Theories of trade and growth with heterogeneous firms and asymmetric countries*

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Abstract

This paper proposes two models of trade and growth with heterogeneous firms and asymmetric countries based on the author’s recent research. After introducing the Melitz model with two symmetric countries and the Baldwin-Robert-Nicoud and related endogenous growth models, we allow for asymmetric countries by giving up either firms’ infinite horizon or transitional dynamics. We focus on the effects of policy shocks on countries’ productivity cutoffs, which provide much information about countries’ welfare and growth. We first see how the cutoffs are determined under symmetric countries, and then how they are additionally affected by endogenous factor prices under asymmetric countries.

JEL classification: F13; F43

Key words: Trade and growth; Heterogeneous firms; Asymmetric countries; Melitz model; Endogenous growth

1 Introduction

Like it or not, the Melitz (2003) model is still arguably the most important general equilibrium trade model1. By combining the Hopenhayn (1992a, b) model of entry and exit of heterogeneous firms under perfect competition with the Krugman (1980) model of trade under monopolistic competition, he discovers that selection (i.e., exit) of unproductive firms is a new source of gains from trade. Then it is natural to ask how trade-induced selection affects countries’ economic growth. Considering economic growth is important because it certainly has an additional effect on countries’ long-run welfare, which could either intensify, weaken, or reverse the static welfare effects of policy changes. Baldwin and Robert-Nicoud (2008) (BRN hereafter) first set up a model of trade and growth with heterogeneous firms by combining

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1) For reviews of theoretical and empirical applications of the Melitz model, see Melitz and Redding (2014), Head and Mayer (2014), and Costinot and Rodriguez-Clare (2014), all of which are included in the latest Volume 4 of Handbook of International Economics.
Melitz (2003) with the Rivera-Batiz and Romer (1991) model of endogenous technological change, and find that trade liberalization may not raise long-run growth because trade-induced selection makes it harder for a potential entrant to survive in its domestic market. However, the literature on trade and growth with heterogeneous firms since BRN depends on one assumption: all countries are symmetric. Not only is it unrealistic, it also prevents us from studying the effects of asymmetric trade policies such as unilateral trade liberalization, optimal tariffs, regional trade agreements (RTAs), and so on. How can we formulate a model of trade and growth with heterogeneous firms and asymmetric countries? The purpose of this paper is to propose two ways to do it based on the author’s recent research.

Considering that this paper aims to be more of a review than an original article, its tone is not as technical as typical theory papers, but as intuitive as good undergraduate textbooks. In particular, we focus on the effects of policy shocks on countries’ productivity cutoffs, above which firms profitably enter markets. In Melitz-based models, the movements of those cutoffs provide much (and often just enough) information about countries’ welfare and growth. We first see how the cutoffs are determined under symmetric countries, and then how they are additionally affected by endogenous factor prices under asymmetric countries. If readers are interested in technical details, they are advised to read Naito (2017a, 2017b, 2019), all of which are open access.

The rest of this paper is organized as follows. Section 2 introduces the Melitz model with two symmetric countries. Section 3 reviews the BRN and related endogenous growth models. Sections 4 and 5 provide two solutions to deal with asymmetric countries in Melitz-based endogenous growth models. Section 6 concludes.

2 The Melitz model

We quickly review the Melitz (2003) model, which incorporates heterogeneous firms a la Hopenhayn (1992a, b) into the Krugman (1980) model of monopolistic competition with CES (constant elasticity of substitution) preferences. The world has two symmetric countries \((i=1, 2)\), each of which has a continuum of differentiated goods and one factor called labor. Both fixed and variable production costs are paid in labor. Let country 2’s labor be the numeraire. Under symmetric countries, the relative wage of country 1 to 2 is fixed at unity, although we will have to endogenize it under asymmetric countries.1

A potential entrant faces two types of fixed costs, namely the entry and overhead costs. After an entrant pays the fixed entry cost, its labor productivity \(\phi\) is determined randomly. If the entrant’s profit in market \(j (=1,2)\) net of the market-specific fixed overhead cost is nonnegative at the realized productivity, then it sells to market \(j\); otherwise, it neither pays the fixed overhead cost nor sells to market \(j\). This is different from the Krugman model, where productivity is nonrandom and the same across firms, and there are no fixed overhead costs.

