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Gao, Xiang

Iowa State University

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Xiang Gao*

Iowa State University

gapt@iastate.edu

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Abstract

This paper reviews the branch of literature that applies models developed in international trade theory (Microeconomics) to explain phenomena found in international finance (Macroeconomics). Among all international trade models, the New New Trade Theory with productivity heterogeneity across firms in the same industry has proved to be a powerful tool to bridge the gap between international trade and finance. As a result, this review focuses on several papers in this nascent field, where the behavior of macroeconomic indicators are generated from sound microeconomic foundation.

Keywords: Heterogeneous firm, Price fluctuation, Innovation.

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Address for correspondence: Department of Economics, 477 Heady Hall, Iowa State University, Ames IA 50011. E-mail: gapt@iastate.edu.

1 Introduction

This paper reviews the branch of literature that applies tools developed in international trade theory to the area of open macroeconomics. The contribution of this branch has been focused on attempts to bridge the gap between international trade and international macro by giving precise micro-foundations to international macro phenomena. This is challenging because trade models, which have so far abstracted from short-run business cycle fluctuations on prices and quantities, are dedicated to address the question why in the long-run countries engage in the exchange of goods.

The methods of introducing dynamics into static trade equilibrium vary with different types of trade models. The first major shift in the frontier of international trade theory can be marked since the 80s when then-prevailing traditional trade theory represented by the Ricardian and Heckscher-Ohlin (henceforth H-O) models give way to the New Trade Theory advocated by Krugman and Helpman. The previous shift was from theories grounded in comparative advantage in terms of differences in sector-specific input requirements and endowment of production factors under perfect competition to those that explain intra-industry trade accompanied by product differentiation under monopolistic competition. In comparison, New New Trade Theory, which is emerging in the latest shift, is characterized by the focus on intra-industry heterogeneity (differences observable even among firms belonging to the same sector). New New Trade Theory feature can be analyzed in both New Trade Theory framework as in Melitz (2003) and traditional trade theory framework as in Bernard, Eaton, Jensen and Kortum (2003). Whereas the earlier two lines of trade theory (traditional and New) have a commonality in that they depend on the industry as a unit of analysis, the New New Trade Theory examines firm-level variations in productivity. Scholars in the New New Trade Theory model a situation in which a limited number of exporting firms and firms not engaged in global activities coexist within a single industry accompanied by their considerable productivity gaps.

In traditional trade theory, allowing key production factor to accumulate over time (capital accumulation through investment or labor knowledge evolvement and spillover) would extend traditional trade models to their dynamic versions. They do provide some insight on the aggregate productivity growth, but they are incapable of explaining short term macroeconomic fluctuations. Two papers of this kind are briefly mentioned in section 3.1. New New Trade Theory models overcome this obstacle by introducing business cycle productivity shocks at the country level, and they can further study long term technological progress as in dynamic traditional trade models by adding costly innovation.

In the New New Trade Theory models built on New Trade Theory framework, countries are populated by consumers with identical CES preference are ex-ante identical, but they still trade for differentiated goods produced by heterogeneous firms with increasing returns to scale. All goods are substitutes to each other, but are not exactly alike. This means the market structure is monopolistically competitive, where many competing firms sell goods that are differentiated from one another. Researchers add business cycle productivity shock at the country level in this class of microeconomic models, and thus study aggregate international relative price as well as exchange rate fluctuation. Further, innovation option is introduced into this kind of models and this new feature induces studies on aggregate productivity growth over time. Section 2 reviews the development of adding another "New" to New Trade Theory in the introductory remarks, and most importantly discusses in detail research papers that analyze open macroeconomic issues on the basis of New New Trade Theory.

Another rising strand of research merges traditional trade theory with heterogeneous productivity characteristic from the New New Trade Theory, and researchers develop a competing class of models comparing to ones based on New Trade Theory. In typical New Trade Theory models, the world consists of two countries with heterogeneous firms producing in each country and exporting to the other. Similarly in the competing models, the world is populated by many countries with heterogeneous productivity in the same fixed basket of goods. The economy structures are alike in the two classifications of models except for how firms or countries compete. Monopolistic competition in the New Trade Theory models is replaced with the case of perfect competition in Eaton and Kortum (2002) or Bertrand competition in Bernard, Eaton, Jensen and Kortum (2003). In section 3.2, I put more efforts on reviewing papers that merge New New Trade Theory thoughts with tradition trade models, especially the Ricardian model.

Written in the style of a literature review, the aim of this term paper is to provide ideas for creative works which will eventually become the second essay of my dissertation. My third year paper on private borrowing and lending with default risk within and across border serves as the first part.

2 New (New) Trade Theory

The so called New Trade Theory importantly departs from the traditional trade theory in the fact that trading countries are ex-ante identical and atomistic firms are responsible for producing and exporting a unique variety of goods. Iso-elastic preferences, monopolistic competition with differentiated substitutes and increasing return to scale due to fixed export cost are three crucial ingredients for models of this kind. In

Krugman (1980) and in a later extension by Krugman and Helpman (1985)[1], consumers have a preference for variety and firms have identical productivity so that they all export if overhead cost f^X for exporting is low enough. Giving up autarky for trade is good because consumers get access to a wider range of differentiated goods. There also exists transportation cost, which means that one unit of good shipped abroad arrives only a fraction $\frac{1}{\tau}$, where $\tau > 0$. When trade costs (either variable transportation cost τ or fixed overhead cost) go down, each exporter increases the volume of its exports, which is known as the *intensive margin* of trade. All varieties are traded in Krugman's model, which contradicts with the observation that only a subset of firms (varieties) actually trade internationally.

New New Trade Theory emerges to correct this shortcoming, Melitz (2003) combines Hopenhayn's (1992) model of heterogeneous firms in closed economy with krugman's theory. By doing this, he can account for the stylized fact in trade data that firms widely differ in terms of size, productivity and exporting decisions. Opening up to trade induces not only a boom in varieties but also an increase in aggregate productivity through a more efficient reallocation of labor. The existence of fixed overhead export cost and heterogeneity in productivity implies that only a subset of firms enter exporting markets. When trade barrier moves downward, besides consumers' gain in intensive margin, they also enjoy an enlargement of the set of exporters, which is referred as the *extensive margin* of trade. The mark-ups are constant in both Krugman's (1980) and Melitz's (2003) model, which is not realistic since firms do change mark-up in response to variations in marginal costs.

To refine the approach, quite a few studies try to account for an endogenous determination of mark-ups. Melitz and Ottaviano (2008) replaced CES utility in Melitz's model with preferences developed in Ottaviano, Tabuchi and Thisse (2002), which gives a linear demand system. Bernard, Eaton, Jensen and Kortum (2003) instead keep the CES preferences assumption, but remove the monopolistic competition assumption and replace it with the case of Bertrand competition in each industry. In addition to intensive and extensive margin, there is another layer of benefits with endogenous mark-ups even for less extreme movements of trade barriers other than going from autarky to trade. Prices consumer pay will decrease since mark-ups charged by firms will endogenously go down when trade barriers moves down. In their models, heterogeneity in productivity, even in the absence of fixed trade barriers, leads to an endogenous selection

[1] Helpman and Krugman (1985) extend Krugman (1980) to a two sector model, one sector is a homogeneous good that is produced under constant returns to scale technology and is freely traded, and the other corresponds to a continuum of differentiated varieties, that are subject to both variable and fixed costs. Provided this homogeneous good is produced in every country, the wage will be constant and equal to 1 in every country.

of firms into the export market.

