Capital Accumulation and the Welfare Gains from Trade*

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Abstract

We measure the gains from a trade cost reduction in a model with dynamic accumulation of factors. We show that the tight link between import intensity and gains from trade that exists in static models breaks down along transition paths in dynamic models. When trade costs are reduced, the need to accumulate factors temporarily shifts spending from consumption to investment. Import intensity may rise or fall along the transition path, depending on the relative import intensity of consumption and investment. Calibrating the model to the U.S. economy, we find that investment is more import intensive than consumption, so that import intensity is falling along the transition path even as consumption is rising. Therefore, while higher import intensity is associated with higher consumption when comparing steady states (as in static models), it is associated with lower consumption along a given transition path. We also consider the case of endogenous firm creation as another form of investment and factor accumulation, and again find a negative relationship between consumption and import intensity along the transition path.

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JEL codes E13 E22 F11 F41.

1 Introduction

The measurement of the effect of lowering trade barriers on welfare has long been a major focus of the study of international trade. This literature is divided into two classes of models: static models that compare equilibria with high and low trade barriers, and dynamic models that account for the adjustment when moving between steady states. While both models generate predictions about increases in allocative efficiency and changes in factor allocations induced by trade, static models are necessarily silent about the elements studied by the literature on dynamic trade models, such as factor accumulation (e.g. Baldwin, 1992, Bajona and Kehoe, 2010, and Anderson, Larch, and Yotov, 2015), overshooting (e.g. Alessandria and Choi, 2014, and Alessandria et al., 2014), or the timing and intensity entry and exit decisions by firms (e.g. Ruhl, 2008, and Alessandria et al., 2014). Instead, gains to real income in many static models can be completely characterized, for a given trade elasticity, by how import intensity changes when trade costs are reduced as demonstrated in Arkolakis, Costinot, and Rodriguez-Clare (2012, hereafter referred to as ACR).

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In this paper, we show that this tight link between gains from trade and import intensity is broken along transition paths in dynamic models. When moving from a high to a low level of trade costs, static models predict that increases in consumption are larger when increases in imports are larger. We demonstrate that along a given transition path this relationship disappears and, in our calibrated model, is reversed. In our baseline model of capital accumulation, consumption is low at the beginning of the transition and grows over time as more capital is accumulated. Import penetration along the transition path depends on the relative import intensity of investment and consumption goods. If they are equal, then import penetration is constant along the transition path. However, in U.S. data we find that investment goods are imported twice as intensively as consumption goods. Therefore, the beginning of the transition path, when investment is highest, exhibits higher import penetration than in the new steady state with low trade costs. So while consumption converges to its new steady state value from below, import intensity converges to its new steady state value from above. This is in stark contrast to the positive relationship that exists when comparing static equilibria or when comparing long run steady states.

To isolate the effect of dynamics on the measurement of gains from trade, we compare a dynamic model with capital accumulation to a static benchmark with one sector. We derive welfare formulae in each model, where welfare in the static model is the gain in real income and in the dynamic model is compensating variation.[1] Calibrating both models to U.S. data so that they have the same initial import penetration ratio and trade elasticity, we simulate a 25% reduction in trade costs in each. The gains in the dynamic model are 3.69% of real income and in the static model are 2.79%.

We then provide a decomposition to clarify the sources of differing predictions for welfare gains in the two models. Welfare differs through four channels: differences induced by the transition (the *transition channel*), by the increase in the capital stock (the *capital channel*), from changes in the composition of imports between consumption and investment goods (the *composition channel*), and because the elasticity of substitution between imported and domestic consumption goods may be different than the trade elasticity (the *elasticity channel*). The decomposition shows that the two most important mechanisms for explaining the difference in gains are the capital channel, which implies greater gains in the dynamic model, and the transition channel, which implies greater gains in the static model.[2]

The model of dynamic factor accumulation illustrates a transition dynamic where consumption converges from below, but an important strand of the dynamic trade literature has mechanisms that imply the opposite. Alessandria and Choi (2014) and Alessandria et al. (2014) consider models with firm entry and exit, and show that hysteresis effects may cause consumption overshooting along transition paths. This is because the initial stock of operating firms is higher than in the new steady state, so the economy initially has an excess number of operating firms. To understand this dynamic, we build a model with firm entry and exit that is designed to capture this overshooting feature of Alessandria and Choi (2014).[3] In our simplified model, firms pay a sunk entry cost that allows them

[1]That is, in the dynamic model welfare is the permanent increase in consumption the household would need in the high trade cost equilibrium to be indifferent between that and the sequence of consumption she would receive with lower trade costs. Notice that this does take into account the transition.

[2]In the appendix, we emphasize that channels that mimic the capital channel are present in models with multiple sectors, as in Section 3.4 of Costinot and Rodríguez-Clare (2014). Intuitively, trade implies cheaper intermediate goods, which reduces the marginal cost of production. We show that under a stark set of assumptions there is an equivalence between that static model and a comparison of steady states in our dynamic model. In that case, the only margin that is different between the dynamic model and the static model with intermediate goods is the transition channel.

[3]Although it captures the essential idea of hysteresis and aggregate consumption dynamics, this simplified model

to operate in the domestic market until they exogenously exit. In each period, the firms may also choose to pay a fixed cost to export.[4] This model captures the mechanism of Alessandria and Choi (2014) that generates overshooting: an initial excess number of small firms operating domestically that dissolve over time until the economy reaches a new steady state. We show that the model also generates overshooting in consumption and, because of the existence of a large number of small non-exporters, it generates lower import penetration along the transition path than in the new steady state. Therefore, consumption and import penetration again have opposite trajectories along the transition path.

This paper complements the dynamic trade literature by providing a basis of comparison between static, CES trade models and a standard dynamic trade model with capital accumulation. The idea of expanding a standard static trade model to a dynamic environment and studying the effects of accumulation of a factor is similar to Baldwin (1992). Our study differs from that in that we focus on how the trade elasticity varies over the transition so that we can more easily compare the welfare results to standard models. Similarly, our modeling of the dynamic economy is related to Bajona and Kehoe (2010), which studies dynamics in a Heckscher-Ohlin model. More broadly, many papers have studied the effect that trade has on the accumulation of other state variables that may increase production. Young (1991) studies economies that grow from learning by doing, and shows that the pattern of trade may have long run dynamic effects. Likewise, Rivera-Batiz and Romer (1991) and Alvarez et al. (2013) study economies in which ideas flow between trading partners, and idea flow is enhanced by higher levels of trade.

