - \alpha \int_0^{a_{iit}} X_{ii}(a)^\alpha \frac{g_i(a)}{G_i(a_{iit})} N_{ii} \, da + \int_{a_{ijt}}^{a_{xjt}} X_{xj}(a)^\alpha \frac{g_j(a)}{G_j(a_{xjt})} N_{xjt} \, da + \int_0^{a_{ijt}} X_{ij}(a)^\alpha \frac{g_j(a)}{G_j(a_{ijt})} N_{ijt} \, da,$$

where $N_{iit}$ is the number of intermediate goods produced by domestic firms, $N_{xjt}$ is the number of intermediate goods imported, and $N_{ijt}$ is the number of intermediate goods produced by foreign MNEs. Also, $G_i(a_{iit}) = (a_{iit}/a_{i0})^{k_i}$ is the probability of domestic firms making the cut-off. $G_j(a_{xjt}) = (a_{xjt}/a_{j0})^{k_j}$ is the probability of a foreign firm that serves the domestic market either through trade or MP. $G_j(a_{ijt}) = (a_{ijt}/a_{j0})^{k_j}$ is the probability of a foreign firm becoming a MNE, so that $G_j(a_{xjt}) - G_j(a_{ijt})$ is the probability of a foreign firm exporting to the domestic market. From these probabilities:

$$g_i(a) = \frac{\partial G_i(a)}{\partial a} = k_i a_i^{k_i-1} \frac{a_i^{k_i}}{a_{i0}^{k_i}} \Rightarrow \frac{g_i(a)}{G_i(a_{iit})} = k_i a_i^{k_i-1} \frac{a_i^{k_i}}{a_{iit}^{k_i}},$$

is the density function conditional on surviving, in which firms get a draw $a$ below the cut-off $a_{iit}$. Similarly,

$$\frac{g_j(a)}{G_j(a_{xjt})} = k_j a_j^{k_j-1} \frac{a_j^{k_j}}{a_{xjt}^{k_j}}, \quad \frac{g_j(a)}{G_j(a_{ijt})} = k_j a_j^{k_j-1} \frac{a_j^{k_j}}{a_{ijt}^{k_j}}.$$

The left-hand-side equation is the density function conditional on a foreign firm serving the domestic market including both trade and MP. The right-hand-side equation is the density function conditional on a foreign firm becoming a MNE.

Substitute $X_{sd}(a)$ for $s \in \{i, x, j\}$ and $d \in \{i, j\}$ using equation (15), using optimal prices (17), and $g_i(a)/G_i(a)$ into the $Y_{it}$ above yield:
\begin{align*}
Y_{it} &= A_i^{1-\alpha} \alpha^{\frac{2\alpha}{1-\alpha}} L_i \left[ \int_0^{a_{ijt}} a^{-\alpha} \frac{k_i a^{k_i-1}}{a_{ijt}} N_{ijt} da \right. \\
& \quad \left. + \int_{a_{ijt}}^{a_{ijt}} (\tau a)^{-\alpha} \frac{k_j a^{k_j-1}}{a_{ijt} - a_{ijt}} N_{ijt} da + \int_0^{a_{ijt}} a^{-\alpha} \frac{k_j a^{k_j-1}}{a_{ijt}} N_{ijt} da \right] \\
& = A_i^{1-\alpha} \alpha^{\frac{2\alpha}{1-\alpha}} L_i \left[ \int_0^{a_{ijt}} a^{-\alpha} \frac{k_i a^{k_i-1}}{a_{ijt}} N_{ijt} da \\
& \quad + \int_{a_{ijt}}^{a_{ijt}} (\tau a)^{-1-\epsilon} \frac{k_j a^{k_j-1}}{a_{ijt} - a_{ijt}} N_{ijt} da + \int_0^{a_{ijt}} a^{1-\epsilon} \frac{k_j a^{k_j-1}}{a_{ijt}} N_{ijt} da \right],
\end{align*}

where \( \epsilon = 1/(1-\alpha) \) so that \(-\alpha/(1-\alpha) = 1-\epsilon. \) Within the brackets \([ \cdot ]\), the first integral is an index of the average productivity of domestic firms multiply by \( N_{ijt} \), the second integral is an index of the average productivity of imported products multiply by \( N_{ijt} \), and the third integral is an index of the average productivity of foreign MNEs multiply by \( N_{ijt} \). These indices of average productivities can be expressed as:

\begin{align*}
\tilde{a}_{ijt}^{1-\epsilon} &= \frac{k_i}{k_i - \epsilon + 1} a_{ijt}^{1-\epsilon}, \quad \tilde{a}_{ijt}^{1-\epsilon} = \frac{k_j}{k_j - \epsilon + 1} a_{ijt}^{1-\epsilon}, \\
\tilde{a}_{ijt}^{1-\epsilon} &= \frac{k_j}{k_j - \epsilon + 1} \left( \frac{k_j - \epsilon + 1}{a_{ijt} - a_{ijt}} \right),
\end{align*}

where \( \tilde{a}_{ijt} \) is the average cost of domestic firms, \( \tilde{a}_{ijt} \) is the average cost of foreign firms that home country import from, and \( \tilde{a}_{ijt} \) is the average cost of foreign MNEs. An index of average productivity of all intermediate goods that will become inputs of the final output can be expressed as:

\begin{align*}
\tilde{a}_{ijt}^{1-\epsilon} &= \frac{N_{ijt} \tilde{a}_{ijt}^{1-\epsilon}}{N_{ijt}} + \frac{N_{ijt} (\tau \tilde{a}_{ijt})^{1-\epsilon}}{N_{ijt}} + \frac{N_{ijt} \tilde{a}_{ijt}}{N_{ijt}}.
\end{align*}

\( Y_{it} \) therefore becomes (26):

\begin{align*}
Y_{it} &= A_i^{1-\alpha} \alpha^{\frac{2\alpha}{1-\alpha}} L_i N_{ijt} \tilde{a}_{ijt}^{1-\epsilon}.
\end{align*}

Knowing that it costs \( a \) units of final output to produce one unit of intermediate good, one can derive the total spending on intermediate goods. Using equation (15), substitute for the optimal price from (17), and replace \( a \) with \( \tilde{a}_{ijt} \) yield:

\begin{align*}
X_i(\tilde{a}_{ijt}) &= A_i^{1-\alpha} \alpha^{\frac{2\alpha}{1-\alpha}} L_i \tilde{a}_{ijt}^{1-\alpha},
\end{align*}

where \( X_i(\tilde{a}_{ijt}) \) represents intermediate goods produced by an average intermediate firm that serve country \( i \). One can think of this as the amount of intermediate goods produced by a representative firm with average cost \( \tilde{a}_{ijt} \). To get the total cost of intermediate goods production:

\begin{align*}
M_{it} &= \tilde{a}_{ijt} N_{ijt} X_i(\tilde{a}_{ijt}) \\
&= \tilde{a}_{ijt} A_i^{\frac{1}{1-\alpha}} \alpha^{\frac{2}{1-\alpha}} L_i \tilde{a}_{ijt}^{1-\alpha} \\
&= \alpha^2 Y_{it}.
\end{align*}
The total spending on intermediate goods $M_{lt}$ turns out to be proportional to final output $Y_{it}$.