In melitz's (2003) model, free entry condition brings in new varieties whenever new firms enter domestic market and start producing. The innovation to create new firms (varieties) is thus called *product innovation*. However, firms have to either live with their initial productivity draw forever or exit the market after they enter the market. Several studies offer individual firms the opportunity of *process innovation*, and investigate how trade liberalization affect endogenous selection into exporting, innovation decisions and, consequently, aggregate growth. Process innovation refers to investment designed to reduce marginal cost, thereby making the firm more productive. Costantini and Melitz (2008) introduce a one-time binary technological upgrading choice that raises the likelihood that the firm will realize higher levels of productivity in future. They then examine the transition dynamics between two steady states from high to low trade costs, and find that productivity effects depend on whether liberalization is anticipated and on how quickly it is implemented. Atkeson and Burstein (2009) introduces innovation as both a continuous process and a continuous choice, and show that a reduction in trade costs exerts a positive effect on process innovation over time, which can be offset by negative effects on product innovation. Impullitti and Licandro (2009) build on endogenous mark-up models with oligopoly competition, and studies how trade barrier movements affect both firm selection and innovation through the competition channel. Baldwin and Robert-Nicoud (2008) explore the effects of trade liberalization on innovation and growth in models of expanding variety (Romer, 1990) with heterogeneous firms. They show that a reduction in trade barriers can increase or decrease growth depending on the form of knowledge spillovers in a separate innovation sector.

All the above basic models and their extensions in New New Trade Theory play key roles in explaining long term fluctuations (specialization of goods production) in aggregate trade flows, especially the intra industry trade flows. In the main body of this section, I review papers which use new trade theoretical tools to study much shorter term fluctuations, for instance, price adjustment. I will mainly focus on three papers: Ghironi and Melitz (2005), Atkeson and Burstein (2008), and Atkeson and Burstein (2009). The first two papers will be discussed in section 2.1 and 2.2 in detail, then a simplified version of Atkeson and Burstein (2009) paper and their most important results are presented in section 2.3. Traditional theory attributes fluctuations in real exchange rates to changes in the relative price of goods in exogenously nontraded industries. Ghironi and Melitz (2005) utilize the original Melitz's (2003) heterogeneous firm model to make the nontraded industries endgenous, which enables them to explain exchange rate volatility in response to productivity shocks hitting all sectors within the country.[2] Atkeson and Burstein's (2008) model is built on the second generation of Melitz's (2003) model with endogenous mark-up. They go further by dissecting exchange rates into different international relative price indices and deriving co-moving relations between them. Their results match the empirical data well in a calibrated model. International trade models with heterogeneous firms alone or heterogeneity plus oligopoly competition help to generate endogenously persistent deviations from Purchasing Power Parity under productivity shock in open macroeconomics. Atkeson and Burstein (2009) offer one-step process innovation option to individual firms in Melitz's (2003) model, which enables them to explore the aggregate growth aspect in dynamic macroeconomics under the impacts of trade liberalization.

There are other studies that use heterogeneous firm model to macroeconomic fields. For example, Bilbiie, Ghironi and Melitz (2007) apply the model to investigate real business cycle transmission with an endogenous determination of the number of producers over the business cycle. Their framework predicts a pro-cyclical number of producers and pro-cyclical profits even for preference specifications that imply countercyclical markups.

2.1 International Relative Price Fluctuations

Ghironi and Melitz (2005, henceforth GM) apply the New New Trade theoretical tools in Melitz's (2003, henceforth M) model to provide a microeconomic foundation for real exchange rate behaviors in international macroeconomics. Empirical finding states that economies with higher GDP per capita (or higher productivity) have higher prices. The fact behind that empirical result is probably that real exchange rate could be affected by productivity shocks, referred as the Harrod-Balassa-Samuelson effect (henceforth HBS effect). Traditional explanation for HBS effect is provided by Balassa and Samuelson who introduce an exogenous non-traded sector. If the tradable sector in a country experiences productivity growth, then the relative price of non tradable goods will rise, so that the aggregate price index in this economy will rise thus consumption based real exchange rate (This notion is defined in equation (1) below) decreases. In the GM dynamic model of trade, aggregate HBS effect is generated through endogenous exporting decisions by heterogeneous firm. The central result of GM is that a permanent increase in productivity results in a higher aggregate price index and a lower consumption based real exchange rate in the country that experiences such higher productivity relative to its trading partners.

[2] In traditional theory, productivity shocks are not country wide, instead they are restricted in nontraded sectors to induce changes in the relative price of nontraded goods.

The basic unit is dollar in M model while in GM everything is expressed in units of home consumption goods. In this paper, I change all the symbols and units in M model to corresponding ones in GM model since it is much easier to compare the two models with consistent notations. All cost incurred are measured in origin country's currency. Firms in both models have to pay a fixed entry cost f_t^E in exchange for a productivity draw. f_t^E is sunk after new firms enter the market. The first difference between these two models is that firms selling domestically in M have to pay a period-by-period fixed cost while firms in GM face no fixed cost when serving domestic market, namely, $f_t^D = 0$.[3] Regardless the different treatment in domestic production cost, both models require exporting firms to pay an extra cost f_t^X every period besides the melting-iceberg cost τ. All kinds of cost are given in effective labor so that we have to transform them into home consumption goods before using. There exists a basket of differentiated goods Ω, and each variety is denoted by $\omega \in \Omega$. $c(\omega)$ is a representative agent's consumption of goods ω, and C denotes the aggregate consumption of a basket of goods. At time t, aggregate consumption

$$C_t = \left(\int_{\omega \in \Omega_t} c_t(\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}}.$$

One can think of C_t as the period t utility from consuming all varieties, and θ is consequently the elasticity of substitution between differentiated goods. θ is identical across the world. The life time utility, especially in GM, is

$$U = E_0 \left[\sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\gamma}}{1-\gamma} \right],$$

where γ is the inverse of inter-temporal elasticity of substitution. For each variety ω, demand function is thus

$$c_t(\omega) = \left(\frac{p_t(\omega)}{P_t} \right)^{-\theta} C_t,$$

where $p_t(\omega)$ is the home currency price for ω and P_t is aggregate price index. Single price and aggregate price index are connected through the relationship below

$$P_t = \left(\int_{\omega \in \Omega_t} p_t(\omega)^{1-\theta} d\omega \right)^{\frac{1}{1-\theta}}.$$

Define, separately, the expenditure $r_t(\omega)$ on each variety ω and total expenditure R_t on the consumption

[3] Any firm in GM, no matter how unproductive it is, will always produce domestically, and will only die of exogenous death. This assumption assumes away the endogenous dynamics in total commodity set when Ghironi and Melitz introduce country specific productivity shocks.

basket as

$$r_t(\omega) = p_t(\omega)c_t(\omega);$$
$$R_t = P_tC_t.$$

Production function is linear and labor is the only input,

$$q_t = zZ_tl_t - f_t^D,$$

where a new entrant firm's productivity draw is denoted by z.