This paper also contributes to the literature on determinants of gains from trade in models that do not conform to the assumptions needed to generate the ACR result. Recent papers have focused on heterogeneous markups, such as Arkolakis et al. (2015), Holmes et al. (2015), and Edmond et al. (2015). Others have studied departures from CES import demand systems, such as Brooks and Pujolas (2014) and Adao et al. (2017). This paper makes two departures in that we consider dynamics and endogenous factors, which are excluded by the assumptions needed to generate the ACR result. Our emphasis is on dynamics, and capital accumulation is the most straightforward way to generate non-trivial dynamics that is in line with the broader literature in international trade and macroeconomics.

Our work is related to Alessandria et al. (2014), which studies a dynamic model with rich firm heterogeneity and compares it to the gains from trade implied by static models. The model we consider in most of this paper has a very different dynamic. When trade costs are reduced, consumption converges from below to its new steady state value as capital is accumulated. However, in Section 6 we also provide a stylized model of firm entry and exit to demonstrate a similarity between these two environments: both predict that consumption and import penetration move in opposite directions along a given transition path, so that the tight positive link between changes in welfare and changes in import penetration implied by static models is reversed along transition paths in both of these dynamic models.

A recent paper by Anderson et al. (2015) develops an empirical framework to estimate the effect of increased trade on growth in which growth in capital is explicitly taken into account. Our study

does not attempt to match the richer firm dynamics in Alessandria and Choi (2014).

[4]This configuration of fixed costs guarantee that overshooting of consumption during the transition. Other configurations, such as ones where the fixed costs to operate and export are both sunk, may have different implications for transition dynamics. We focus on this case because our goal is to study a setting with consumption overshooting.

differs from theirs in several important ways. First, our focus is on the welfare effects of trade and not on output growth. In this dynamic context with an endogenous choice between investment and consumption, that distinction is important. Second, their innovation is to provide an empirical framework in which the growth effects from capital and trade can be separately identified. Our motivating question is how welfare gains from trade differ in static and dynamic models. Finally, in Section 5 of this paper we consider a model with firm entry and exit, which Anderson et al. (2015) does not. The accumulation of operating firms has a qualitatively different transition than usual capital accumulation models.

2 Models

In this section we develop two separate models. First, we develop our baseline dynamic model, which consists of a two country, infinite horizon trade model with investment in capital. Second, we develop a static version with a single sector that has a welfare gains prediction that is consistent with the formula given in Arkolakis et al. (2012).

2.1 Dynamic model

There are two identical countries labeled *home* (with variables labeled h) and *foreign* (with variables labeled f), and time is infinite. Households in each country value consumption goods and own all factors, which are used by firms to produce outputs.

Households

We describe the problem of a household in country $j \in \{h, f\}$. The country is populated by a unit mass of households, each of whom is endowed with k_{j0} units of capital in period 0, and L_j unit of labor in every period t. These consumers derive utility from the consumption in period t of c_{jt}, which is an aggregate of the home consumption good c_{hjt} and the foreign consumption good c_{fjt}. The problem of each household consists of:

$$
\begin{aligned}
\max_{\substack{\{c_{jt}, c_{hjt}, c_{fjt}, x_{jt},\\ x_{hjt}, x_{fjt}, k_{jt+1}\}_{t=0}^{\infty}}} \quad & (1-\beta)\sum_{t=0}^{\infty}\beta^t \frac{c_{jt}^{1-\eta}-1}{1-\eta}, \\
\text{subject to:} \quad & c_{hjt} + x_{hjt} + p_t\tau_t(c_{fjt} + x_{fjt}) = w_{jt} + r_{jt}k_{jt}, \\
& c_{jt} = \left(\mu^{\rho-1}c_{hjt}^{\rho} + (1-\mu)^{\rho-1}c_{fjt}^{\rho}\right)^{\frac{1}{\rho}}, \\
& x_{jt} = \left(\nu^{\rho-1}x_{hjt}^{\rho} + (1-\nu)^{\rho-1}x_{fjt}^{\rho}\right)^{\frac{1}{\rho}}, \\
& k_{j,t+1} = (1-\delta)k_{j.t} + x_{j,t}, \\
& k_{j,0} > 0,
\end{aligned}
\tag{2.1}
$$

where $\beta \in (0, 1)$ is the discount factor, η is the reciprocal of the intertemporal elasticity of substitution, $\rho < 1$ governs the elasticity of substitution between domestic and foreign goods. We allow for consumption and investment goods to have different import intensity. In particular, $\mu \in (0, 1)$ determines home bias in consumption, and $\nu \in (0, 1)$ determines home bias in investment. The depreciation rate of capital is $\delta \in (0,1)$. Factor prices are the wage rate w_t, and the return to capital r_t. Consumption of home and foreign goods are given by c_{hjt} and c_{fjt}, and the intermediate of home and foreign goods are x_{hjt} and x_{fjt}. Home goods are numeraire and the price p_t is the price of foreign goods. There is an iceberg trade cost τ_t incurred on traded goods. The final consumption good c_{jt} and final investment good x_{jt} cannot be traded between countries.

Firms

Firms are perfectly competitive and produce final output y_{jt} using a Cobb-Douglas technology that combines capital k_{jt} with labor l_{jt} for a productivity A_{jt}. These firms solve the problem:

$$\begin{aligned} \max_{y_{jt}, k_{jt}, l_{jt}} \quad & y_{jt} - w_{jt} l_{jt} - r_{jt} k_{jt}, \\ \text{subject to:} \quad & y_{jt} \leq A_{jt} k_{jt}^{\alpha} l_{jt}^{1-\alpha}. \end{aligned} \tag{2.2}$$

Since firms are perfectly competitive and their production functions exhibit constant returns to scale, profits are zero and aggregate income is equal to factor payments. Likewise, taking into account that there is one unit of labor supplied in each period, aggregate income can be written as:

$$A_{jt} k_{jt}^{\alpha} L_j^{1-\alpha} = w_{jt} L_j + r_{jt} k_{jt} = y_{jt}. \tag{2.3}$$

Market clearing

Finally, prices are determined by market clearing conditions.

$$\text{Labor Market:} \qquad l_{jt} = L_j, \; j \in \{h, f\}, \tag{2.4}$$

$$\text{Trade Balance:} \qquad y_{jt} - c_{hjt} - x_{hjt} = p_t \tau_t (c_{fjt} + x_{fjt}). \tag{2.5}$$

Competitive equilibrium in the dynamic economy

We complete our description of the economy with a full definition of the competitive equilibrium.