Next, from the final good producer’s problem:

$$
Y_{it} = w_{it}L_i + \int_0^{N_{it}} p_lX_{it}dl
= w_{it}L_i + \left[ \int_0^{a_{lit}} p(a)X_{ii}(a)\frac{g_i(a)}{G_i(a_{lit})}N_{it}da \\
+ \int_{a_{jit}}^{a_{xjt}} p(a)X_{jj}(a)\frac{g_j(a)}{G_j(a_{xjit})}N_{jit}da + \int_0^{a_{xjt}} p(a)X_{xt}(a)\frac{g_j(a)}{G_j(a_{xjit})}N_{ixt}da \right]
= w_{it}L_i + (N_{it}\tilde{\pi}_{iit} + N_{xjt}\tilde{\pi}_{xjt} + N_{ijt}\tilde{\pi}_{ijt} + N_{iit}F_{ii} + N_{xjt}F_{xjt} + N_{ijt}F_{ijt})
+ N_{ijt}F_{ij} + \tilde{a}_{it}N_{it}X_{i}(\tilde{a}_{it})
$$

To get from the second to the third line of the equation, one can think of the total revenue generated from selling intermediate goods in country $i$ must equal to the sum of domestic innovators’ profits, foreign exporters’ and MNEs’ profits, the fixed costs that all firms paid to access domestic market, and the total costs of production. Substituting out $\tilde{a}_{it}N_{it}X_{i}(\tilde{a}_{it})$ yields:

$$
Y_{it} - \alpha^2 Y_{it} = w_{it}L_i + N_{it}\tilde{\pi}_{iit} + N_{xjt}\tilde{\pi}_{xjt} + N_{ijt}\tilde{\pi}_{ijt} + N_{iit}F_{ii} + N_{xjt}F_{xjt} + N_{ijt}F_{ijt}.
$$

Using this equation, the budget constraint (8) can be further rewritten as:

$$
R_{it} = w_{it}L_i + N_{it}\tilde{\pi}_{iit} + N_{xjt}\tilde{\pi}_{xjt} + N_{ijt}\tilde{\pi}_{ijt} + N_{iit}F_{ii} + N_{xjt}F_{xjt} + N_{ijt}F_{ijt}
+ (N_{xit}\tilde{\pi}_{xit} - N_{xjt}\tilde{\pi}_{xjt}) + (N_{jxt}\tilde{\pi}_{jxt} - N_{ijt}\tilde{\pi}_{ijt}) - C_{it}
= (1 - \alpha^2)Y_{it} - C_{it} - E_{it},
$$

which can be further expressed as (12) given $M_{lt} = \alpha^2 Y_{it}$, and

$$
E_{it} = - [(N_{xit}\tilde{\pi}_{xit} - N_{xjt}\tilde{\pi}_{xjt}) + (N_{jxt}\tilde{\pi}_{jxt} - N_{ijt}\tilde{\pi}_{ijt})].
$$

Net exports can be further written as:

$$
E_{it} = - \left[ \left( \frac{N_{xit}\tilde{\pi}_{xit} - N_{xjt}\tilde{\pi}_{xjt}}{N_{it}} \right) + \left( \frac{N_{jxt}\tilde{\pi}_{jxt} - N_{ijt}\tilde{\pi}_{ijt}}{N_{j} - N_{it}} \right) \right] N_{it} = \nu_t N_{it}.
$$

### A.2 Average Net Profit of Intermediate Firms

To derive the average net profit of intermediate firms originated from country $i$, it is necessary to first derive the average net profits from serving at home, from exports, and from foreign market subsidiary.

The average net profit of intermediate firms from country $i$ that serve $i$ is given by:

$$
\tilde{\pi}_{iit} = \pi_{iit}(\tilde{a}_{it}) = \left( \frac{1 - \alpha}{\alpha} \right) \tilde{a}_{iit} A_i^{\frac{1}{1 - \alpha}} \alpha^{-\frac{2}{1 - \alpha}} L_i - F_{iit}.
$$
Substitute for $\tilde{a}_{iit}$, make use of $1 - \epsilon = -\alpha/(1 - \alpha)$, $a_{iit}$ from (22) and the scale-effect-corrected fixed cost yield:

$$\tilde{\pi}_{iit} = \left(1 - \frac{\alpha}{\alpha}\right) A_i^{\frac{1 - \alpha}{\alpha}} a_{iit} \tilde{a}_{iit}^{1 - \epsilon} - F_{iit}$$

$$= \left(1 - \frac{\alpha}{\alpha}\right) A_i^{\frac{1 - \alpha}{\alpha}} A_{i}^{\frac{2}{1 - \alpha}} \left(\frac{k_i}{k_i - \epsilon + 1}\right) \left[1 - \frac{A_i^{\frac{1 - \alpha}{\alpha}} a_{iit}^{1 - \epsilon}}{F_{iit}}\right]^{-1} - F_{iit}$$

$$= \left(\frac{k_i}{k_i - \epsilon + 1}\right) \frac{F_{iit} - F_{iit}}{F_{iit}}$$

$$= \left(\frac{\epsilon - 1}{k_i - \epsilon + 1}\right) r_{it} A_i^{\frac{1 - \alpha}{\alpha}} \tilde{a}_{iit}^{1 - \epsilon} L_i.$$