Countries in the M model are identical while GM model considers the case of asymmetry, where countries differ not only in population but also in aggregate labor productivity. The second additional feature Ghironi and Melitz add into M model is thus Z_t, the country-specific aggregate labor productivity, through which asymmetric shocks at national level can be later introduced. One can think of GM model as a generalized version of M model, in which Z_t is the same as Z_t^* and both of them equal to 1 in home and foreign countries.[4] L (L^*) is the mass of domestic (foreign) workers. Let W (W^*) be the domestic (foreign) nominal wage, and define $w_t = \frac{W_t}{P_t}$ the real wage in home country. In M, home country nominal wage W is normalized to 1 since only symmetric equilibria are considered, and then there is no role for relative wages adjustment. However, in GM relative wage is the channel through which international relative price is affected by productivity shocks.

Q_t is the consumption based real exchange rate (units of home consumption per unit of foreign consumption) relying on ideal price indices P_t and P_t^*

$$Q_t = \varepsilon_t \frac{P_t^*}{P_t}, \tag{1}$$

where ε_t is the nominal exchange rate (units of home currency per unit of foreign currency). Ghironi and Melitz use another consumption based real exchange rate depending on real price indices $\widetilde{P}_t$ and $\widetilde{P}_t^*$ to explain their results.

$$\widetilde{Q}_t = \varepsilon_t \frac{\widetilde{P}_t^*}{\widetilde{P}_t},$$

where $P_t = N_t^{\frac{1}{1-\theta}}\widetilde{P}_t$, $P_t^* = {N_t^*}^{\frac{1}{1-\theta}}\widetilde{P}_t^*$ and N_t (N_t^*) denotes the number of firms producing at home (foreign) country in equilibrium. Intuitively, $\widetilde{Q}_t$ is the real exchange rate after getting rid of the dynamic impact from goods variety set on ideal price indices. If we use the ideal price index to investigate the response of exchange

[4] The supercript star $*$ means the same concept in foreign country in the rest of this section.

rate on shock, then the increased availability of domestic varieties at home would unambiguously dominate the increase in average prices, so that the domestic ideal price index would decrease relative to the foreign one given there is a positive productivity shock at home.

Consider a firm with idiosyncratic labor productivity z operating in the domestic market. In M model's closed economy, the firm in focus would set price at

$$\begin{cases} p^D(z) = \frac{\theta}{\theta-1}\frac{W}{z} = \frac{\theta}{\theta-1}\frac{1}{z} \text{ in home currency;} \\ \rho^D(z) = \frac{p^D(z)}{P} = \frac{\theta}{\theta-1}\frac{1}{zP} \text{ in home consumption goods,} \end{cases}$$

and its corresponding net profit is

$$\begin{cases} \pi^D(z) = \frac{1}{\theta}\left[p^D(z)/P\right]^{1-\theta} PC - f^D \text{ in home currency;} \\ d^D(z) = \frac{1}{\theta}\left[\rho^D(z)\right]^{1-\theta} C - \frac{f^D}{P} \text{ in home consumption goods.} \end{cases}$$

In GM model, since $f^D = 0$ and time denoted by t matters now. The similar definitions for price and profit are, respectively,

$$\begin{cases} p_t^D(z) = \frac{\theta}{\theta-1}\frac{W_t}{Z_t z} \text{ in home currency;} \\ \rho_t^D(z) = \frac{p_t^D(z)}{P_t} = \frac{W_t}{\rho Z_t z P_t} = \frac{w_t}{\rho Z_t z} \text{ in home consumption goods,} \end{cases}$$

and

$$\begin{cases} \pi_t^D(z) = \frac{1}{\theta}\left[p_t^D(z)/P_t\right]^{1-\theta} P_t C_t \text{ in home currency;} \\ d_t^D(z) = \frac{1}{\theta}\left[\rho_t^D(z)\right]^{1-\theta} C_t \text{ in home consumption goods.} \end{cases}$$

What is more, in GM model firm z might turn out to be high productive, hence export with profits (measured in home consumption goods) from international activities defined as

$$d_t^X(z) = \frac{Q_t}{\theta}\left[\rho_t^X(z)\right]^{1-\theta} C_t^* - \frac{w_t f_t^X}{Z_t},$$

where

$$\rho_t^X(z) = \frac{p_t^X(z)}{P_t^*} = \frac{1}{Q_t}\tau_t \rho_t^D(z)$$

and $\frac{w_t f_t^X}{Z_t}$ is the exporting overhead cost with units transformed from effective labor to consumption goods.

All firms are divided into three categories: (I) firms with productivity draw below $z_{\min}$ do not produce at all, (not applicable to GM since $f^D = 0$) (II) firms with productivity between $z_{\min}$ and z_t^X only serve their domestic market and (III) firms with productivity above z_t^X also export. The first cutoff $z_{\min}$ is determined by the zero domestic profit condition $\pi(z_{\min}) = 0$ in M model. In GM model since there is no overhead cost in domestic production, $z_{\min}$ is exogenously given as the lower bound of support for the distribution from which entering firms draw productivity. The second cutoff z_t^X is determined by positive export profit condition $z_t^X = \inf\left\{z : d_t^X(z) > 0\right\}$. Suppose z is a draw from the distribution $H(z)$. In equilibrium, all firms producing in the domestic market have the distribution of productivity given by

$$g(z) = \begin{cases} \frac{h(z)}{1-H(z_{\min})} \text{ if } z \geqslant z_{\min}; \\ = 0 \text{ otherwise.} \end{cases}$$

And all domestic exporting firms have the distribution of productivity

$$g_t^X(z) = \begin{cases} \frac{g(z)}{1-G(z_t^X)} \text{ if } z \geqslant z_t^X; \\ = 0 \text{ otherwise.} \end{cases}$$

In GM model, we can define the average productivity of all firms serving domestic consumers as

$$\widetilde{z} = \left(\int_{z_{\min}}^{\infty} z^{\theta-1} g(z) dz\right)^{\frac{1}{\theta-1}},$$

where $\widetilde{z}$ is time independent because $z_{\min}$ is exogenous. And the average productivity of all domestic firms who export is

$$\widetilde{z}_t^X = \left(\int_{z_t^X}^{\infty} z^{\theta-1} g_t^X(z) dz\right)^{\frac{1}{\theta-1}}.$$

Given these average productivities, the economy behaves as if there were N_t domestic producers with the same productivity $\widetilde{z}$ and N_t^X domestic exporters with productivity $\widetilde{z}_t^X$. Then the average total profits is

$$\overline{d_t} = d_t^D(\widetilde{z}) + [1 - G(z_t^X)] d_t^X(\widetilde{z}_t^X).$$

When a new entrant in GM model decides whether or not to pay sunk cost for one drawing opportunity, the firm will write down its ex-ante discounted future profits as

$$\overline{v_t} = E_t\left[\sum_{s=t+1}^{\infty} [\beta(1-\delta)]^{s-t} \left(\frac{C_s}{C_t}\right)^{-\gamma} \overline{d_t}\right],$$

where δ denotes the probability of death shock to active firms.

To complete the GM model, three conditions are needed to characterize the equilibrium of their economy.

- Zero cutoff profits condition

$$\overline{d_t} = d_t^D(\widetilde{z}) + [1 - G(z_t^X)] d_t^X(\widetilde{z}_t^X).$$

  The average productivity of all domestic firms $\widetilde{z}$ is exogenously given in GM since $\widetilde{z}$ is a function of $z_{\min}$. The zero cutoff condition thus relates two unknowns, $\overline{d_t}$ and w_t. Notice that nominal wage W_t can not be normalized to 1 in GM with an asymmetric country setup.