Definition 2.1. Given initial capital stocks $\{k_{j0}\}_{j \in \{h,f\}}$, an equilibrium in this economy is a sequence of prices $\{w_{jt}, r_{jt}, p_t\}_{t=0, j \in \{h,f\}}^{\infty}$ and allocations $\{c_{jt}, c_{hjt}, c_{fjt}, x_{jt}, x_{hjt}, x_{fjt}, y_{jt}, l_{jt}, k_{jt+1}\}_{t=0, j \in \{h,f\}}^{\infty}$ such that households solve problem (2.1), the firm solves problem (2.7), the labor market clears as in (2.4), and trade balances as in (2.5).

For further reference, in Appendix A.1 we characterize the equilibrium in this economy as well as the steady state values.

2.2 Static model

In this section we develop a static model with one sector that is similar to the dynamic model, except there is no investment and the capital stock is exogenous. As in the dynamic model, we describe the problems of households and firms taking care to point out where they differ from those in the dynamic model.

Households

Households value a single, final consumption good composed of traded intermediate goods from the home and foreign countries. Capital and labor are in fixed supply, and there is no investment good. Households in country j solve:

$$\begin{aligned}
&\max_{\{c_j, c_{hj}, c_{fj}\}} && u(c_j), \\
&\text{subject to:} && c_{hj} + p\tau c_{fj} = w_j L_j + r_j k_j, \\
& && c_j = (\mu^{\rho-1} c_{hj}^{\rho} + (1-\mu)^{\rho-1} c_{fj}^{\rho})^{1/\rho}.
\end{aligned} \tag{2.6}$$

Variables are the same as in the dynamic problem with the time subscripts removed. Because intertemporal elasticity of substitution plays no role, there is no need to specify the functional form of u except to require that it is strictly increasing.

Firms

Firms are perfectly competitive and produce final output y_j using a Cobb-Douglas technology as in the dynamic model. These firms solve:

$$\begin{aligned}
&\max_{y_j, k_j, l_j} && y_j - w_j l_j - r_j k_j, \\
&\text{subject to:} && y_j \leq A_j k_j^{\alpha} l_j^{1-\alpha}.
\end{aligned} \tag{2.7}$$

Since firms are perfectly competitive and their production functions exhibit constant returns to scale, profits are zero and aggregate income is equal to factor payments.[5] Likewise, taking into account that there is one unit of labor supplied in each period, aggregate income can be written as:

$$A_j k_j^{\alpha} L_j^{1-\alpha} = w_j L_j + r_j k_j = y_j. \tag{2.8}$$

Market clearing

Prices are determined by these market clearing conditions:

$$\text{Labor Market:} \qquad l_j = L_j, \qquad j \in \{h, f\}, \tag{2.9}$$

$$\text{Trade Balance:} \qquad y_j - c_{hj} = p\tau c_{fj}. \tag{2.10}$$

Competitive equilibrium in the static economy

Once we have described all the agents in this economy, we can proceed to define the equilibrium of this economy.

Definition 2.2. Given the capital stocks $\{k_j\}_{j\in\{h,f\}}$, an equilibrium in this economy are prices $\{w_j, r_j, p\}_{j\in\{h,f\}}$ and allocations $\{c_{hj}, c_{fj}, y_j, l_j\}_{j\in\{h,f\}}$ such that the household solves the problem (2.6), the firm solves problem (B.2), labor markets clear, equation (2.9), and trade balances, equation (2.10).

[5] Notice that the fact that both factors are in fixed supply and production is constant returns to scale implies that factor prices will always move proportionally to one another. This is important for recovering the ACR result in this environment.

As in the case of the static model developed in the previous section, this model can also be solved in closed form. We refer the reader to Appendix A.2 for its characterization.

3 Welfare

In this section we characterize the welfare gains from trade that each model delivers, and provide a decomposition of the ratio of welfare gains from those models. This allows us to explicitly separate the channels identified in the introduction so that we can understand why welfare predictions differ across the two models.

3.1 Welfare equations

We measure welfare gains from a symmetric trade cost reduction in the dynamic and static models. In the static model we compute welfare as the increase in real income from the reduction in trade costs. In the dynamic model, it is the amount of additional consumption the household would need every period in the initial steady state to be indifferent between that and the stream of consumption implied by the trade cost reduction.

Welfare in the dynamic model

To measure welfare, we begin by defining some convenient terms that will be used later. First, total expenditure on investment, E_{Ijt}, and total expenditure on consumption, E_{Cjt}, are given by:

$$
\begin{aligned}
E_{Ijt} &= x_{h,j,t} + p_t \tau_t x_{fjt} = x_{hjt}\left(1 + \frac{\nu}{1-\nu}(p_t\tau_t)^{\frac{\rho}{\rho-1}}\right), \\
E_{Cjt} &= c_{hjt} + p_t \tau_t c_{fjt} = c_{hjt}\left(1 + \frac{\mu}{1-\mu}(p_t\tau_t)^{\frac{\rho}{\rho-1}}\right).
\end{aligned}
\tag{3.1}
$$

The domestic expenditure shares of consumption, investment and total expenditure respectively in period t in country j are given by:

$$
\lambda_{jt}^{C} = \frac{c_{hjt}}{E_{Cjt}}, \qquad \lambda_{jt}^{X} = \frac{x_{hjt}}{E_{Ijt}}, \qquad \lambda_{jt} = \frac{c_{hjt} + x_{hjt}}{E_{Cjt} + E_{Ijt}}. \tag{3.2}
$$

Given these, we use the utility function in the dynamic model given in equation (2.1) to derive lifetime utility for given trade costs τ and initial capital k_{j0}.[6] Utility is expressed as a function of observables: output, investment expenditure and the import penetration of consumption. Namely,

$$
U_j(\tau, k_{j0}) = \frac{(1-\beta)\mu^{\frac{\rho-1}{\rho}}\left(\sum_t \beta^t (y_{jt} - E_{Ijt})^{1-\eta} (\lambda_{jt}^{C})^{(1-\eta)\frac{\rho-1}{\rho}}\right) - 1}{1-\eta}. \tag{3.3}
$$

For comparison, consider the lifetime utility of a household that is always at the steady state of an economy with trade cost τ. Suppose that household was exogenously assigned a proportional increase

[6] See Appendix A.1 for the explicit characterization of the dynamic model used to derive this equation.

in their consumption every period of Δ_j^D. Then that household's lifetime utility would be:

$$\tilde{U}_j(\Delta_j^D, \tau) = \frac{\mu^{\frac{\rho-1}{\rho}} \left(\Delta_j^{D\,1-\eta} (y_{jH} - E_{IjH})^{1-\eta} (\lambda_{jH}^C)^{(1-\eta)\frac{\rho-1}{\rho}} \right) - 1}{1-\eta}. \tag{3.4}$$

Note that time subscripts have been replaced with subscripts H to emphasize that these are the values from the steady state of the economy associated with the high trade cost τ^H.