Similarly, substitute for $\tilde{a}_{xit}$, make use of equation (22) and the scale-effect-corrected fixed costs, the average net profit from exporting is given by:

$$\tilde{\pi}_{xit} = \left(1 - \frac{\alpha}{\alpha}\right) A_j^{\frac{1 - \alpha}{\alpha}} L_j (\tau \tilde{a}_{xit})^{1 - \epsilon} - F_{xit}$$

$$= \left(1 - \frac{\alpha}{\alpha}\right) A_j^{\frac{1 - \alpha}{\alpha}} A_j^{\frac{2}{1 - \alpha}} L_j \tau^{1 - \epsilon} \times$$

$$\frac{k_i}{k_i - \epsilon + 1} \frac{f_{xi}^{k_i^{1 - \epsilon} + 1}}{f_{xi}^{k_i^{1 - \epsilon} - k_i}} \tau^{-k_i} - \left(\frac{f_{ji} - f_{xi}}{1 - \tau^{1 - \epsilon}}\right)^{\frac{1}{1 - \epsilon}} a_{iit}^{1 - \epsilon} - F_{xit}$$

$$= \left(\frac{k_i}{k_i - \epsilon + 1} f_{xi}^{k_i^{1 - \epsilon} + 1} \tau^{-(k_i - 1)} - \left(\frac{f_{ji} - f_{xi}}{1 - \tau^{1 - \epsilon}}\right)^{\frac{k_i^{1 - \epsilon} + 1}{1 - \epsilon}} a_{iit}^{1 - \epsilon} - F_{xi}\right) r_{it} A_i^{\frac{1 - \alpha}{\alpha}} \tilde{a}_{iit}^{1 - \epsilon} a_{jhit}^{1 - \epsilon}$$

where average productivity of an exporting firm

$$\tilde{a}_{xit}^{1 - \epsilon} = \frac{k_i}{k_i - \epsilon + 1} \frac{a_{xit}^{k_i^{1 - \epsilon} + 1}}{a_{jhit}^{k_i^{1 - \epsilon} + 1}}$$

can be found by $\int_{a_{xit}}^{a_{jhit}} a^{1 - \epsilon} (k_i a_{xit}^{1 - \epsilon} - a_{jhit}^{1 - \epsilon}) da$.

By the same token, substitute for $\tilde{a}_{jhit}$, make use of equation (23) and the scale-effect-corrected fixed costs, the average net profit from foreign market subsidiary is given by:

$$\tilde{\pi}_{jhit} = \left(1 - \frac{\alpha}{\alpha}\right) A_j^{\frac{1 - \alpha}{\alpha}} A_j^{\frac{2}{1 - \alpha}} L_j \tilde{a}_{jhit}^{1 - \epsilon} - F_{jhit}$$

$$= \left(1 - \frac{\alpha}{\alpha}\right) A_j^{\frac{1 - \alpha}{\alpha}} A_j^{\frac{2}{1 - \alpha}} L_j \frac{k_i}{k_i - \epsilon + 1} \left(\frac{f_{ji} - f_{xi}}{1 - \tau^{1 - \epsilon}} \frac{A_i^{\frac{1 - \alpha}{\alpha}} L_i}{A_j^{\frac{2}{1 - \alpha}} L_j}\right) a_{xhit}^{1 - \epsilon} - F_{jhit}$$

$$= \left(\frac{k_i}{k_i - \epsilon + 1}\right) f_{ji} - f_{xi} (1 - \tau^{1 - \epsilon}) - f_{ji} r_{it} A_i^{\frac{1 - \alpha}{\alpha}} \tilde{a}_{jhit}^{1 - \epsilon}$$

where average productivity of foreign subsidiary

$$\tilde{a}_{jhit} = \left(\frac{k_i}{k_i - \epsilon + 1}\right)^{\frac{1}{\alpha}} a_{jhit}$$
can be found by \( \int_0^{a_{jit}} a^{1-\epsilon}(k_i a^{k_i - 1})/(a_{jit}) \)da.

Define the average net profit of an average intermediate firm originated from country \( i \) as the average net profit it earns from domestic market \( i \) plus the possibility to earn profits from serving foreign market \( j \) either through exporting or outward MP. This can be written as (28):

\[
\tilde{\pi}_{it} = \bar{\pi}_{iit} + \frac{G_i(a_{xit}) - G_i(a_{iit})}{G_i(a_{iit})} \bar{\pi}_{xit} + \frac{G_i(a_{jdt})}{G_i(a_{iit})} \bar{\pi}_{jdt},
\]

where \((G_i(a_{xit}) - G_i(a_{iit}))/G_i(a_{iit})\) is the probability of a domestic firm exporting, and \(G_i(a_{jdt})/G_i(a_{iit})\) is the probability of a domestic firm that becomes a MNE to serve abroad. Notice that these probabilities also represent the fractions of all domestic firms that export and engage in outward MP, respectively.

### A.3 International Spillovers

The degree of international spillovers is measured by the share of foreign intermediate goods sales in a country’s total intermediate goods sales. To derive this, it is necessary to first derive the different components of intermediate goods sales as well as the total sales.

**Domestic firms sales:**

\[
p_{ii}(\tilde{a}_{iit})X_{ii}(\tilde{a}_{iit})N_{iit} = \frac{\tilde{a}_{iit}}{\alpha} A_i^{1-\alpha} \alpha^{\frac{2}{1-\alpha}} L_i \tilde{\alpha}_{iit}^{-\epsilon} N_{iit} = A_i^{1-\alpha} \alpha^{\frac{1}{1-\alpha}} L_i \tilde{\alpha}_{iit}^{-\epsilon} N_{iit}.
\]

**Import sales:** (by substituting out \( \tilde{a}_{xjt} \))

\[
p_{xj}(\tilde{a}_{xjt})X_{xj}(\tilde{a}_{xjt})N_{xjt} = \frac{\tau \tilde{a}_{xjt}}{\alpha} A_i^{1-\alpha} \alpha^{\frac{2}{1-\alpha}} L_i (\tau \tilde{a}_{xjt})^{-\epsilon} N_{xjt}
\]

\[
= A_i^{1-\alpha} \alpha^{\frac{1+\epsilon}{1-\alpha}} L_i \tilde{\alpha}_{xjt}^{-\epsilon} N_{xjt} \left( A_i^{1-\alpha} \frac{L_i}{A_j^{1-\alpha} L_j} \right)^{\frac{k_j-\epsilon+1}{1-\epsilon}} \left( f_{ji} (1 - \tau^{-1}) \right) \left( f_{ij} / f_{xj} \right)^{\frac{k_j-\epsilon+1}{1-\epsilon}}
\]