- Free entry condition

$$\overline{v_t} = \frac{w_t f_t^E}{Z_t}.$$

  Potential firms are indifferent between staying out of and entering the market. This condition together with the zero cutoff condition above give us solutions for $\overline{d_t}$ and w_t

- Labor market clearing condition

$$R_t = W_t L.$$

  Labor market clearing is the equilibrium condition that equates total expenditure to total revenue, which will determine the total number of domestic firms N_t.

GM model is essentially a dynamic problem with total home firm number the state variable. The total number of domestic firms must equal the number of surviving firms from last period plus the number of new entrants in this period.

$$N_t = (1-\delta)N_{t-1} + N_t^E.$$

The stationary steady state in GM is just an extension of M's model, where the total number of firms producing domestically stays the same over time. In other words, every dying firm is replaced by a new entrant.

$$\delta N = N^E.$$

Ghironi and Melitz also investigate the non-stationary equilibrium through the tool of numerical simulation.

The main finding in GM is that the redefined consumption based real exchange rate, $\widetilde{Q}_t$, responds to productivity shock Z_t because of the free-entry condition of domestic firms. In the steady state equilibrium, free entry condition affects exchange rate through three channels. The first two are related to wage that is driven up by endogenous entry of firms. And the last channel is about consumer utility function. The empirical evidence is that more productive economies (more productive across all sectors) have higher aggregate price levels. Assume that a positive productivity shock affects all firms in home country (for example, a 1% rise in Z).

- The home market being more productive, more firms want to enter and produce here. If wages did not adjust, all firms would locate at home. To keep foreign labor employed, domestic relative wages have to rise. This is an appreciation in the "terms of labor". This induces the price of domestic goods (in units of wage per effective labor) to go up. Due to the presence of trade barriers, consumers spend more income on domestically produced goods than on foreign goods (since we are using constant elasticity specification for utility function). This rise will further induce an increase in the price of home non traded goods relative to foreign non traded goods. That is the first channel through which the domestic real exchange rate appreciates.

- Because domestic labor is more expensive as wage goes up, domestic firms are less profitable in the export market (the domestic terms of trade deteriorate). Hence, the productivity cutoff for exporting goes up, only the most productive firms can keep exporting. Symmetrically, it becomes easier for foreign firms to export, and more foreign firms start exporting due to a lower cutoff abroad. This increase in the domestic wages has changed endogenously the set of exporters in both countries. Less productive firms charge a higher price than more productive firms. So on average domestic imports become more expensive, whereas domestic exports become cheaper. Hence, domestic consumers now consume on average more expensive imports, whereas foreign consumers now consume on average cheaper imports. This is the second channel through which the domestic real exchange rate appreciates.

- Finally, as more firms enter the domestic market, there are more domestic varieties available for domestic consumers. Because consumers value variety, this induces domestic consumers to switch their expenditure towards new home goods produced by newly entrants. Because domestic varieties are more expensive, this further increases the price of the consumption basket of domestic consumers. This is that last effect through which the real exchange rate appreciates.

2.2 International Relative Price Co-movements

Built on Melitz's export selection mechanism plus endogenous mark-up, Atkeson and Burstein (2008, henceforth AB) remove the assumptions on free entry and exogenous death, and thus study a partial equilibrium version of the M's model. Instead, they add two extra assumptions, which are finite number of firms within each sector and hierarchy in good aggregation. There are a continuum (infinite number) of sectors in both home and foreign country. Within each sector, a finite number of firms are selling domestically, and at the same time making the decision of whether or not to enter the exporting market based on their individual productivity draw. By hierarchy I mean that each sector produces sectoral output using goods supplied by all domestic firms and exporting foreign firms in that sector, then agents consume a basket of sectoral outputs. Only goods produced by firms can be traded international, sectoral output cannot cross over the border. Atkeson and Burstein show that deviations from purchasing power parity (henceforth PPP) at the aggregate level arise as a result of the decisions of individual firms to sell in both home and foreign market with endogenous pricing-to-market.

PPP theory suggests that producer price index (henceforth PPI) based exchange rates should move identically with the terms of trade (henceforth TOT), or the ratio of export and import price indices (henceforth EPI and IPI). It also suggests that fluctuations in consumer price index (henceforth CPI) based exchange rates should be smoother than its PPI based counterpart. Empirical results turn out to be different from above traditional PPP theoretical predictions. The truth is that PPI based real exchange rates are more volatile than TOT, and they are as volatile as their PPI based counterpart. These discrepancies can be explained by PPP deviations, and the deviations are generated in this model because firms price discriminate between home and foreign country. When dig deeper, you will find that the discrimination behavior comes from endogenous mark-up, which is a direct result from that two extra assumptions they made about finite firms and hierarchy.

There are two countries home and foreign like GM model. Life time utility of a representative agent living in home country is all future cobb-douglas combination of consumption and leisure discounted to time zero.

$$U = \sum_{t=0}^{\infty} \beta^t \left[\mu \ln C_t + (1-\mu) \ln(1-L_t)\right].$$

Drop the time subscription for now since I will write down everything happened at some specific time t. Stationary CES consumption composite C is defined over a continuum of sector-manufactured outputs c_j indexed by $j \in [0,1]$ in home country.

$$C = \left[\int_0^1 c_j^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}.$$

International trade happens at the firm level, and trade enables foreign firms' goods to be used in the production of sector output at home country. Consider home country, there exist $2K$ firms in every sector j: $k = 1, 2, .., K$ are domestic firms and $k = K+1, K+2, ...2K$ are foreign firms. Each sector j in home country again employs CES technology to produce output c_j using $2K$ different goods as inputs with amount q_{jk} from firm k.

$$c_j = \left[\sum_{k=1}^{2K} q_{jk}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}.$$

In AB's model, there are no entrance and exit dynamics for domestic firms. Recall the GM model, exogenous death occurs to domestic firms but free entry ensures stationarity in steady state. In the presence of trade barrier, all K domestic firms and some (can be none or all) foreign firms together contribute to the output in the same sector at home country. Similarly, only part of home originated firms actually export when opening up to trade. The demand function for sector output j in home country is thus

$$c_j = \left(\frac{p_j}{P}\right)^{-\theta} C,$$

and the demand function for each good k from sector j in home country is

$$q_{jk} = \left(\frac{p_{jk}}{p_j}\right)^{-\sigma} c_j,$$

where p_{jk} is the price of good k, p_j is the price index for sectoral output j,

$$p_j = \left[\sum_{k=1}^{2K} p_{jk}^{1-\sigma}\right]^{\frac{1}{1-\sigma}},$$

and P is the price index for consumption composite at home,

$$P = \left[\int_0^1 p_j^{1-\theta} dj\right]^{\frac{1}{1-\theta}}.$$

Only finite firms competing within each sector allows AB model to use oligopoly competition in which firms take into account the impact they have on the aggregate prices of output in the same sector. At the sector level, Atkeson and Burstein maintains the assumption of infinite differentiated outputs so that all firms take final consumption C and the corresponding price index P as given. A natural assumption to make is that goods are more substitable within sectors than sectoral outputs within final consumption composite.

$$1 < \theta < \sigma < \infty,$$

Where θ is the elasticity of substitution between sectoral outputs and σ is the elasticity of substitution between goods within the same sector. Suppose the oligopoly competition takes the form of Cournot (firms simultaneously set quantities), then individual firm takes the amount of good supplied by other firms within their own sector as given, and choose its own supply quantity to maximize profit. All sectors are assumed to be symmetric, thus I can drop the subscript j when writing down the production function of firm k in home country.

$$q_k = z_k Z l_k,$$

where l_k is the labor utilized by firm k, Z is the country-specific aggregate labor productivity as in GM and z_k is firm's idiosyncratic draw from a log normal distribution. In general, z_k is different across firms and fixed over time once it is revealed.