We consider changes in the trade cost from an initial high level τ^H to a low level τ^L, and we assume the steady state capital stock in the economy with trade cost τ^H is k_{j0}. Our measure of welfare is the value of Δ_j^D that solves:

$$\tilde{U}_j(\Delta_j^D, \tau^H) = U_j(\tau^L, k_{j0}^H). \tag{3.5}$$

Combining equations (3.3) and (3.4), we get that the increase in income, Δ^D that is required so that equation (3.5) holds is:

$$\Delta_j^D = \left((1-\beta) \sum_t \beta^t \left(\frac{y_{jt} - E_{Ijt}}{y_{jH} - E_{IjH}} \right)^{1-\eta} \left(\frac{\lambda_{jt}^C}{\lambda_{jH}^C} \right)^{(1-\eta)\frac{\rho-1}{\rho}} \right)^{\frac{1}{1-\eta}}. \tag{3.6}$$

This is the compensating variation that summarizes the dynamic welfare gain from the household transitioning from the steady state with high trade costs to the one with low trade costs.

Notice that our model abstracts from international borrowing and lending, which certainly affects this welfare calculation. We make this modeling choice for two reasons. First, our goal is to study the transition between steady states with different levels of trade costs, and the ability to borrow and lend internationally would dampen the transition.[7] Second, it is well-known that the welfare implications of capital account openness are very small, as in Gourinchas and Jeanne (2006).

Welfare in the static model

Finally, real income in the static model can be directly computed from the equilibrium characterization (see Appendix A.2) and is equal to:

$$c_j = A_j k_j^\alpha \mu^{\frac{\rho-1}{\rho}} (\lambda_j)^{\frac{1-\rho}{\rho}}. \tag{3.7}$$

Note that the trade elasticity in this model is defined as:

$$\varepsilon = \frac{\partial \log \left(\frac{1-\lambda_j}{\lambda_j} \right)}{\partial \log(\tau)} = \frac{\rho}{\rho - 1}. \tag{3.8}$$

Then, when the trade cost τ is reduced from τ^H to τ^L, the increase in consumption in the static model Δ^S is given by:

$$\Delta_j^S = \left(\frac{\lambda_{jL}}{\lambda_{jH}} \right)^{\frac{1}{\varepsilon}}. \tag{3.9}$$

[7] In the small open economy case with a fixed interest rate, the transition lasts only one period.

Here we have subscripts L to denote values of variables in the equilibrium with the low trade cost τ^L. This is the ACR formula in this context, so this confirms that that result extends to this environment.[8]

3.2 Comparing gains in static and dynamic models

In the remainder of this paper we compare the welfare outcomes in the static and dynamic models. To make the comparison meaningful, we require that the import penetration ratios associated with the two trade cost levels, λ_{jH} and λ_{jL}, be the same in both models. We also require that the trade elasticity ε be the same in both models. In the dynamic economy, ε is defined as:

$$\varepsilon = \frac{\log\left(\frac{1-\lambda_{jH}}{\lambda_{jH}}\right) - \log\left(\frac{1-\lambda_{jL}}{\lambda_{jL}}\right)}{\log(\tau^H) - \log(\tau^L)}. \tag{3.10}$$

The static and dynamic models may require different parameter values in order to generate the same values for the import penetration ratio and trade elasticity. For example, while the trade elasticity is a simple function of ρ in the static model, it is a more complicated endogenous object in the dynamic model. Likewise, the magnitude of trade cost may need to be different in the two economies to generate the same change in import penetration.

Our exercise then is as follows: simulate the trade cost reduction in the dynamic economy, then compare the computed equivalent consumption variation in the dynamic model with what the ACR formula implies for gains from steady state to steady state. Notice that performing this exercise does not require us to parameterize the static model. As in ACR, the parameterization that generated those outcomes are irrelevant. Therefore, in what follows we will not assign a particular parameterization to the static model.

3.3 Decomposition of welfare

We compare gain from trade in the dynamic model given in equation (3.6) to the gains in the static model given in equation (3.9). Our exact exercise is a bilateral, unforeseen reduction of trade costs from τ^H to τ^L. We compare the welfare gains from this change in the dynamic model to a static model that has the same trade elasticity, and the same initial and final import penetration λ_{jH} and λ_{jL}.

Our interpretation of this exercise is to measure the error from incorrectly applying the ACR formula to data generated by the dynamic model. The fact that this incorrect application would lead to incorrect results is not surprising, but our decomposition shows through what channels the error would occur.

Notice that the ratio of those two equations can be written as:

$$\frac{\Delta_j^D}{\Delta_j^S} = \underbrace{\left((1-\beta)\sum_{t=0}^{\infty}\beta^t\left(\frac{c_{jt}}{c_{jL}}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}}_{\text{Transition}} \underbrace{\left(\frac{y_{jL} - E_{IjL}}{y_{jH} - E_{IjH}}\right)}_{\text{Capital}} \times \tag{3.11}$$

[8] Note that ACR assumes a single factor of production in fixed supply, while our static model has two factors of production. However, notice that if all modes of production use the same Cobb-Douglas production function, then all factors are used in fixed shares and we can use cost minimization to define a composite factor and write an equivalent model that has that composite factor as a single factor of production. Therefore, the fact that we recover the ACR formula in this environment is not surprising.

$$\times \underbrace{\left(\frac{\lambda^C_{jL}/\lambda_{jL}}{\lambda^C_{jH}/\lambda_{jH}}\right)^{\frac{\rho-1}{\rho}}}_{\text{Composition}} \underbrace{\left(\frac{\lambda_{jL}}{\lambda_{jH}}\right)^{\frac{\rho-1}{\rho}-\frac{1}{\epsilon}}}_{\text{Elasticity}}.$$

We divide this ratio into four components.