**Foreign MNEs sales:** (by substituting out \( \tilde{a}_{ijt} \))

\[
p_{ij}(\tilde{a}_{ijt})X_{ij}(\tilde{a}_{ijt})N_{ijt} = \frac{\tilde{a}_{ijt}}{\alpha} A_i^{1-\alpha} \alpha^{\frac{2}{1-\alpha}} L_i \tilde{\alpha}_{ijt}^{-\epsilon} N_{ijt}
\]

\[
= A_i^{1-\alpha} \alpha^{\frac{1+\epsilon}{1-\alpha}} L_i \tilde{\alpha}_{ijt}^{-\epsilon} N_{ijt} \times
\]

\[
\frac{k_j}{k_j-\epsilon+1} \left( f_{jj} (1 - \tau^{-1}) \right) \left( f_{ij} / f_{xj} \right)^{\frac{k_j-\epsilon+1}{1-\epsilon}}
\]

**Total sales in country \( i \) = domestic firm sales + import sales + foreign MNEs sales:**

\[
p_i(\tilde{a}_{it})X_i(\tilde{a}_{it})N_{iit} = A_i^{1-\alpha} \alpha^{\frac{1+\epsilon}{1-\alpha}} L_i \left( N_{iit} \tilde{\alpha}_{iit}^{-\epsilon} + N_{xjt} (\tau \tilde{a}_{xjt})^{-\epsilon} + N_{ijt} \tilde{\alpha}_{ijt}^{-\epsilon} \right)
\]

\[
= A_i^{1-\alpha} \alpha^{\frac{1+\epsilon}{1-\alpha}} L_i N_{iit} \tilde{\alpha}_{iit}^{-\epsilon}.
\]
Notice that the total sales in country \( i \) is also equal to \( \alpha Y_{it} \), which implies that an \( \alpha \) share of final output goes to the sales of intermediate goods. This is also implied by the aggregate production function (3).

The degree of international spillovers in country \( i \) is given by:

\[
\lambda_{it} = \frac{\text{import sales}_t + \text{foreign MNE sales}_t}{\text{total sales}_t},
\]

which can be further expressed as:

\[
\lambda_{it} = \frac{\left(\frac{a_{ijt}}{a_{ijt}}\right)^{1-\epsilon} N_{ijt}^{1-\epsilon} \Sigma}{1 + \left(\frac{a_{ijt}}{a_{ijt}}\right)^{1-\epsilon} N_{ijt}^{1-\epsilon} \Sigma},
\]

where

\[
\Sigma = \left(\frac{\left(f^{\frac{1}{\epsilon}}_{jjj} + f^{\frac{1}{\epsilon}}_{xj} - f^{\frac{1}{\epsilon}}_{xji} - f^{\frac{1}{\epsilon}}_{xij} \right)}{f^{\frac{1}{\epsilon}}_{xj} - f^{\frac{1}{\epsilon}}_{xii} \right)^{\frac{1}{1-\epsilon}}},
\]

\[A.4 \text{ The Generality and Robustness of the Quality-Adjusted Spillovers Function}\]

This section of the Web Appendix discusses the key feature of the productivity of innovation \( h_{it} \) given by (32) that generates the U-shaped results in the paper, and examines the robustness of these results to the way quality-adjusted spillovers are being modelled. I start off by explaining the generality of the \( h_{it} \) function, and then perform some robustness checks to support the U-shaped results.

a) Following Melitz (2003) and Helpman, Melitz, and Yeaple (2004), I define average cost \( \tilde{a}_{it} \) for country \( i \) in equation (27) in the paper:

\[
\tilde{a}_{it} = \left[\frac{N_{iiit}^{1-\epsilon} + N_{ijt}^{1-\epsilon} + N_{ijt}^{1-\epsilon}}{N_{it}}\right]^{\frac{1}{1-\epsilon}},
\]

where \( \epsilon > 1 \) and \( j \) is the foreign country. \( \tilde{a}_{it} \) is the average unit cost of domestic firms, \( \tilde{a}_{xjt} \) is the average unit cost of foreign firms exporting to country \( i \), and \( \tilde{a}_{ijt} \) is the average unit cost of foreign multinational enterprises (MNEs). The total number of intermediate firms \( N_{it} \) in country \( i \) is equal to the sum of domestic firms \( N_{iit} \), foreign exporters \( N_{xjt} \), and foreign MNEs \( N_{ijt} \).

In the model, technology spillovers are not only in terms of quantity, but also in terms of quality. To capture the quality of technology spillovers from country \( j \) to \( i \), I define the average cost \( \bar{a}_{xjt} \) of country \( j \) similar to the weighted average structure as seen in \( \tilde{a}_{it} \). It is given by (34):

\[
\bar{a}_{xjt} = \left[\frac{N_{xjt}^{1-\epsilon} + N_{ijt}^{1-\epsilon}}{N_{xjt}^{1-\epsilon} + N_{ijt}^{1-\epsilon}}\right]^{\frac{1}{1-\epsilon}}.
\]

Note that the "\( \cdot \)" notation is used in this weighted average to distinguish \( \bar{a}_{xjt} \) from \( \tilde{a}_{xjt} \). Unlike in \( \tilde{a}_{it} \), \( \tau \) is taken away to reflect the "true" productivity of the exporting firm in the absence of the iceberg
trade cost arising from gravity or trade barriers. Similar to \( \tilde{a}_{it} \) in (27), \( \tilde{a}_{xjt} \) in (34) is driven by the selection of country \( j \)'s firms to become exporters or MNEs based on their unit costs draw from a Pareto distribution given by equation (5). Since the fixed cost to become a MNE is the highest, follow by the fixed cost to become an exporter, the most productive firms with the lowest unit costs draw become MNEs, followed by exporters who are less productive than the MNEs. \( \tilde{a}_{xjt} \) captures the fact that an increase in the relative number of MNEs in country \( j \), \( N_{ijt} \), can lead to a decrease in average cost \( \tilde{a}_{xjt} \), conditional on \( \tilde{a}_{ijt} < \tilde{a}_{xjt} \). This average cost enters into the technology spillovers process which will be described below.

Next, I define \( h_{it}^{(0)} \) the productivity of innovation given by (41) which is standard in the growth literature:
\[
h_{it}^{(0)} = R_{it}^{-\phi} (N_{it} + \lambda_{it} N_{jjt})^\phi.
\]

As suggested by Eaton and Kortum (1999) and Rodriguez-Clare (1996), and based on the empirical evidence from Alfaro and Charlton (2007), Pradhan (2006), and Smeets (2008), the quality of technology is important for technology diffusion. Moreover, as pointed out in Lai and Yan (2013), foreign direct investment is much more significant as a channel to exploit invention internationally than exporting, due to the empirical fact that firm revenues follow a fat-tailed distribution and that multinationals are more productive than exporters. To capture the importance of technology quality in technology spillovers, I multiply \( N_{iit} \) and \( N_{jjt} \) by measures of the quality of domestic and foreign technology, \( \omega_{iit} \) and \( \omega_{jjt} \), respectively. The productivity of innovation then becomes the following, without loss of generality:
\[
h_{it}^{(1)} = R_{it}^{-\phi} (\omega_{iit} N_{iit} + \lambda_{it} \omega_{jjt} N_{jjt})^\phi.
\]
The \( \omega \) terms act like weights on the quantities of domestic and foreign technology, \( N_{iit} \) and \( \lambda_{it} N_{jjt} \), respectively. \( h_{it}^{(1)} \) can be interpreted as a function of the weighted average of domestic and foreign technologies, where the weights are determined by the quality of technology.