As in GM model, there is no overhead cost for firms to serve domestic market, thus $f^D = 0$. To export, a firm must incur a fixed cost of f^x units of labor and a per unit iceberg cost of τ. For any firm k, the marginal cost of a unit sold at home and abroad are $\frac{W}{Zz_k}$ and $\tau\frac{W^*}{Z^*z_k}$, respectively. The price in GM model is a constant mark-up, $\frac{\theta}{\theta-1}$, of the firm's marginal cost. However, in AB model firm k in sector j at home country sets its domestic price as a endogenous mark-up of its marginal cost because of Cournot competition replacing monopolistic competition.

$$p_{jk} = \frac{\varepsilon(s_k)}{\varepsilon(s_k)-1}\frac{W}{Zz_k},$$

where

$$\varepsilon(s_k) = \frac{1}{\frac{1}{\sigma}(1-s_k)+\frac{1}{\theta}s_k}$$

and s_k is the firm k's market share in sector j at home country.

$$s_k = \frac{p_{jk}^{1-\sigma}}{\sum_{l=1}^{K+n}(p_{jl})^{1-\sigma}}.$$

n can be any integer from 0 to K. Two extreme cases are: (I) $n = 0$ means autarky, no foreign firms export to home country; (II) $n = K$, all foreign firms export. Any n in between 0 and K says that foreign firms $K, K+1, .., K+n$ from sector j export to home county while other foreign firms $K+n+1, ..., 2K$ only serve their domestic market. The cutoff n will be determined later by the positive exporting profit condition. Choose any foreign firm l with $l \leqslant K+n$, it exports to home country and sells its goods at price

$$p_{jl} = \frac{\varepsilon(s_l)}{\varepsilon(s_l)-1}\frac{\tau W^*}{Z^*z_l},$$

where W^* is normalized to 1. Hence the mark-ups both domestic and exporting firms charge are endogenous because they depend on firms' market share s. If $\sigma = \theta$, then $\varepsilon(s) = \sigma$, the mark-up is the Dixit-Stiglitz constant one at $\frac{\sigma}{\sigma-1}$ just like in GM. As $s \to 1$, $\varepsilon(s) = \theta$, the firm controls near 100% market shares in sector j. The market power it exercises is through its supply to the final goods sector. On the other hand, if $s \to 0$, as it would be the case if there were a continuum of firms in each sector, then $\varepsilon(s) = \sigma$. For any s in between the two extreme cases, the mark-up is increasing in the firm's market share for we have assumed $\theta < \sigma$.

Domestic profits for firms originated from the home country are as follows,

$$\pi^D = pq - q\frac{W}{Zz} = \frac{1}{\varepsilon(s)}pq.$$

In equilibrium some foreign firms in sector j will also be supplying to home country's production of c_j. Who are these firms? The candidates include firm $K+1, K+2, ..., K+n, ..., 2K$ in sector j in the foreign country.

Profits from serving home country for all the candidate foreign exporting firms are

$$\pi^X = pq - q\frac{\tau W^*}{Z^* z} - W^* f^X.$$

If we rank all the K firms in sector j at foreign country by their productivity, i.e., the firm with highest productivity z is $K+1$ and the lowest is $2K$. Foreign firms from $K+1$ to $K+n$ will export while the rest of them will not, where the cutoff n is determined by

$$n = \max\left\{l : \pi^X (K+l) \geqslant 0\right\} \text{ for } l = 1, ..., K.$$

For the problem to be interesting I rule out the autarky case in which none of the K firms from foreign country exports,[5] therefore at least one foreign firm exports in the equilibrium. Surely, if any foreign firm exports to the home country, it must be the highest productivity firm $K+1$.

Assume there is complete risk sharing between the two countries through a full-set of state-contingent claims. Then the general equilibrium is characterized at every time point t by consumption smoothing in the world

$$\frac{C_t}{C_t^*} = \frac{P_t^*}{P_t},$$

and the efficient allocation of labor endowment between leisure and job in household utility maximization is thus

$$\frac{P_t C_t}{W_t(1-l_t)} = \frac{P_t^* C_t^*}{W_t^*(1-l_t^*)} = \frac{\mu}{1-\mu}.$$

Main results are illustrated in AB's paper by calibration, and they are heavily rely on the essence of M's model, which is that only a subset of firms export in equilibrium at both countries in the presence of fixed exporting cost and iceberg melting cost. Assume a negative productivity shock affects all firms originated from home country (for example, a 1% fall in Z).

- With trade costs the domestic market is dominated by domestic firms. Since all domestic firms face the same increase in marginal cost and only a small share of foreign exporters are not affected, there is no fear of decline in shares in the domestic market. Things are opposite abroad, where home country firms exporting to foreign country compete against all unaffected foreign firms, and only against a few other domestic exporters. Thus they lose competitiveness abroad than it does at home, and they further lose market shares in the same sector abroad at foreign county, and therefore raise prices by

[5] This is possible if the most productive firm among all K foreign firms, no. $K+1$, lose money when exports to home market, $\pi^X(K+1) < 0$.

the smaller amount than they do it at home. The exporting firms from home country bear part of the shock by reducing mark-up in order to protect their market share abroad. Endogenous pricing-to-market appears because firms change differently the price they charge in different markets when hit by productivity shocks. With common parameter values, home country's PPI will increase by 0.86% and EPI by 0.69%.

$$\widehat{PPI} > \widehat{EPI}.$$

- Symmetrically, foreign country origin firms exporting to the home country gain market share abroad and therefore raise prices higher than they do it at home. Thus foreign exporters will increase their mark-up for exports more than for goods sold domestically at foreign country. Home country's IPI increase by 0.31% and foreign country's PPI increases by 0.14% in respond to a 1% change in home country's aggregate productivity.

$$\widehat{IPI} > \widehat{PPI^*}.$$

- So far, I have discussed the different price indices' responds of exporting and non-exporting firms within one country. On the other hand, I can compare the price index fluctuations between home country who encounters negative shock and unaffected foreign country. Since foreign firms do not experience any change in costs, and their price increases are relatively smaller and only due to their expansion in market share. Home country's IPI increases by 0.31%.

$$\widehat{EPI} > \widehat{IPI}.$$

Combining the above three inequalities with the two equations below, which are percentage changes in PPI based real exchange rate $\left(\frac{\widehat{PPI}}{PPI^*}\right)$ and percentage changes in TOT $\left(\frac{\widehat{EPI}}{IPI}\right)$,

$$\left(\frac{\widehat{PPI}}{PPI^*}\right) \simeq \widehat{PPI} - \widehat{PPI^*} = 0.72\%;$$

$$\left(\frac{\widehat{EPI}}{IPI}\right) \simeq \widehat{EPI} - \widehat{IPI} = 0.38\%,$$