To characterize an equilibrium, we have two types of equations: the zero cutoff profit (ZCP) and free entry (FE) conditions. The ZCP condition states that country \(i\)’s net profit in

1) One popular way to fix the relative wage even under asymmetric countries is to consider a homogeneous good sector subject to constant returns to scale (e.g., Helpman et al., 2004; Melitz and Ottaviano, 2008). A theoretical drawback of this method is to ignore general equilibrium effects of policy changes, which could often reverse partial equilibrium effects. We will see this point later.
market $j$ is zero at the cutoff productivity $\phi_j$. The profit is positive for $\phi > \phi_j$, whereas it is zero for $\phi \leq \phi_j$. The FE condition requires that the sum of the expected net profits over all markets is equal to the fixed entry cost. Due to the fixed and variable trade costs, where the latter is often expressed in an iceberg form (i.e., $\tau_{ij} (> 1)$ units must be shipped from country $i$ to deliver one unit to country $j (\neq i)$), country $i$’s productivity cutoff for exports $\phi_i$ is usually larger than that for domestic sales $\phi_i$. This means that only the most productive part of domestic surviving firms can also export.

In Figure 1, there are two horizontal lines measuring productivity $\phi$, the top and bottom lines for countries 1 and 2, respectively. By symmetry, we have only to look at the top line for country 1. The left and right vertical lines represent $\phi_{11}$ and $\phi_{12}$, country 1’s domestic and export cutoffs, respectively. The least productive firms with $\phi < \phi_{11}$ cannot profitably enter any market. For firms with $\phi_{11} \leq \phi$, mediocre ones with $\phi_{11} \leq \phi < \phi_{12}$ enter only domestic market, whereas the most productive ones with $\phi_{12} \leq \phi$ enter export as well as domestic markets.

Starting from the situation described in Figure 1, suppose that country 2’s iceberg trade cost for imports $\tau_{12}$ are reduced at the same rate as country 1’s. Figure 2 summarizes what is going on. From the ZCP condition for exports, country 1’s export cutoff decreases from $\phi_{12}$ (as indicated by the right vertical dashed line) to $\phi_{12}' (< \phi_{12})$, meaning that more firms enter their export market 2. From the FE condition, the resulting increase in country 1’s expected net profit from exports must be compensated by a decrease in its expected net profit from domestic sales. This implies that, from the ZCP condition for domestic sales, country 1’s domestic cutoff increases from $\phi_{11}$ (as indicated by the left vertical dashed line) to $\phi_{11}' (> \phi_{11})$, that is, more firms exit from their domestic market. Consequently, country 1’s average productivity of domestic surviving firms increases, which increases its real wage in terms of a composite of differentiated goods as its welfare measure.

The above exercise reveals that selection (i.e., exit) of unproductive firms as a result of

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3) Precisely speaking, in Melitz (2003) the FE condition states that the sum of the expected net present values of future profits over all markets is equal to the fixed entry cost paid only once at the time of entry. However, since there is no intertemporal choice, his seemingly dynamic formulation is technically equivalent to our static formulation.

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Figure 1: Market entry status in terms of productivity: symmetric countries.
reallocations across heterogeneous firms is the third source of gains from trade, in addition to comparative advantage (as in the Ricardian and Heckscher–Ohlin models) and love of variety (as in the Krugman model)\(^4\). In the next section, we introduce the BRN model that adds endogenous growth to the Melitz model.