The *transition channel* takes into account how the transition path of consumption affects welfare gains. The static model clearly has no transition. In particular, our baseline dynamic model implies that consumption is lower along the transition path than in the new steady state, and the transition effect shows how costly this transition is. This is the only term where the discount factor and intertemporal elasticity enter the welfare formula. In our baseline this channel will always be negative, but if consumption were *overshooting* on the transition as considered in later sections, then it could be positive.

The *capital channel* shows how much gains from trade are affected by changes in the capital stock that ultimately arise from the change in trade costs. Since capital is endogenous in the dynamic model and exogenous in the static model, this channel summarizes the effect in the dynamic model of achieving greater factor availability in the new steady state. In Section 5 we also consider a static model with intermediate goods, and show it can achieve a channel that is very similar to this.

The *composition channel* takes into account that the dynamic and static models disagree on the welfare-relevant measure of trade intensity. In the static model, since there is no investment all trade is consumed. Therefore, greater access to any imports leads directly to lower consumption prices. In the dynamic model, the same logic is true but, since not all goods are consumed, we must distinguish between the import intensity of consumption goods and the import intensity of goods overall. In particular, if investment goods have a different import intensity than consumption goods, then the composition of imports matters.

Finally, the *elasticity channel* takes into account that the measured trade elasticity given by equation (3.10) may differ from the elasticity that is relevant for welfare. Like with the composition channel, this arises when an increase in import intensity is due to greater imports of investment goods, but would be incorrectly interpreted if one was to incorrectly apply the static model to data output from the dynamic model, as greater demand for foreign goods in consumption. In the static model, this would be used to identify the elasticity of substitution between home and foreign goods in consumption, which is then applied in the ACR formula.

In the next section, we measure the relative magnitudes of these effects in a calibrated dynamic model, and see how those magnitudes change under different counterfactuals.

3.4 Illustration of results: an analytical decomposition

Before moving on to the calibrated model, we first consider a case where the dynamic model can be solved analytically. If capital fully depreciates each period and if $\eta = 1$, then when countries are symmetric that model can be solved in closed form. In particular, given that k_{j0} is the steady state capital level from the high trade cost steady state, then it is easy to show that:

$$k_{jt} = k_{jh}^{\alpha^t} \kappa_L^{\frac{1-\alpha^t}{1-\alpha}}, \tag{3.12}$$

where

$$\kappa_L = \alpha\beta A_j L_j^{1-\alpha} \nu^{1-\frac{1}{\rho}} \left(1 + \frac{\nu}{1-\nu} (\tau^L)^{\frac{\rho}{\rho-1}}\right)^{\frac{1}{\rho}-1}. \tag{3.13}$$

Then consumption is just a constant fraction of output and on the transition to the new steady state with low trade costs, it is given by:

$$c_{jt} = (1-\alpha\beta) A_j k_{jt}^{\alpha} L_j^{1-\alpha} \mu^{1-\frac{1}{\rho}} \left(1 + \frac{\mu}{1-\mu} (\tau^L)^{\frac{\rho}{\rho-1}}\right)^{\frac{1}{\rho}-1}. \tag{3.14}$$

We can then proceed to solve for each of the four channels in the decomposition analytically. The *transition channel* is given by:

$$\prod_{t=0}^{\infty} \left(\frac{c_{jt}}{c_{jL}}\right)^{(1-\beta)\beta^t} = \left(\frac{k_{jH}}{k_{jL}}\right)^{\alpha\frac{1-\beta}{1-\alpha\beta}} = \left(\frac{1 + \frac{\nu}{1-\nu} (\tau^H)^{\frac{\rho}{\rho-1}}}{1 + \frac{\nu}{1-\nu} (\tau^L)^{\frac{\rho}{\rho-1}}}\right)^{\alpha\frac{1-\beta}{1-\alpha\beta}\frac{1-\rho}{\rho}}. \tag{3.15}$$

This illustrates that the transition is always costly, and it is more costly the larger is α or the smaller is β.

Next, the *capital channel* can be computed exactly:

$$\frac{y_{jL} - E_{IjL}}{y_{jH} - E_{IjH}} = \left(\frac{k_{jL}}{k_{jH}}\right)^{\alpha} = \left(\frac{1 + \frac{\nu}{1-\nu} (\tau^L)^{\frac{\rho}{\rho-1}}}{1 + \frac{\nu}{1-\nu} (\tau^H)^{\frac{\rho}{\rho-1}}}\right)^{\alpha}. \tag{3.16}$$

This term is unambiguously positive, as it reflects the fact that the new steady state has higher capital, and is only a function of how much more capital the economy accumulates and the capital share.

The last two terms depend on the import intensity of consumption and investment goods. The *composition channel* is given by:

$$\left(\frac{\lambda_{jL}^C/\lambda_{jL}}{\lambda_{jH}^C/\lambda_{jH}}\right)^{\frac{\rho-1}{\rho}} = \left(\frac{1 - \alpha\beta + \alpha\beta\frac{\lambda_{jL}^X}{\lambda_{jL}^C}}{1 - \alpha\beta + \alpha\beta\frac{\lambda_{jH}^X}{\lambda_{jH}^C}}\right)^{\frac{1-\rho}{\rho}}. \tag{3.17}$$

This demonstrates that this channel depends on the relative import intensity of consumption and investment goods, weighted by their relative expenditures. It is immediate that if consumption and investment have equal import shares, then the composition channel is absent.