Following Melitz (2003) and Helpman, Melitz, and Yeaple (2004), for an average unit cost \( \tilde{a} \), \( \tilde{a}_{iit}^{1-\epsilon} \) can be defined as a measure of average productivity for \( \epsilon > 1 \). To associate the quality of technology with firm productivity, I define \( \omega_{iit} = \tilde{a}_{iit}^{1-\epsilon} \), the average domestic productivity, and \( \omega_{jjt} = \tilde{a}_{xjt}^{1-\epsilon} \), the average foreign productivity. \( h_{it}^{(1)} \) then becomes:
\[
h_{it}^{(1)} = R_{it}^{-\phi} \left( \tilde{a}_{iit}^{1-\epsilon} N_{iit} + \lambda_{it} \tilde{a}_{xjt}^{1-\epsilon} N_{jjt} \right)^\phi.
\]
The function is normalized with the average domestic productivity in order to highlight the role of relative productivity between foreign and domestic technology, I divide both side of the equation by \( \tilde{a}_{iit}^{1-\epsilon} \). The term \( (\tilde{a}_{xjt}/\tilde{a}_{iit})^{1-\epsilon} \) then becomes a measure of relative productivity. \( h_{it} \) is given by (32) in the paper:
\[
h_{it} = R_{it}^{-\phi} \left( N_{iit} + \lambda_{it} N_{jjt} \left( \frac{\tilde{a}_{xjt}}{\tilde{a}_{iit}} \right)^{1-\epsilon} \right)^\phi.
\]
The key feature in \( h_{it} \) to generate the U-shaped results is the relative productivity of foreign technology. The apparently restrictive functional form of \( (\tilde{a}_{xjt}/\tilde{a}_{iit})^{1-\epsilon} \) in \( h_{it} \) is a special case of \( \omega_{jjt}/\omega_{iit} \) in \( h_{it}^{(1)} \).
from above. Although this is just one way of associating the quality of technology with productivity, I show in below that this functional form is general enough to cover a wide range of impact of increasing quality on technology spillovers.

Indeed, the U-shaped results do not rely on particular forms that the $\omega$ terms take, as long as the relative productivity of foreign technology is an increasing function of $\tau$. This condition implies that imposing trade barriers, which causes less productive imports to exit and more productive foreign MNEs to enter, can improve the quality of technology diffused. The quality improvement lowers the cost of innovation. As discussed in Section 3.1.2, the benefit from lower innovation cost can be more than offsetting the expected losses arising from smaller sales abroad. This in turn induces a higher rate of innovation and hence higher equilibrium growth rate. In sum, innovation productivity that is increasing in $\tau$ (or cost of innovation that is decreasing in $\tau$) is a necessary condition for the equilibrium growth rate to increase in $\tau$ for $\tau$ greater than a cut-off $\tau^*$ as shown in proposition 3. This is also a necessary condition for welfare gains to increase in $\tau$ in some range of $\tau$, given that dynamic effect plays a significant role in determining the welfare effects from openness as shown in Section 4.

b) It may seem that the relative productivity of foreign technology in $h_{it}$, which raises to the power of $1 - \epsilon$, is restrictive. In other words, the choice of $\epsilon$ may seem to matter in order to give rise to the U-shaped relationships between $\tau$ and the equilibrium growth rates/welfare gains. In the following exercise, I show that the U-shaped results do not depend on the choice of $\epsilon$. This example is sufficient to show that the U-shaped results are robust as long as the necessary condition that the innovation productivity $h_{it}$ is increasing in $\tau$ holds. Specifically, I multiply $1 - \epsilon$ by a free parameter, $\psi$, so that the U-shaped results are not specific to the $\epsilon$ being chosen.

By incorporating $\psi$ into $h_{it}$, I define:

$$h_{it}^{(2)} = R_{it}^{-\phi} \left( N_{it} + \lambda_{it} N_{jjt} \left( \frac{\bar{a}_{xjt}}{\bar{a}_{iit}} \right)^{(1-\epsilon)\psi} \right)^\phi,$$

where $\psi \geq 0$. In particular, $\psi \in [0, \infty)$ implies that $(\bar{a}_{xjt}/\bar{a}_{iit})^{(1-\epsilon)\psi} \in [1, -\infty)$, where $(\bar{a}_{xjt}/\bar{a}_{iit}) < 1$ as given by the equilibrium result. Quality adjustment in technology spillovers has no impact on technology spillovers if $\psi = 0$, and the equation simply becomes (41) in the paper. As $\psi$ increases, the importance of quality adjustment in technology spillovers increases. $\psi = 1$ is the case where $h_{it}^{(2)}$ is the same as $h_{it}$ given by (32).

Using the calibrated version of the model, Figures A.1 and A.2 are generated to show that $\psi$ controls the curvature of the U-shaped curves between welfare costs and $\tau$. U-shaped results hold for a wide range of $\psi$, even though quantitatively the welfare gains are different.
A.5 Cost of Innovation and Aggregate R&D Expenditure

Since the focus is on the balanced growth path (BGP), I drop the time subscript for the variables that do not change along the BGP. From Section 2.5.1, the stock of knowledge relative to the size of economy is given by:

\[(K_{it}/Y_{it})^{-1} = A_i^{1-\alpha} \alpha^{2\alpha} L_i.\]

Using this fact and \(h_{it}\) from equation (32), the cost of innovation from equation (35) can be rewritten as:

\[\eta_{it} = \left(1 + \lambda_{it} \frac{N_{j\bar{it}}}{N_{iit}} \left(\frac{\bar{a}_{xjt}}{a_{iit}}\right)^{1-\epsilon}\right)^{-\phi} \left(\frac{R_{it}}{N_{iit}}\right)^{1-\phi} f_i^I (A_i^{1-\alpha} \alpha^{2\alpha} L_i)^{1-\phi}.\]