3 Trade and growth with heterogeneous firms and symmetric countries

BRN incorporates the Melitz-type heterogeneous firm framework into the Rivera–Batiz and Romer (1991) model of endogenous technological change, the most popular model of trade and endogenous growth. One major difference from Melitz (2003) is that the fixed entry and overhead costs are paid in the “knowledge good” produced in the R&D sector\(^5\). Rivera–Batiz and Romer (1991) consider two specifications for R&D, namely the knowledge-driven and lab-equipment specifications. Labor and public knowledge are used in the former, whereas a composite of differentiated goods is used in the latter. BRN tries five R&D specifications, of which one is the lab-equipment specification and two (i.e., the Grossman–Helpman and Coe–Helpman specifications) are in a class of the knowledge-driven specification\(^6\). Another difference is that both fixed entry and overhead costs are paid only once at the time of entry. This implies that those fixed costs are compared with the present values of

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\(^4\) Gains from selection are not necessarily “additional” gains from trade compared with gains from variety. Arkolakis et al. (2012) show that gains from trade in the Melitz model with a Pareto distribution for productivity is quantitatively the same as those in the CES Krugman model, as long as country \(j\)’s “elasticity of trade” (i.e., the elasticity of country \(j\)’s expenditure for country \(l(\neq j)\)’s varieties, relative to country \(j\)’s expenditure for domestic varieties, with respect to country \(j\)’s import trade cost) is estimated from each theory-based gravity equation.

\(^5\) BRN calls the good just “knowledge”. However, to distinguish it from the stock of knowledge represented by the existing numbers of varieties, we call it the “knowledge good”.

\(^6\) Under the Grossman–Helpman specification, country \(i\)’s unit labor requirement for R&D is inversely proportional to \(n_i + \psi_i n_{ij}\), where \(n_i\) is country \(i\)’s number of domestic varieties, and \(\psi_i\) is the country \(i\)’s coefficient of international knowledge spillovers, which is exogenously given. Under the Coe–Helpman specification, \(\psi_i\) is increasing in country \(j(\neq i)\)’s fraction of exporters in its domestic surviving firms with the elasticity of one.
future profits.

Focusing on a balanced growth path (BGP), where all variables grow at constant (including zero) rates, BRN shows that the balanced growth rate (i.e., countries’ common long-run growth rate of domestic varieties) is inversely related to the product of $p^K_i$ and $κ_i$, the price of the knowledge good in terms of labor normalizing the negative price effect of variety growth, and the expected total fixed costs in terms of the knowledge good conditional on domestic survival, respectively. The “$p^K_i$–channel” is present even without heterogeneous firms, whereas the “$κ_i$–channel” appears only with heterogeneous firms.

Symmetric trade liberalization decreases countries’ export cutoffs $ϕ_{ij}$ but increases their domestic cutoffs $ϕ_{ii}$ in the same way as the previous section and Figure 27). These cutoff changes affect the balanced growth rate through the two channels mentioned above. On the one hand, they increase $κ_i$ by making it less likely for country $i$’s potential entrant to survive domestically. On the other hand, they typically decrease the cost and hence the price of the knowledge good $p^K_i$. The total long-run growth effect of symmetric trade liberalization depends on the R&D specifications. Under the knowledge–driven specification (including the Grossman-Helpman and Coe-Helpman specifications), the $p^K_i$–channel is weaker than the $κ_i$–channel, thereby decreasing the balanced growth rate. Under the lab–equipment specification, the $p^K_i$–channel outweighs the $κ_i$–channel, so that the balanced growth rate increases.

Since BRN, there has been many papers on Melitz–based endogenous growth models. Dinopoulos and Unel (2011) express firm heterogeneity in terms of quality instead of productivity. Perla et al. (2019) consider costly technology adoption as the engine of growth. Sampson (2016) assumes that an entrant learns from the average productivity of heterogeneous incumbent firms. Fukuda (2016) reconsiders BRN’s long–run growth effect of trade liberalization under an alternative assumption that the fixed overhead cost for exports is smaller than that for domestic sales. Ourens (2016) corrects BRN’s long–run welfare analysis. Haruyama and Zhao (2017) embed firm heterogeneity in a Schumpeterian growth model featuring creative destruction. Fukuda (forthcoming) adds to BRN publicly provided basic research increasing the productivity of applied research.