Finally, the *elasticity channel* shows how the trade elasticity in this model may not be informative about the elasticity of substitution between home and foreign goods, as in standard static trade models. We begin by explicitly computing the trade elasticity in general for infinitesimal changes in trade costs.

$$\varepsilon = \frac{\partial \log\left(\frac{1-\lambda_j}{\lambda_j}\right)}{\partial \log(\tau)} = \frac{\rho}{\rho-1} \frac{\alpha\beta\lambda_j^X(1-\lambda_j^X) + (1-\alpha\beta)\lambda_j^C(1-\lambda_j^C)}{\lambda_j(1-\lambda_j)}. \tag{3.18}$$

Then we can see immediately that, like the composition channel, the elasticity channel has no effect when consumption and investment are imported with equal intensity. That is because the trade elasticity in this model captures two effects illustrated in equation (3.18). The first term measures how substitutable home and foreign varieties are and it is informative about the welfare-relevant elasticity. The second term takes into account that measuring the aggregate trade elasticity, which measures changes in the expenditure-weighted sum of the import intensities of consumption and investment, is different than taking the weighted average of import intensities of consumption and investment. If the latter exercise were used to compute trade elasticities, in this model that would eliminate the elasticity channel.[9]

4 Quantitative exercise

We now simulate the dynamic model and demonstrate two main results.

First, we show there is a qualitative difference between the static and dynamic models. In the static model, whenever import intensity is higher, that is associated with higher gains from trade as is immediately obvious from the welfare formula (3.9). While the same is true in the long run (when comparing steady states) in the dynamic model, in our calibrated model the opposite is true in the short run (along transition paths) following a trade cost reduction. The reason is that, along a transition path, investment is higher than in the new steady state so the intensity of imports along the transition path reflects, to a greater degree, the import intensity of investment goods than of consumption goods. In U.S. data we conclude that investment goods are more intensively imported than consumption goods, which implies that the transition path is characterized by higher import intensity than in the new steady state. Yet the fact that investment is particularly intensive along the transition path also implies that consumption is then lower. Hence, in the short run periods of high import intensity are periods characterized by lower consumption. This is the opposite of the prediction of the static model.

Second, we apply the decomposition developed in the previous section to simulated output from the transition of the dynamic model. This exercise allows us to measure the magnitude of the error from incorrectly applying our measure of welfare gains from static models to output from dynamic models. Furthermore, we consider a variety of counterfactuals.

To calibrate the model, first we choose parameter values that are common in the trade and macroeconomics literatures. We assume the countries are symmetric. We normalize the technology level to $A = 1$ and set the discount factor $\beta = 0.96$. We set the depreciation rate to $\delta = 0.1$, and choose $\eta = 0.5$ to generate an intertemporal elasticity of substitution of 2 to be consistent with the meta-study on intertemporal elasaticity of substitution estimates in Havranek et al. (2015). We consider an initial trade cost level of $\tau^H = 1.5$ so that we can consider trade cost reductions of up to 50 percentage points.[10]

Next, we target moments from the U.S. economy and calibrate parameters to meet those targets. We target a trade elasticity ε of -5 for our baseline exercise of reducing trade costs by 25 percentage points, which is at the lower range of estimates in Anderson and Van Wincoop (2004). This implies that $\rho = 0.8361$. We target a capital-output ratio of 2.3, which implies a value of $\alpha = 0.3414$.

Finally, we use the U.S. input-output table from 2013 to measure import intensity of investment and consumption goods separately. To do this, we measure import intensity of each sector, then

[9] The fact that computing the trade elasticities for consumption and investment goods separately would yield the welfare-relevant elasticity is because expenditure shares on consumption and investment are constant when $\eta = 1$. In general, if expenditure shares change with trade costs that affects the trade elasticity, as shown in Brooks and Pujolas (2014).

[10] Note that our choice of τ^H is irrelevant, since the home bias parameters μ and ν will be used to match import shares.

take total use in final consumption in each industry as a weight to compute a consumption-weighted average of import intensity across sectors.[11] This yields a measure of import intensity for consumption equal to 0.0803. Instead, taking an investment-weighted average of import intensity across sectors implies an import intensity for investment equal to 0.1648.[12] Our maintained assumption is that all uses within a sector are imported with equal intensity.[13] Given these targets and the other parameter values, we calibrate the weighting term on home goods in consumption $\mu = 0.4085$ and the weighting term on home goods in investment $\nu = 0.6094$. These parameter values are summarized in Table 1.

Our experiment consists of a bilateral 25 percentage point reduction in trade costs. The transition paths for consumption, capital, import penetration and investment are in Figure 1.[14] The transition between steady states in this case has the same shape as the neoclassical growth model when it starts with an initial capital stock that is lower than in the steady state: investment increases capital, consumption grows slowly, and the economy converges to a new steady state with higher capital, output and consumption. Moreover, in this figure we include the trade elasticity over the transition period-by-period using the formula:

$$\varepsilon_{jt} = \frac{\log\left(\frac{1-\lambda_{jH}}{\lambda_{jH}}\right) - \log\left(\frac{1-\lambda_{jt}}{\lambda_{jt}}\right)}{\log(\tau^H) - \log(\tau^L)}. \tag{4.1}$$

These transition paths immediately reflect our first result. Comparison of steady states exhibits the qualitative pattern of the static model: imports are substantially higher and consumption has increased. However, along the transition the pattern is exactly the opposite. Points along the transition with the highest import intensity are also the points with the lowest consumption.

However, the formula for the static model depends on both import intensity and the trade elasticity, so it would also be useful to take into account that the measured trade elasticity varies along the transition path. To do this, we apply equation (3.10) period-by-period along the transition path to measure a sequence of implied trade elasticity $\{\varepsilon_{jt}\}$ and also look at an alternative, period-by-period application of the formula for static gains given by:

$$\Delta_{jt} = \left(\frac{\lambda_{jt}}{\lambda_{H,SS}}\right)^{\frac{1}{\varepsilon_{jt}}}. \tag{4.2}$$

Figure 2 compares changes in consumption along the transition path in the dynamic model to two applications of equation (4.2). We include the sequence of Δ_{jt} if we restricted $\varepsilon_{jt} = -5$ in every period as well as the case where we use the period-by-period measure of the trade elasticity. This shows that the pattern of consumption and import intensity have the opposite relationship along the transition path than they do in the long run.

Our second set of results is to apply our decomposition to measure why the gains from trade in the dynamic environment are different than in the static model. These results are listed in Table 2.

[11] Sector-level import intensity is measured as imports in that sector divided by the sum of final and intermediate uses in that sector.

[12] In the input-output table, for consumption we use "Personal consumption expenditures" and for investment we use the sum of "Nonresidential private fixed investment in structures", "Nonresidential private fixed investment in equipment", "Nonresidential private fixed investment in intellectual property rights" and "Residential private fixed investment". Importantly, we did not include inventories as investment, which likely includes durable consumption goods.