Next, \(\dot{N}_{iit} = g_i N_{iit}\), where \(g_i\) is the rate of innovation. R&D expenditure from equation (9) can be rewritten as:

\[R_{it} = \left(\frac{a_i0}{a_{i0}}\right)^{k_i} \eta_{it} \dot{N}_{iit}\]

\[= \left(\frac{a_i0}{a_{i0}}\right)^{k_i} \left(1 + \lambda_{it} \frac{N_{j\bar{it}}}{N_{iit}} \left(\frac{\bar{a}_{xjt}}{a_{iit}}\right)^{1-\epsilon}\right)^{-\phi} \left(\frac{R_{it}}{N_{iit}}\right)^{1-\phi} f_i^I (A_i^{1-\alpha} \alpha^{2\alpha} L_i)^{1-\phi} g_i N_{iit}\]

\[= \left(\frac{a_i0}{a_{i0}}\right)^{k_i} \left(1 + \lambda_{it} \frac{N_{j\bar{it}}}{N_{iit}} \left(\frac{\bar{a}_{xjt}}{a_{iit}}\right)^{1-\epsilon}\right)^{-\phi} \left(\frac{R_{it}}{N_{iit}}\right)^{1-\phi} f_i^I (A_i^{1-\alpha} \alpha^{2\alpha} L_i)^{1-\phi} \Gamma_i N_{iit}.\]

By substituting out \(R_{it}\), \(h_{it}\) becomes:

\[h_{it} = \left(\frac{f_i^I g_i}{a_{i0}}\right)^{1-\phi} \left(\frac{a_i0}{a_{i0}}\right)^{k_i \phi \Gamma_i} \left(1 + \lambda_{it} \frac{N_{j\bar{it}}}{N_{iit}} \left(\frac{\bar{a}_{xjt}}{a_{iit}}\right)^{1-\epsilon}\right)^{\phi \Gamma_i} (A_i^{1-\alpha} \alpha^{2\alpha} L_i)^{-\phi}.\]
By substituting out $h_{it}$ and $\eta_{it}$, the free-entry condition (30) becomes:

$$W_{it} = \left(\frac{a_{i0}}{a_{ii}}\right)^{k_i} h_{it}^{-1} f_i^i A_i^{1 - \omega} L_i^{1 - \phi}$$

$$= f_i^{1 - \phi} \left(\frac{a_{iit}}{a_{ii}}\right)^{\frac{-k_i}{1 - \phi}} \left(1 + \lambda_{it} \frac{N_{jjt}}{N_{iit}} \left(\frac{\bar{a}_{xjt}}{\bar{a}_{iit}}\right)^{1 - \epsilon}\right)^{\frac{-\phi}{1 - \phi}} g_i^{1 - \phi} A_i^{1 - \alpha} \frac{1}{\alpha^{1 - \alpha}} L_i.$$

Since $\eta_{it} = (a_{iit}/a_{i0})^{k_i} W_{it}$ from free-entry condition (30):

$$\eta_{it} = f_i^{1 - \phi} \left(\frac{a_{iit}}{a_{ii}}\right)^{\frac{-k_i}{1 - \phi}} \left(1 + \lambda_{it} \frac{N_{jjt}}{N_{iit}} \left(\frac{\bar{a}_{xjt}}{\bar{a}_{iit}}\right)^{1 - \epsilon}\right)^{\frac{-\phi}{1 - \phi}} g_i^{1 - \phi} A_i^{1 - \alpha} \frac{1}{\alpha^{1 - \alpha}} L_i.$$

### A.6 The Existence of the Balanced Growth Path

The time subscript is dropped for the variables that do not change along the BGP. From equation (36):

$$g_i = \left(\frac{R_{iit}}{N_{iit}}\right)^{1 - \phi} \left(1 + \lambda_{it} \frac{N_{jjt}}{N_{iit}} \left(\frac{\bar{a}_{xjt}}{\bar{a}_{iit}}\right)^{1 - \epsilon}\right)^{\phi} (\bar{f}_i)^{-1},$$

which is an increasing and concave function of the ratio $N_{jjt}/N_{iit}$. I call the above condition (AI). In the $(g, N_{jjt}/N_{iit})$ space, aggregate innovation (AI) is an upward sloping curve, as shown in Figure 2.

Notice that from the AI relationship, a large $N_{jjt}/N_{iit}$ ratio implies a large $g_i$, while the foreign rate of innovation $g_j$ is small.\(^1\) Since final output is produced using both domestic and foreign intermediate inputs, output growth depends on both countries’ rates of innovation. Because the output growth rate is the weighted average between $g_i$ and $g_j$, country $i$’s output growth must be lower than $g_i$ when the $N_{jjt}/N_{iit}$ ratio is large. The vice-versa is true. Using the final output equation (26) and equation (38), and by taking logarithm and time derivative yields the condition $(YI)^2$:

$$\frac{\dot{Y}_{it}}{Y_{it}} = (1 - \Psi)g_i + \Psi g_j,$$

where

$$\Psi = \left(1 + \frac{G_j(a_{xjt}) N_{jjt}}{G_j(a_{xjjt}) N_{iit}}\right)^{-1} \frac{G_j(a_{xjt}) N_{jjt}}{G_j(a_{xjjt}) N_{iit}}.$$

First, $g_i$ rises and $g_j$ falls as $N_{jjt}/N_{iit}$ ratio increases. This is based on the AI relationship. $\Psi$ in $YI$ is increasing with $N_{jjt}/N_{iit}$, which assigns more weight on the decreasing $g_j$ as $N_{jjt}/N_{iit}$ increases. In the $(g, N_{jjt}/N_{iit})$ space, the $YI$ condition can possibly have an upward sloping section, followed by a downward sloping section. This can be seen by rewriting the $YI$ condition as:

$$\frac{\dot{Y}_{it}}{Y_{it}} = g_i + \Psi (g_j - g_i).$$

---

\(^1\)A large $N_{jjt}/N_{iit}$ ratio means a small $N_{iit}/N_{jjt}$ ratio. There are less technologies diffused from domestic to foreign country. Consequently, foreign cost of innovation is high and the foreign rate of innovation $g_j$ is low.

\(^2\)Since a small change in the $N_{jjt}/N_{iit}$ ratio has a small indirect effect on the cut-off costs, the indirect effect on $\bar{a}_i$ is close to zero.
The output growth rate may increase initially at small $N_{jjt}/N_{ii}$ if $g_i$ increases faster than the decline in $\Psi(g_j - g_i)$. Output growth eventually decreases with $N_{jjt}/N_{ii}$ for $\Psi \geq \Psi^*$, where $\Psi^*$ is the point where the increase in $g_i$ is fully offset by the decrease in $g_j - g_i$. Thus implying a downward sloping $YI$ curve for $\Psi \geq \Psi^*$.