All papers mentioned in the previous paragraph share one assumption in common: symmetric countries. Despite being unrealistic, it is useful in highlighting the sources of trade gains other than comparative advantage. However, the assumption is problematic when it comes to analyzing trade policies that are often asymmetric across countries. For example, a country’s optimal tariff cannot be calculated without taking other countries’ tariffs as given. Also, an RTA necessarily discriminates between its member and nonmember countries in terms of tariffs. To study the effects of asymmetric trade policies, we have to depart from the convenient assumption.

It is much harder than one might think to allow for asymmetric countries in models of trade and growth with heterogeneous firms. The difficulty is to evaluate an entrant’s future profits possibly growing at different rates across countries and over time during the transition. There are two solutions to resolve this problem. The first solution, taken by Naito

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7) In fact, BRN expresses firm heterogeneity in terms of the unit labor requirement for production. However, since the unit labor requirement is just the inverse of the productivity of labor, it does not matter which formulation is used. To be consistent with the original Melitz model, we use the productivity formulation throughout.
(2017a), is to give up firms’ infinite horizon. Specifically, by assuming that each firm’s product life ends in each period, we can formulate a model simple enough to describe transitional dynamics. The second solution, adopted by Naito (2017b), is to give up transitional dynamics. By focusing on a BGP, we can still calculate the present values of future profits over an infinite horizon even with asymmetric countries. In the next two sections, we look at each solution in turn.

4 Introducing asymmetric countries I: without infinite horizon, with transitional dynamics

To incorporate endogenous growth and asymmetric countries into the Melitz model, Naito (2017a) takes a completely different approach from BRN by assuming that firms make static decisions. Extension of the Melitz model to allow for asymmetric countries and endogenous relative wage is successfully done by Felbermayr et al. (2013) and Demidova and Rodríguez-Clare (2013)\(^8\). Naito (2017a) replaces labor in their asymmetric Melitz models with capital, which is accumulated using a composite of differentiated goods as in Acemoglu and Ventura (2002)\(^9\). Another trick is to assume that each country’s fixed entry and overhead costs are proportional to its GDP. This balances out those fixed costs and the country’s gross profits, which also grow proportionally with its GDP. In this model, the short-run equilibrium given capital stocks is the same as that in the static asymmetric Melitz models of Felbermayr et al. (2013) and Demidova and Rodriguez-Clare (2013), but it translates into countries’ growth rates of capital in each period. On a BGP, all countries’ capital stocks grow at a common balanced growth rate. Just as an increase in a country’s domestic productivity cutoff implies its higher welfare in the original Melitz model, we can show that each country’s growth rate of capital in each period increases if and only if its domestic productivity cutoff increases in that period.

Let country 2’s capital be the numeraire. Suppose that the world economy is originally on a BGP, for example a symmetric BGP as described in Figure 1, and that only country 1 permanently reduces its import trade cost \(\tau_{21}\). We first see its short-run effects on cutoffs, with the relative supply of capital of country 1 to 2 given. Figure 3 shows its partial equilibrium effects, with the relative rental rate of country 1 to 2 given. On the bottom line for country 2, a decrease in \(\tau_{21}\) directly allows more firms in country 2 to start exporting (i.e., decreases country 2’s export cutoff from \(\phi_{21}\) (as indicated by the right vertical dashed line) to \(\phi'_{21}(<\phi_{21})\)), which drives more firms out of their domestic market (i.e., increases country 2’s domestic cutoff from \(\phi_{22}\) (as indicated by the left vertical dashed line) to \(\phi'_{22}(>\phi_{22})\)). Then on the top line for country 1, competing with country 2’s more productive domestic surviving firms, less firms from country 1 survive in their export market (i.e., country 1’s export cutoff increases from \(\phi_{12}\) (as indicated by the right vertical dashed line) to \(\phi'_{12}(>\phi_{12})\)). This keeps more firms staying at their domestic market (i.e., decreases country 1’s domestic cutoff from \(\phi_{11}\) (as indicated by the left vertical dashed line) to \(\phi'_{11}(<\phi_{11})\)). To sum up, country 1’s unilateral trade liberal-

\(^8\) Felbermayr et al. (2013) use their asymmetric Melitz model to characterize countries’ optimal tariffs. Demidova and Rodríguez-Clare (2013) go on to express a small country as a limiting case.