[13] If the same industries that are more intensively used in investment are also the industries that are more intensively imported, then our exercise concludes that investment is more import intensive than consumption.

[14] Import penetration is the ratio of imports to gross output. It is equal to $1 - \lambda_j$.

Overall, the gains from the trade cost reduction in the dynamic model are 3.69% and are 2.79% in the static model. The largest effect driving the difference comes from the capital channel. This means there is a greater capital stock, an effect that is absent in the static model. This effect is large enough to make the gains in the dynamic model larger despite the fact that the transition is costly, reflected by a negative value for the transition channel, and the fact that the greater total import intensity is disproportionately driven by investment imports rather than consumption imports, summarized by the composition channel. The effect from mismeasurement of trade elasticity, measured as the elasticity channel, is very small. Therefore, the endogenous response of capital accumulation is key to accounting for the greater gains realized in the dynamic model than in the static model.

Next we consider several other counterfactuals to understand how they affect the decomposition. First, we consider reductions of 5, 10, 25 (our baseline), 40 and 50 percentage points. We do this in two ways. First, we keep all parameters to their values calibrated in the baseline. In this case, as shown in Table 2, the trade elasticity varies with the magnitude of the change in trade costs. To account for this, our second set of exercises is to recalibrate each change in trade cost reductions to keep the trade elasticity constant as shown in Table 1. We see in both sets of exercises that the effects from our baseline case roughly scale with the magnitude of overall gains. We do see that the elasticity channel does get disproportiately more important for larger changes in trade costs, but even at a 50 percentage point reduction in trade costs, the elasticity channel is very small.

Second, we consider cases where consumption and investment are equally intensively imported, or where consumption is more intensively imported than investment (the opposite of the baseline calibration). In these cases, our first result about the transition relationship between consumption and import intensity disappears or is reversed, emphasizing that that result does depend on the empirical result that investment goods are more intensively imported than consumption goods. In the first case we set the parameter on the import intensity of investment to that of consumption from the baseline $\mu = \nu = 0.4085$. In this case, Figure 3 demonstrates that the import penetration ratio is constant across the entire transition path. Therefore there is no correlation between changes in imports and changes in consumption across the transition. However, in the case where we reverse the calibrated values of μ and ν, so that now consumption is more intensively imported than investment, then the positive relationship between consumption and import penetration is restored. In both cases, the composition channel is the only effect that is qualitatively different. The composition channel is necessarily absent when $\mu = \nu$, since the import intensity of consumption is the same as overall import intensity. Moreover, when consumption is more import intensive than investment, then this channel becomes positive. This reflects the fact that increases in total import penetration now understates the increase in consumption import penetration.

Next we vary the targeted trade elasticity and the intertemporal elasticity. We consider trade elasticity values of -3 and -8, and intertemporal elasticities of 3 and 0.1. In each case, we see that there are changes in magnitudes of the effects, but there do not appear to be qualitatively different changes in the channels explaining the changes.

Finally we consider the case where the two countries are asymmetric. We implement this by assigning a larger endowment of labor to the foreign country. Besides the larger labor endowment, all parameters for both countries are the same, and the matrix of trade costs is symmetric. We calibrate the size of the foreign country to match U.S. G.D.P. as a fraction of world G.D.P. We add the target moment that the U.S. accounts for 25.2% of world G.D.P. as in 2007, and recalibrate the model also allowing the labor endowment in the foreign country to vary. We find that the labor endowment in the foreign country is 3.37 times as large as it is in the U.S.

In the asymmetric case we see the magnitudes are very similar as in the baseline case. One difference is that transition is somewhat less severe. In the symmetric case both the home and foreign countries begin the transition equally far from their final steady state and their price levels follow the same trajectories. However, in the asymmetric case, the reduction in trade cost has a smaller effect on the large, foreign country than on the small, home country. So the foreign country has a flatter trajectory than does the home country. Because of this, early in the transition foreign goods are cheaper relative to home goods than they are later in the transition. Then, relative to the symmetric benchmark, the beginning of the transition has relatively cheaper foreign goods, which dampens the transition channel.

5 Dynamic model with firm entry and exit

The baseline dynamic model considered so far exhibits a particular type of transition dynamic as a result of the accumulation of capital. In this section we consider the dynamic that exhibits overshooting in consumption, which can be implied by trade models with heterogeneous firms and dynamic entry and exit.

We will present a highly stylized version of Alessandria and Choi (2014) that captures the fundamental nature of the overshooting of consumption along the transition. That is, because a larger number of firms are operating in steady state when trade costs are high than when they are low, if exit takes time, then there are more firms operating along the transition than in the new steady state. Therefore, consumption is actually higher along the transition than in the new steady state.

We capture this dynamic in a very simple way. Each period a mass of potential entrepreneurs is born. Each entrepreneur knows her productivity and can, at a cost, pay to begin operating. As long as the firm is in operation, it may costlessly sell domestically. To export the firm must pay a cost each period. Every period, the firm has an exogenous probability of exiting.

Because this model is so simple, it will not match the richer entry and exit dynamics in Alessandria and Choi (2014), but it does qualitatively capture the consumption overshooting result along the transition. We first present a general version of the entry and exit model. Then we calibrate and simulate the case without capital, and finally calibrate and simulate the case with both capital and firm entry and exit.

This exercise is similar in spirit to Alessandria et al. (2014). However, the model we study here is considerably simpler. This is because our goal is to demonstrate how the dynamic compares to the model of capital accumulation, not to measure the magnitude of the difference.

5.1 Firm's problem

At any point in time, the household in country j buys varieties of home goods from a set of domestic firms Ω_{jht} and a set of foreign firms Ω_{jft}. These varieties are imperfectly substitutes for varieities originating in the same country and have a constant elasticity of substitution given by σ with one another.