Atkeson and Burstein come to the conclusion that PPI based exchange rate is more volatile than TOT under productivity shock in their numerical model,

$$\frac{\left(\frac{\widehat{EPI}}{IPI}\right)}{\left(\frac{\widehat{PPI}}{PPI^*}\right)} \simeq \frac{\widehat{EPI} - \widehat{IPI}}{\widehat{PPI} - \widehat{PPI^*}} = 53.4\% < 1.$$

In other words, TOT can only explain about half of PPI based exchange rate fluctuations. Pricing-to-market in each country by individual firms accounts for the rest of the movements. As for the second result, CPI based exchange rates is almost as volatile as its PPI based counterpart, AB first decompose CPI in both country in the following way

$$\begin{aligned}\widehat{CPI} &= (1-s_M)\widehat{PPI} + s_M\widehat{IPI}; \\ \widehat{CPI^*} &= (1-s_M)\widehat{PPI^*} + s_M\widehat{EPI},\end{aligned}$$

where s_M is the weight assigned to foreign goods price when computing the domestic consumer price index

$$s_M = \int_0^1 s_j \sum_{k=K+1}^{2K} s_{jk} dj.$$

Now I can look at the ratio of CPI and PPI based exchange rate fluctuations,

$$\begin{aligned}\frac{\left(\widehat{\frac{CPI}{CPI^*}}\right)}{\left(\widehat{\frac{PPI}{PPI^*}}\right)} &\simeq \frac{\left(\widehat{CPI}-\widehat{CPI^*}\right)}{\left(\widehat{PPI}-\widehat{PPI^*}\right)} \\ &= (1-s_M) - s_M\frac{\left(\widehat{EPI}-\widehat{IPI}\right)}{\left(\widehat{PPI}-\widehat{PPI^*}\right)} \\ &= 1 - s_M\left[\frac{\left(\widehat{EPI}-\widehat{IPI}\right)}{\left(\widehat{PPI}-\widehat{PPI^*}\right)}+1\right] \\ &= 82.3\%\end{aligned}$$

CPI based exchange rate explains a large portion of PPI based exchange rate fluctuations, thus they move together roughly. Both of the above two theoretical predictions are consistent with real world data.

2.3 Innovation and Growth

After dealing with New New Trade Theory's application on international relative price movements, I now dive into growth literature and see what implications M's model has when we augment it with innovating firms. Consider the closed economy version of the M's model where each entering firm draws its productivity from an exogenously given distribution $H(z)$. I abstract from knowledge spillover in Baldwin and Robert-Nicoud (2008) so that there exists no independent innovation sector, instead each surviving firm is an productivity innovating entity. Every period, firm can choose to invest in research and improve its productivity in the following binary way. For a firm with current productivity z, investing $zc(a)$ units of labor in research implies that the firm will have a productivity of $z + \varphi$ with probability a and have no technological breakthrough (stay with the current productivity z) with probability $1-a$. To improve its chance a of achieving a higher productivity, the firm must invest a higher amount. Therefore, R&D cost $c(a)$ is assumed to be increasing and convex. For simplicity, I replace the research cost function in Atkeson and Burstein (2009) with my speicification. Let

$$c(a) = \frac{a}{1-a}.$$

Notice that I maintain the key features of process innovation in Atkeson and Burstein (2009). The first feature is that innovation outcome is stochastic and the other feature is that firms already differ in their initial productivity before innovation opportunity arises. Surviving firms are now going to solve the following dynamic program

$$v(z) = \max_{a} \left\{ \pi^{D}(z) - zc(a) + (1-\delta)\left[av(z+\varphi) + (1-a)v(z) \right] \right\},$$

where $\pi^{D}(z)$ and f^{D} are firm's net profits and overhead cost for producing domestically, respectively, as in the M's model. $v(z)$ summarizes the value of having current productivity z. It is implied that firms with productivity below $z_{\min}$ exit and therefore the zero domestic value condition is

$$v(z_{\min}) = 0,$$

where $z_{\min}$ has the same meaning as M's model in the above section 2.1.

The above dynamic program further implies that the policy function will map productivities to research costs: $a(z)$. The stationarity will require that the measure of firms at every z remain constant, i.e.,

$$Ng(z) = N^{E}h(z) + (1-\delta)N\left[a(z-\varphi)g(z-\varphi) + (1-a(z))\,g(z) \right],$$

where all notation other than that technological breakthrough probability a related to research follow from M's Model in the above section 2.1.

In the model of Atkeson and Burstein (2009), firms have productivity dynamics due to innovation option but exit and export decisions are independent of size. Their central finding is that, despite the fact that a change in trade costs can have a substantial impact on individual firms' exit, export, and process innovation decisions, the firms' free-entry condition places a constraint on the overall response of aggregate productivity to the change in trade costs. In particular, after they solve the numerical model with parameterized specifications, they show that the steady-state response of product innovation largely off sets the impact of changes in firms' exit, export, and process innovation decisions on aggregate productivity. They also find that the dynamic welfare gains from a reduction in trade costs are very similar to the welfare gains that arise directly from the reduction in trade costs. Although the microeconomic evidence on individual firms' response to changes in international trade costs may account for international relative price fluctuation and co-movements as in the above two sections, it may not be informative about the macroeconomic implications of changes in these trade costs for aggregate productivity, growth and welfare.

3 Traditional Trade Theory

Unlike the New Trade Theory, traditional school of trade theory says that country trades because they are different in nature, either their technologies to produce each good differ in the Ricardian models, or their factor endowments differ like in H-O models. Both models result in a situation of comparative advantage, and lead to a partial or a complete specialization. In section 3.1, I introduce early efforts in making Ricardian and H-O models dynamic before the emergence of New New Trade Theory with heterogeneous firms. After M's model, researchers add into traditional trade theory with the ingredient that firms possess heterogeneous productivity. This strand of literature is initiated by Eaton and Kortum (2002) and will be discussed in section 3.2. It represents a competing class of models with M's New New Trade Theory. I also compare New New Trade Theory models built on New Trade Theory assumptions and their counterpart that incorporating New New Trade Theory feature in a traditional trade theory framework. Finally, in section 3.3, I mention other schools of thoughts linking international trade flows and macroeconomic phenomena.

3.1 Early Efforts

Early attempts to add dynamic features in traditional trade models fall short in open macroeconomic implications. The reason might be the ad-hoc assumptions these early papers have made in order to get dynamic results. Redding (1999) assumes learning by doing in a Ricardian model where labor technology in one sector evolves faster overtime just because more labor is used in that sector. Atkeson and Kehoe (2000) assume that one of the two traded goods is investment goods, which is not edible and only useful in creating new capital every period.