A.6.1 A Proof of Proposition 2

Since the $AI$ curve can possibly intersect both the upward and downward sloping sections of $YI$ curve, I focus on the intersection at the downward sloping section only in which the equilibrium is stable. For $N_{jjt}/N_{ii} > (N_{jjt}/N_{ii})^*$, where the asterisk denotes equilibrium, $g_i > g^*$ and $g_j < g^*$ according to the $AI$ relationship. This causes the output growth of country $i$ to drop below its equilibrium value according to the downward-sloping $YI$ curve. However, the cost of innovation $\eta_i$ is reduced due to a large $N_{jjt}/N_{ii}$ ratio which results in a greater degree of international spillovers. As a result, $g_i$ increases as a greater variety of intermediate goods in country $i$ will be developed and produced. As long as the rate of innovation $r_i > r_j$, the $N_{jjt}/N_{ii}$ ratio keeps decreasing. This process continues until $N_{jjt}/N_{ii} = (N_{jjt}/N_{ii})^*$ and $g_i = g_j = g^*$. The vice-versa is true for $N_{jjt}/N_{ii} < (N_{jjt}/N_{ii})^*$.

A.7 Trade Openness and the Quality-Adjusted Spillovers Process

A.7.1 Properties of $\partial \ln r / \partial \tau$

Since $r = (a_{ii}/a_{i0})^k \tilde{\pi}_i/\eta_i$ along the BGP as given by free-entry condition (30) and equation (37), this implies that:

$$\frac{\partial \ln r}{\partial \tau} \approx \frac{\partial \ln \tilde{\pi}_i}{\partial \tau} - \frac{\partial \ln \eta_i}{\partial \tau}.$$

First, making use of $\eta_i$ from Web Appendix A.5, which involves quality-adjusted spillovers process, the function $\ln \eta_i$ is strictly decreasing in $\tau$ and is strictly convex, i.e. $\partial \ln \eta_i / \partial \tau < 0$ and $\partial^2 \ln \eta_i / \partial \tau^2 > 0 \forall \tau$.

Next, if $\partial \ln \tilde{\pi}_i / \partial \tau > \partial \ln \eta_i / \partial \tau$ for some range of $\tau$, then $\partial \ln r / \partial \tau > 0$. An increase in $r_i$ decreases the cut-off cost $a_{ii}$. Selection drives the least productive domestic firms to exit. For a certain range of $\tau$ and depending on other parameters, this selection effect and the entry of new MNEs together can offset the losses from exports sales, i.e. $\partial \ln \tilde{\pi}_i / \partial \tau$ can be positive or negative. But despite the sign of the first derivative, $\partial^2 \ln \tilde{\pi}_i (\tilde{a}) / \partial \tau^2 > 0$ for all $\tau$. These properties together imply that $\ln \tilde{\pi}_i$ can either be strictly decreasing, or can be first decreasing and then increasing. Since the function is strictly convex, the function becomes increasing once its slope turns positive.

A.7.2 A Proof of Proposition 3

From the free-entry condition (30) and equation (37), the sign of $\partial \ln g / \partial \tau = \partial \ln r / \partial \tau$, it suffices to show the changes in $\partial \ln r / \partial \tau$ and the existence and uniqueness of the cut-off trade cost $\tau^*$. If $\tau^*$ exists, it is unique because both $\ln \tilde{\pi}_i$ and $\ln \eta_i$ are strictly convex, such that for the functions $\partial \ln \tilde{\pi}_i / \partial \tau$ and

3The indirect effect of small changes in $\tau$ on $r_i$ through $a_{ii}$ is small.
\(\partial \ln \eta_i / \partial \tau\), if they ever cross, will only cross once. Based on the properties of \(\partial \ln \tilde{\pi}_i / \partial \tau\) and \(\partial \ln \eta_i / \partial \tau\) discussed in Web Appendix A.7.1, two results can be established:

1) If \(\partial \ln r / \partial \tau\) is first negative and then turns into positive, there exists a unique \(\tau^*\) such that \(\partial \ln \tilde{\pi}_i / \partial \tau < \partial \ln \eta_i / \partial \tau\) for \(\tau < \tau^*\), and \(\partial \ln \tilde{\pi}_i / \partial \tau > \partial \ln \eta_i / \partial \tau\) for \(\tau > \tau^*\). This also implies that \(\partial g / \partial \tau > 0\) for \(\tau > \tau^*\), and \(\partial g / \partial \tau \leq 0\) for \(\tau \leq \tau^*\). The cut-off point \(\tau^*\) is the point where \(\partial \ln r(\tau^*) / \partial \tau = 0\).

2) If \(\partial \ln r / \partial \tau < 0\) for all \(\tau\), then \(\tau^*\) does not exist, i.e. \(\partial \ln \tilde{\pi}_i / \partial \tau < \partial \ln \eta_i / \partial \tau\) for all \(\tau\), and \(\partial g / \partial \tau < 0\).

### A.7.3 A Proof of Proposition 4

Since the sign of \(\partial \ln g / \partial \tau = \partial \ln r / \partial \tau\), it suffices to show the changes in \(\partial \ln r / \partial \tau\) and the existence and uniqueness of the cut-off trade cost \(\tau'\). Replacing \(h_i\) in the cost of innovation \(\eta_i\) in (35) by (41) yields a \(\ln \eta_i\) function that is strictly increasing in \(\tau\) and is strictly convex. However, since \(\partial \ln \tilde{\pi}_i / \partial \tau\) can be positive or negative, and is strictly convex as discussed in Web Appendix A.7.1, two results can be established:

1) If \(\partial \ln \tilde{\pi}_i / \partial \tau > 0\) for some range of \(\tau\), and is large enough to offset \(\partial \ln \eta_i / \partial \tau\) which is positive \(\forall \tau\), there exists a unique \(\tau'\) such that \(\partial \ln \tilde{\pi}_i / \partial \tau < \partial \ln \eta_i / \partial \tau\) for \(\tau < \tau'\), and \(\partial \ln \tilde{\pi}_i / \partial \tau > \partial \ln \eta_i / \partial \tau\) for \(\tau > \tau'\). This also implies that \(\partial g / \partial \tau < 0\) for \(\tau < \tau'\), and \(\partial g / \partial \tau \geq 0\) for \(\tau \geq \tau'\). The cut-off point \(\tau'\) is the point where \(\partial \ln r(\tau') / \partial \tau = 0\). Moreover, \(\ln \eta_i\) is strictly increasing in \(\tau\) without a quality-adjusted technology spillovers process, but the function is strictly decreasing in \(\tau\) if quality adjustment is accounted for. So, for a given \(\ln \tilde{\pi}_i\) function, \(\partial \ln r / \partial \tau\) must turn positive starting from a smaller \(\tau\) with quality-adjusted spillovers process than otherwise, i.e. \(\tau^* < \tau'\).