\(^9\) The assumption of one-period product life is inconsistent with the R&D–based growth models, where firms have either infinite or finite but long-term horizon in making their R&D decisions. This is why we consider capital accumulation as the engine of growth.
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In fact, the relative rental rate changes to satisfy countries’ balances of trade. As explained above, a decrease in $\tau_{21}$ causes country 1 to run a trade deficit. For the deficit to be cleared, country 1’s capital should become relatively cheaper. Then exporters from country 1 become more competitive relative to country 2’s domestic firms, whereas those from country 2 become less competitive relative to country 1’s domestic firms. As a result of the general equilibrium effects, all cutoffs move in the opposite directions of the partial equilibrium effects. In Figure 4, compared with Figure 3, we have $\varphi_{21}^{\ast} > \varphi_{11}^{\ast}$, $\varphi_{22}^{\ast} < \varphi_{12}^{\ast}$, $\varphi_{21}^{\ast} < \varphi_{11}^{\ast}$, $\varphi_{22}^{\ast} > \varphi_{12}^{\ast}$ (as indicated by the movements from the four vertical dotted to solid lines). Then how are the total (i.e., sum of partial and general equilibrium) short-run effects, compared with the old BGP (as indicated by the four vertical dashed lines)? We can generally show that the direct, partial equilibrium effects are stronger than the indirect, general equilibrium effects for the partner country 2 (i.e., $\varphi_{21}^{\ast} < \varphi_{21}^{\ast}$, $\varphi_{22}^{\ast} > \varphi_{22}^{\ast}$), whereas the opposite is true for the liberalizing country 1 (i.e., $\varphi_{12}^{\ast} < \varphi_{12}^{\ast}$, $\varphi_{11}^{\ast} > \varphi_{11}^{\ast}$). Interestingly, the total short-run effects of unilateral trade liberalization on cutoffs are qualitatively the same as symmetric trade liberalization in symmetric Melitz models. Consequently, both countries start to grow faster than the old BGP in the short run.

In the long run, capital stocks are adjusted to equalize countries’ growth rates. Suppose that a decrease in $\tau_{21}$ increases country 1’s growth rate by more than country 2’s in the short run (in the opposite case, we can apply the same logic, with countries 1 and 2 interchanged). Since this increases country 1’s fixed costs that are assumed to be proportional to its GDP by more than country 2’s, exporters from country 1 become relatively less competitive, whereas those from country 2 become relatively more competitive. This causes less domestic selection and hence slower growth for country 1, but more domestic selection and thus faster growth for country 2, compared with the short-run equilibrium. Such adjustment process continues until countries’ growth rates are equalized at the new BGP, where the new balanced growth rate lies between countries’ short-run growth rates, which are higher than the old balanced growth rate. Therefore, a permanent decrease in a country’s import trade cost increases the growth rates of all countries for all periods, compared with the old BGP. Finally, since all

![Figure 3: The effect of 1’s unilateral liberalization on entry status: partial equilibrium.](image)
countries grow faster than the old BGP for all periods, the path of consumption is higher than the old BGP for all countries for all periods, implying that a permanent decrease in a country’s import trade cost increases the welfare of all countries.

A benefit of Naito (2017a) is that we can study the transitional dynamics caused by asymmetric trade policies. In particular, in the two-country case, we analytically obtain the above strong results about the growth and welfare effects of unilateral trade liberalization. However, the benefit is gained at the cost of oversimplification: each firm’s product life ends in each period. In the next section, we set up another asymmetric Melitz model of trade and growth while keeping firms’ infinite horizon.

5 Introducing asymmetric countries II: without transitional dynamics, with infinite horizon

Naito (2017b) allows for asymmetric countries in the BRN model only under the knowledge-driven specification for R&D. Specifically, he generalizes BRN’s Coe–Helpman specification by allowing the elasticity of each country’s coefficient of international knowledge spillovers to be different from one (corresponding to the Coe–Helpman specification) or zero (corresponding to the Grossman–Helpman specification). By focusing on a BGP, he shows that the effects of changes in trade costs on cutoffs can be examined in the same way as Naito (2017a). The relative wage of country 1 to 2 is determined by the balanced trade condition (i.e., a country’s value of exports is equal to its value of imports), whereas the relative number of domestic varieties of country 1 to 2 is determined by the balanced growth condition (i.e., countries’ numbers of domestic varieties grow at the same rate).