The simple Ricardian model depicts a world of two countries, home and foreign, each using a single factor labor to produce two goods, c and x. Technology is linear and different in two countries, meaning that home (foreign) country can produce one unit of good c (x) by A_c (A^*_x) units of labor. Redding use the basic model to define the dynamic comparative advantages. In the augmented Ricardian model by Reddig (1997) with productivity dynamics, $A's$ in each of the two sectors evolve endogenously over time as learning by doing occurs. The paper denotes time by t infinite and continuous. Preferences of consumers are identical in both home and foreign countries

$$U = \int_{t=0}^{\infty} e^{-\beta t} u(c_t, x_t) dt,$$

where period utility u takes the form of cobb-douglas specification

$$u(c_t, x_t) = c_t^{\theta} x_t^{1-\theta}.$$

c and x are low and high technology goods, respectively. Labor is the only production factor needed, and home country is populated with L units of labor while foreign country with L^*. The labor used in industry c and x must add up to the total labor supply, $L_c(t) + L_x(t) = L$. Productivity is denoted as

Time t	Home	Foreign
Goods c	$A_c(t)$	$A_x^*(t)$
Goods x	$A_c(t)$	$A_x^*(t)$

,

where $A_j(t) = \psi_j K_j(t)$ and $A_j^*(t) = \psi_j^* K_j^*(t)$ for $j = c, x$. Production functions in home country (symmetrically in foreign country) is thus

$$Q_j = A_j(t) L_j(t) \text{ for } j = c, x.$$

Productivity dynamics in home country comes from knowledge evolvement, whose evolving rule is specified as

$$\dot{K}_j(t) = \mu_j L_j(t) K_j(t),\ \mu_j > 0 \text{ for } j = c, x.$$

The pattern of trade at any time t is determined by the static comparative advantage. Thus, home country is said to have a static comparative advantage in the low-tech sector c at time t if the opportunity cost of producing the low-tech good at home is lower than in the other economy,

$$\frac{A_x(t)}{A_c(t)} < \frac{A_x^*(t)}{A_c^*(t)}.$$

The main result of this paper is that developing economies (home country in the model) may face a trade-off between specializing according to existing static comparative advantage (in low-technology goods c), and entering sectors in which they currently lack a comparative advantage, but may acquire such an advantage in the future as a result of the potential for productivity growth (in high-technology goods x). Comparative advantage is endogenously determined by past technological change, while simultaneously shaping current rates of innovation. Hence, specialization according to current static comparative advantage under free trade is welfare reducing. Trade policy intervention may be welfare improving, both for the economy undertaking it, and for its trade partner. In conclusion, productivity evolvement induced by labor input helps explain trade pattern changes, welfare improvement and aggregate productivity growth in the long run, but it has little power in addressing short term fluctuations in open macroeconomics.

Unlike the Ricardian trade model emphasizing on differences in production technology, H-O model family features in differences in factor endowment. Atkeson and Kehoe (2000)'s model discuss a dynamic version of H-O model in which they turn one of the tradable goods from consumption basket into investment goods. Through investment goods, countries can build up the stock of capital used in goods production. As a result, countries in their paper are differed in the timing of development. In other words, they differ in the size of capital stock, thus different capital abundance at time t as in static H-O models. Time is infinite and continuous. Preferences of consumers are identical across country

$$U = \int_{t=0}^{\infty} e^{-\beta t} u(c_t) dt.$$

Technology takes the form of constant return to scale production function. For consumption goods c and investment goods x, respectively,

$$\begin{cases} Q_c = F_c\left(K_c, L_c\right) \\ Q_x = F_x(K_x, L_x) \end{cases}.$$

It is easier if we proceed with intensive form

$$\begin{cases} q_c = f_c(k_c) l_c \\ q_x = f_x(k_x) l_x \end{cases},$$

where $k_j = \frac{K_j}{L_j}$, $l_j = \frac{L_j}{L}$ and $q_j = \frac{Q_j}{L}$ for $j = c, x$. They assume that investment goods x are more capital intensive than consumption goods c, $k_x > k_c$, which means there will be no factor intensity reversals. Resource constraints in this economy are

$$\begin{cases} k_x l_x + k_c l_c = k \\ l_x + l_c = 1 \end{cases},$$

where $k = \frac{K}{L}$ and K and L are home country's endowment of capital and labor. As you can see, capital is not sector specific in this model. Capital accumulation over time is governed by the following evolving rule

$$\dot{k} = x - \delta k,$$

where x is the investment and δ is the depreciation rate. Consumers in each country trade consumption and investment goods, taking as given the time path for p, the world price of the investment good relative to the consumption good. Assume that trade for each country is balanced at each date, so that $c + px = rk + w$, where r is the rental rate on capital and w is the wage rate in that country. Accordingly, the representative consumer in each country chooses time paths for consumption and capital to maximize life time utility subject to

$$\dot{k} = (rk + w - c)/p - \delta k$$

with $k \geqslant 0$. Firms in each country maximize

$$f_c(k_c)l_c + pf_x(k_x)l_x - r(k_c l_c + k_x l_x) - w(l_c + l_x).$$

As for the main results, they show that in a dynamic H-O model the timing of a country's development relative to the rest of the world affects the path of the country's development. A late-bloomer country that begins the development process later than most of the rest of the world ends up with a permanently lower level of income than the early-bloomers that developed earlier. This is true even though the late-bloomer has the same preferences, technology, and initial capital stock that the early-bloomers had when they started the process of development. This result stands in contrast to that of the standard one-sector growth model in which identical countries converge to a unique steady state, regardless of when they start to develop. Adding dynamic feature makes the history matter here.

3.2 Melitz Meets Traditional Trade Theory

Dornbusch, Fischer, and Samuelson (1977, henceforth DFS) examine a continuum of goods first in a Ricardian model. Their key idea is to span goods on a unit interval, and thus summarize the endogenous equilibrium specialization pattern by two cutoff values (pivotal goods) defining the set of goods that are produced only by country 1 and the set of goods that are produced only by country 2. However, the model is constrained to two countries and is difficult to extend to a multi-country framework in full generality until Eaton and Kortum's parameterization. Eaton and Kortum (2002) extend DFS to a probabilistic technology distribution of countries (firms) and incorporate ingenious and elegant treatment of geography into a Ricardian model to study gravity equations. Alvarez and Lucas (2007) later perform a general equilibrium analysis of Eaton-Kortum model by generating the input goods market, and they use it to find out whether the cross-country distribution of trade volumes is consistent with the behavior of volumes in the data.

Based on DFS's continuum version of Ricardian model, Eaton and Kortum (2002) add heterogeneous productivity ingredients from New Trade Theory in a way that they keep the CES preferences assumption, but instead remove the monopolistic competition assumption for perfect competition. Perfect competition actually gives results that are almost identical to monopolistic competition: instead of all firms charging a constant Dixit-Stiglitz mark-up over their marginal cost in monopolistic competition, they charge exactly their marginal cost. The following two paragraphs revisit the environment of Eaton and Kortum's model, then propose one way (at primitive stage) to make it dynamic. A continuum of goods indexed by $\omega \in \Omega \equiv [0,1]$. Country i's efficiency in producing good ω is denoted as usual by $z_i(\omega)$. Price of one unit of good ω produced in country i and sold in country n is thus $p_{ni}(\omega) = \frac{c_i}{z_i(\omega)}\tau_{ni}$, where c_i is the input cost in country i and for any good ω, τ_{ni} denotes the units required to produce in country i when delivering one unit from country i to country n. Under the assumption of *perfect competition*, buyers in country n compare the prices offered by all countries and actually buy from the lowest price available. The lowest price $p_{ni}(\omega) = \min\{p_{ni}(\omega) : i = 1, ..., N\}$, where N is the number of countries. Consumers maximize a CES utility

$$C = \left[\int_0^1 c(\omega)^{\frac{\theta-1}{\theta}} d\omega\right]^{\frac{\theta}{\theta-1}}.$$