2) If \(\partial \ln \tilde{\pi}_i / \partial \tau < 0\ \forall \tau\), or if it is positive for some range of \(\tau\), but is smaller than \(\partial \ln \eta_i / \partial \tau\), then \(\partial \ln r / \partial \tau < 0\) for all \(\tau\) and \(\tau'\) does not exist.

### A.8 The Average OECD Case

In this section of the Web Appendix, I discuss the quantitative results for the average OECD case. I assume that there are two identical countries, both sharing the characteristics of an average OECD country. I calibrated the parameters for the two identical countries to fit the average exports and outward MNE sales shares of GDP across nineteen OECD countries including the US. In particular, this ratio is larger than that in the US-OECD case where the two economies are asymmetric. Comparing the results from the two cases allows us to examine how the different trade-to-MNE sales ratios can affect long-run consumer welfare when trade and/or MP is liberalized. Moreover, since the theoretical model is jump-stable for the symmetric case, the quantitative results from the average OECD case can be served as a robust check to the results from the US-OECD case.

Specifically, I take the average of the exports and imports shares of GDP from all nineteen OECD countries, and I assume the average outward MNE sales share to be twice the outward MNE sales share.

\[\text{This case can happen whether } \partial \ln \tilde{\pi}_i / \partial \tau \text{ is positive or negative, as long as } \partial \ln r / \partial \tau > 0.\]
of the US to the rest of the OECD due to data limitations.\footnote{Given that the size of the US is similar to the rest of the OECD countries, and that only the data on bilateral MNE sales with the US are available, I assume each economy’s total outward MNE sales to its peers (i.e. the OECD group excluding itself) is twice as much as its bilateral MNE sales with the US.} I assume $A_d$ and $L_d$ for $d \in \{i, j\}$ to be 1 since the two countries are identical. The calibration targets are given by Table 1 in the main text and in the following table:

Table A1: Multiple Parameters Calibrated

| $f_{sd}$ fixed costs, $s \in \{i, x, j\}$ |  
|--------------------------------------|---|
| Average exports sales share of GDP | 19.4% |
| Average outward MNE sales share of GDP | 24.6% |

Table A2 presents the long-run per capita growth rates of the average OECD case under different degrees of openness. Since the results from the no spillovers case in the third column are similar to those in the fourth column, I focus on the results from columns 4 and 5 when international spillovers are present. The benchmark growth rate is 2\% as shown in the first row. In the second row, when the trade cost is increased to the historical level in 1970, the growth rate drops to 1.87\% when the spillovers process is not quality-adjusted. However, the growth rate rises to 2.14\% with quality-adjusted spillovers, consistent with the US-OECD case. From the third row, when MP is shut down, the growth rate drops to 1.79\% and 1.66\%, respectively, across the two spillovers settings. These results reinforce the importance of MP on economic growth. When the economy is in autarky, the growth rate drops to 1.36\% and 1.46\%, respectively.

Table A2: Changes in Growth Rates: Average OECD

<table>
<thead>
<tr>
<th>Trade</th>
<th>MNE</th>
<th>Growth (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no spill</td>
<td>w/ spill</td>
<td>w/ quality</td>
</tr>
<tr>
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<td>bench</td>
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</tr>
<tr>
<td>aut</td>
<td>aut</td>
<td>1.45</td>
<td>1.36</td>
</tr>
</tbody>
</table>

The relationship between the growth rate and the iceberg trade cost is illustrated in Figure A.3. After a cut-off trade cost $\tau^*$ at 1.38, the growth rate of the average OECD country rises as the trade cost increases. As the trade cost is reduced from 1.38 towards 1, the growth rate rises as well, creating a U-shaped pattern between the growth rate and the trade cost similar to the US-OECD case.
Table A3 illustrates the welfare results for the average OECD case. In the second row of the top panel, the average OECD country would experience a 1.36% welfare loss when the historical trade cost is imposed, despite a positive dynamic effect as shown previously. To understand the reason behind, first notice that by comparing to the trade and MNE sales shares from Table 2 in the main text, the exports-to-outward MNE sales ratio for the average OECD country is about 4/5, whereas the US exports-to-outward MNE sales ratio is about 1/3, which is much smaller. The larger exports-to-outward MNE sales ratio for the average OECD country implies that it is more difficult for an increase in MNE sales to offset the loss in exports sales. The strong negative static effect comes from the decrease in intermediate firm’s average profit and consumption level as exports sales are substantial to begin with, contrary to the US-OECD case in which exports sales are relatively less important.

Put differently, even if the dynamic effect from imposing trade barriers is positive, the total welfare gain still depends on the static effect. If a country’s trade-to-MNE sales ratio is large to begin with, the increase in MNE sales cannot offset losses in exports sales when trade barriers are imposed. The potentially large negative static effect coming from trade restrictions can be dominating the positive dynamic effect.

Figure A.4 shows that the consumer welfare of a household decreases with the trade cost initially due to the dominance of the static effect, but rises back up after a trade cost of 1.59. Yet, at the historical trade cost of 1.74, the overall welfare effect is still negative.

The welfare cost is around 20% when MP is shut down, as shown in Table A3. The autarkic welfare cost can go up to 51.23%, which is much larger than in the US-OECD case in Table 5 in the main text. Moreover, the dynamic effect accounts for 36.5% of the total cost, which is a substantial part of the welfare cost despite the dominance of the static effect.

To summarize, when the export-to-outward MNE sales ratio is large, as it is in the average OECD case, the results imply that trade liberalization over the past few decades has been welfare-improving. In contrast, when the trade-to-MNE sales ratio is small as it is in the US-OECD case, the effect of trade liberalization, holding constant the barriers on multinational activity, can be negative once we account
for the lower quality of technology being diffused by a smaller share of MP.

Table A3: Welfare Effects: Average OECD

<table>
<thead>
<tr>
<th>Trade MNE</th>
<th>Welfare (%)</th>
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</thead>
<tbody>
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<td></td>
<td>Total</td>
<td>Static</td>
<td>Dynamic</td>
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References