With the relative number of domestic varieties given, the effects of a permanent decrease in country 1’s import trade cost $\tau_{21}$ on cutoffs are qualitatively the same as its short-run effects in Naito (2017a): because of the general equilibrium effects through a decrease in country 1’s relative wage, country 1’s unilateral trade liberalization causes more exports and more domestic selection in both the partner and liberalizing countries. However, the cutoff changes have
opposing effects on countries’ growth rates of domestic varieties as explained in section 3: they increase $\kappa_i$ but decrease $p^k_i / w_i$. Although the $p^k_i / w_i$ -channel is always weaker than the $\kappa_i$ -channel under both the Grossman-Helpman and Coe-Helpman specifications of the symmetric BRN model, the $p^k_i / w_i$ -channel is stronger than the $\kappa_i$ -channel under the generalized Coe-Helpman specification if the elasticity of each country’s coefficient of international knowledge spillovers is sufficiently large (typically larger than unity). In this case, country 1’s unilateral trade liberalization can increase countries’ growth rates. Then, even if the relative number of domestic varieties is adjusted, the new balanced growth rate is higher than the old one.

Naito (2019) does a follow-up study of Naito (2017b) by replacing the knowledge-driven specification with the lab-equipment specification. Things become more complicated because each country’s price of the knowledge good is equal to its price of the composite final good, which includes more variables than its R&D unit labor requirement function under the knowledge-driven specification. In spite of that, he shows that country 1’s unilateral trade liberalization always increases the balanced growth rate. There are two reasons for this result. First, the $\kappa_i$ -channel is offset by a part of the $p^k_i / w_i$ -channel. Second, since each country’s price of the knowledge good is equal to its price of the composite final good, $p^k_i / w_i$ is inversely proportional to country i’s real wage in terms of its final good, which in turn is increasing in its domestic productivity cutoff as in static Melitz models. A permanent decrease in $\tau_{21}$ causes more exports and more domestic selection in both countries just like Naito (2017b). Since this increases each country’s real wage in terms of its final good, its $p^k_i / w_i$ decreases, contributing to its faster growth.

6 Concluding remarks

This review paper provides two methods to extend the Melitz model to include both endogenous growth and asymmetric countries. In considering asymmetric countries, it is vital not to overlook general equilibrium effects through endogenous factor prices. As revealed in Figures 3 and 4, the effects of asymmetric policy changes on countries’ productivity cutoffs are quite asymmetric before factor prices change, but they tend to be qualitatively symmetric after that. Even in complicated trade models with heterogeneous firms, endogenous growth, and asymmetric countries, it is not so difficult to determine factor prices: just look at countries’ trade balances.

The baseline models of Naito (2017a, 2017b, 2019) can be applied to a variety of asymmetric trade policies. One example is Naito (2018) for an RTA. It is well known that, in a wide class of static three-country general equilibrium trade models, an RTA between countries 1 and 2 usually increases their internal exports and welfare (i.e., trade creation), but decreases country 3’s exports to the RTA members and its welfare (i.e., trade diversion). However, Baldwin (2011) points out that some empirical papers find “reverse trade diversion”, a phenomenon that nonmember countries also export more to member countries. By extending Naito (2017a) to include three countries, Naito (2018) finds the possibility of reverse trade diversion in terms

10) In the present model with asymmetric countries, country i’s normalized price of the knowledge good in terms of labor is expressed by dividing $p^k_i$ by $w_i$, which is not necessarily equal to unity.
of revenue shares in the long run. Of course, the applications are not limited to trade policies. Readers can use the models developed so far to examine how policies of their interest, whether symmetric or asymmetric, affect countries’ welfare through reallocations across heterogeneous firms and economic growth.

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