The efficiency of producing each good ω in country i is draw independently from Type II extreme value distribution:

$$F_i(z) = \Pr[Z_i \leq z] = e^{-T_i z^{-\eta}}.$$

For any good ω, the price distribution of ω produced in country i and shipped to country n is thus:

$$\begin{aligned} G_{ni}(p) &= \Pr[P_{ni} \leq p] \\ &= 1 - e^{-T_i(c_i\tau_{ni})^{-\eta}p^{\eta}}. \end{aligned}$$

The price distribution of ω country n actually buys is:

$$\begin{aligned} G_n(p) &= \Pr[P_n \leq p] \\ &= 1 - \prod_{i=1}^{N}[1 - G_{ni}(p)] \\ &= 1 - e^{-\Phi_n p^{\eta}}, \end{aligned}$$

where $\Phi_n = \sum_{i=1}^{N}\left[T_i(c_i\tau_{ni})^{-\eta}\right]$. This happens to be the same as the price distribution of ω which country n actually buys from country i computed in a different way. Notice it is the same for any country i.

$$g_{ni}(p) = \frac{1}{\pi_{ni}} \int_{q=0}^{p} \prod_{s \neq i}[1 - G_{ns}(q)]dG_{ni}(q) = G_n(p),$$

where $\pi_{ni} = \frac{T_i(c_i\tau_{ni})^{-\eta}}{\Phi_n}$, the probability that country i provides variety ω at the lowest price in country n. It can also be referred as the fraction of goods that country n actually buys from country i. Suppose the average expenditure per good in country n is X_n because $g_{ni}(p) = G_n(p)$ does not vary by source country i. Notice that this is also the total spending of country n since there is a continuum of goods normalized to 1. The spending of country n on goods from i is denoted as $X_{ni} = X_n * \pi_{ni}$. We can get

$$\frac{X_{ni}}{X_n} = \pi_{ni} = \frac{T_i(c_i\tau_{ni})^{-\eta}}{\Phi_n} = \frac{T_i(c_i\tau_{ni})^{-\eta}}{\sum_{i=1}^{N}\left[T_i(c_i\tau_{ni})^{-\eta}\right]}.$$

The above expression bears semblance to the standard gravity equation in that bilateral trade is related to the importer's total expenditure and to geographic barriers. Other justifications for a gravity equation have rested on the traditional Armington and monopolistic competition models. Under the Armington assumption goods produced by different sources are inherently imperfect substitutes by virtue. Under monopolistic competition each country chooses to specialize in a distinct set of goods. The more substitutable are goods from different countries, the higher is the sensitivity of trade to production costs and geographic barriers. In such models, adjustment is at the *intensive margin*: Higher costs or geographic barriers leave the set of goods that are traded unaffected, but less is spent on each imported good. In contrast, in Eaton and Kortum's model the sensitivity of trade to costs and geographic barriers depends on the technological parameter η (reflecting the heterogeneity of goods in production) rather than the preference parameter θ (reflecting the heterogeneity of goods in consumption). Trade shares respond to costs and geographic barriers at the *extensive margin*: As a source becomes more expensive or remote it exports a narrower range of goods.

Here are some primitive thoughts to make Eaton and Kortum (2002) dynamic. For simplicity, I reduce the number of country to two. Consumers now have intertemporal choices to make:

$$U = E_t\left[\sum_{t=0}^{\infty}\beta^t u(C_t)\right],$$

where the period utility is the same as before

$$C_t = \left[\int_0^1 c_t(\omega)^{\frac{\theta-1}{\theta}} d\omega\right]^{\frac{\theta}{\theta-1}}.$$

Since there are only two countries, we can drop the subscript i. The production efficient draws in home (foreign) country could now be related to each other or/and to their own histories through a country-specific technological shock Z_t (Z_t^*).

$$F_t(z) = e^{-Z_t T z^{-\eta}}.$$

Price of one unit of goods ω produced in foreign country and sold in home country at time t is thus $p_t^X(\omega) = \frac{c_t^*}{z_t^*(\omega)}\tau$ compared to the home market goods price at $p_t^D(\omega) = \frac{c_t}{z_t(\omega)}$. Then it is possible to study international relative price fluctuations as in GM model. More works need to be done from this point on.

Instead of Melitz's monopolistic competition between firms and Eaton and Kortum's perfect competition between countries, Bernard, Eaton, Jensen and Kortum (2003, BEJK henceforth) consider Bertrand competition between heterogeneous firms in the same industry, and the winning firm represents the country to compete perfectly with other countries. With Bertrand competition, once heterogeneous firms compete in prices of identical goods, since the price they charge depends on the pricing rules of their direct competitors, mark-ups will endogenously respond to changes in the toughness of competition, which will be the case when countries open up to trade. At this point, the BEJK model which builds on traditional Ricardian trade model plus heterogeneous feature merges with AB model which is grounded on New Trade Theory. Atkeson and Burstein (2008) model is a more generalized version of BEJK model if one imagines the sector in AB as the variety ω in BEJK. Both models have domestic and foreign firms competing in the same sector (variety) according to Counrnot (Bertrand) rules. Within sector goods are perfect substitutes (they are actually identical) in BEJK so that BEJK simply corresponds to the extreme case where $\sigma = +\infty$ is section 2.2. In the extreme case (BEJK), firm charges a cost equal to the marginal cost of the second lowest cost in the variety so that it does not have to worry about competition from other varieties. However, AB has an intermediate case where both the competition of firms within the sector and of firms in other sectors always matters.

Bernard, Redding and Schott (2007) put New New Trade Theory into a factor endowment H-O model. In a general equilibrium framework, they characterize how country, industry and firm characteristics interact and respond to trade liberalization. When firms possess heterogeneous productivity, countries differ in relative factor abundance and industries vary in factor intensity, falling trade costs induce reallocations of resources both within and across industries and countries. These reallocations generate substantial job turnover in all sectors, spur relatively more creative destruction in comparative advantage industries than comparative disadvantage industries, and magnify ex ante comparative advantage to create additional welfare gains from trade. The improvements in aggregate productivity as countries liberalize dampen and can even reverse the real wage losses of scarce factors.

3.3 Other Thoughts

Dynamics in trade is also found in international flows of ideas. It is inspired by the second wave of globalization from 1960 to present, in which international flows in goods was accompanied by flows of ideas. Eaton and Kortum (1999) and (2006) show that, to some extent, technology diffusion substitutes for trade in goods. Knowledge accumulation and patent protected spillover provide incentive for innovation and aggregate productivity growth.

All the above researches on international trade pattern focus on deep primitive causes of trade, such as difference in technology in Ricardian model, national factor endowment in H-O model, love of variety preferences in New Trade Theory model, heterogeneous firms in New New Trade Theory model or invent and patent mechanism in Trade in Ideas model. And such trade patterns give rise to various macroeconomic phenomena. However, macroeconomic behaviors of countries can sometimes, the other way around, determine the pattern of international trade.

In the study of Rose and Spiegel (2002), monetary union stimulates trade and multilateral trade system has strong effect on trade too.

First brought up by Bulow and rogoff (1989) and most recently developed by Mendoza and Yue (2008), trade models with sovereign debt default in equilibrium affect trade in a dynamic way. Specifically, sovereign debts repayment and default over time could determine the volume of international trade. Creditor countries might threaten to damage debtor countries' trade in the case of default. Because there is risk of losing benefits from international trade, this kind of threat provides debtor countries incentive to repay. However, default in equilibrium would lead to a smaller trade size than it will be in a full risk sharing environment without commitment problem.

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