Varieties produced from the home country can be used to produce home domestic and consumption goods. The price index in each country is determined by cost minimization on the part of the representative household. For a given choice of purchases of the home variety y_{jht} the household solves:

$$P_{jht}y_{jht} = \min_{\{y_{jht}(m)\}} \int_{\Omega_{jht}} p_{jht}(m)y_{jht}(m)dm,$$
$$\text{subject to: } y_{jht} = \left(\int_{\Omega_{jht}} y_{jht}(m)^{1-1/\sigma}dm \right)^{\frac{\sigma}{\sigma-1}}. \tag{5.1}$$

Likewise, for the foreign variety y_{jft} the household solves:

$$P_{jft}y_{jft} = \min_{\{y_{jft}(m)\}} \int_{\Omega_{jft}} \tau_t p_{jft}(m)y_{jft}(m)dm,$$
$$\text{subject to: } y_{jft} = \left(\int_{\Omega_{jft}} y_{jft}(m)^{1-1/\sigma}dm \right)^{\frac{\sigma}{\sigma-1}}. \tag{5.2}$$

All varieties are produced by a monopolist that internalizes their effect on the price of their own variety when making production choices. From the problem of the representative household given by (5.1), we derive the inverse demand function:

$$p_{jht}(y) = P_{jht} \left(\frac{y}{y_{jht}} \right)^{-1/\sigma}. \tag{5.3}$$

Likewise, the inverse demand for a variety sold to the foreign country is:

$$p_{jft}(y) = \frac{P_{jft}}{\tau} \left(\frac{y}{y_{jft}} \right)^{-1/\sigma}. \tag{5.4}$$

Firms produce with a Cobb-Douglas production technology and have heterogeneous productivity z. Then a firm operating in country j in period t with productivity level z has profits from its domestic sales given by:

$$\pi_{jht}(z) = \max_{\{y,k,l\}} p_{jht}(y)y - w_{jt}l - r_{jt}k, \tag{5.5}$$
$$\text{subject to: } y \leq zk^{\alpha}l^{1-\alpha}.$$

A firm in country j in period t with productivity z generates profits from exporting given by:

$$\pi_{jft}(z) = \max_{\{y,k,l\}} p_{jft}(y)y - w_{jt}l - r_{jt}k, \tag{5.6}$$
$$\text{subject to: } y \leq zk^{\alpha}l^{1-\alpha}.$$

Every period a mass $1 - \delta_f$ of potential entrepreneurs are born. Each draws a productivity level z from a Pareto distribution. This Pareto distribution has positive mass from $[1, \infty)$ and has curvature parameter θ. They either pay a fixed cost to enter in that period, or they may never enter again. In every period the firm operates, it may sell in the domestic market and, if it pays an export fixed cost that period, may sell in the foreign market. At the end of each period, the firm exits with probability $1 - \delta_f$. All profits are rebated to the representative household. The good used to pay fixed costs is assembled using a Cobb-Douglas function of labor and capital with the same parameters as the production function of the firms. Cost minimization implies that the cost of the goods used to pay fixed costs is:

$$q_{jt} = \left(\frac{r_{jt}}{\alpha}\right)^{\alpha} \left(\frac{w_{jt}}{1-\alpha}\right)^{1-\alpha}. \tag{5.7}$$

To operate the entrepreneur pays f units of the fixed cost good, and pays f_x units in each period the firm exports.

The decision to pay the fixed cost to open the firm is characterized by the following cutoff rule:

$$q_{jt} f \leq \max_{e_{jt+s}(z)} \sum_{s=0}^{\infty} R_{jt,t+s} \delta_f^s \left[\pi_{jht+s}(z) + e_{jt+s}(z)\left(\pi_{jft+s}(z) - q_{jt+s} f_x\right)\right], \tag{5.8}$$

$$\text{subject to:} \qquad e_{jt+s}(z) \in \{0,1\}.$$

Here, $R_{jt,t+s}$ is the relative marginal utility of consumption in periods t and $t+s$ for the representative household in country j. This is given by:

$$R_{jt,t+s} = \beta^s \left(\frac{c_{jt+s}}{c_{jt}}\right)^{-\eta}. \tag{5.9}$$

5.2 Firms and No Capital

First we consider the case where there is no capital ($\alpha = 0$) to concentrate on the overshooting dynamic inherent in this model with firm entry and exit.

We normalize the fixed operating cost f to one. We choose the parameter δ_f to match the entry rate of firms in the U.S., which is 6.2% per year according to Clementi and Palazzo (2016). In this model, markups are governed by σ, and we choose $\sigma = 5.35$ to generate a markup of 23%, which is near the midpoint of estimates from De Loecker and Warzynski (2012). The trade elasticity from steady state to steady state in this model is equal to $-\theta$ so, as before, we set the trade elasticity to -5. We initially set the trade cost parameter $\tau = 1.25$ and will consider reducing τ to one. Then we jointly calibrate μ, which governs home bias in consumption, and f_x, the fixed cost to export, to match U.S. import penetration of 8.34% and the U.S. fraction of firms that export to 18% from Bernard et al. (2007). This generates $\mu = 0.23$ and $f_x = 0.03$. These values are listed in Table 5.

As displayed in Figure 4, the transition dynamic exhibits overshooting in consumption, since consumption at every point in the transition is higher than consumption in the new steady state. As in the static Chaney (2008) model, reducing trade costs causes the cutoff productivity defined by equation (5.8) to go up, because the profits from operating domestically decline for every z. Therefore, the set of operating firms is larger in the steady state with higher trade costs than in the steady state with lower trade costs. But since the exit of these firms is slow due to the exogenous exit rate, along the transition path there are more operating firms than in the new steady state.

This has two effects. First, because more varieties are available consumption is higher, which generates the overshooting dynamic.[15] Second, because the transition has a larger proportion of low productivity, non-exporting firms than in the new steady state, the import penetration ratio is lower along the transition path than in the new steady state. Like in the calibrated baseline model, this generates a negative relationship along the transition between import penetration and consumption.

Quantitatively, in the calibrated example we see that the dynamic gains from trade are necessarily higher than the static gains, since the only difference is a transition in which consumption is higher

[15] Section 5.4 contains a discussion of how this overshooting dynamic arises.

than in the new steady state. However, the difference in this case is small. Consumption in the new steady state is 3.21% higher than in the old steady state. The compensating variation given by equation (3.6) is 3.35%.[16]

5.3 Firms with Capital

Finally we calibrate the model to include both the capital accumulation dynamic and the firm entry and exit dynamic. We follow the same calibration targets as before with one exception. When we measure the capital stock in the model we assume that both capital used as inputs and fixed costs used to create new firms are part of the capital stock. The set of calibrated parameter values are given in Table 5.

The transition in this model is given in Figure 5. We see that the transition dynamic is determined by the two forces from the two dynamic models discussed so far. At the beginning of the transition the returns to capital are very high, which induces a shift in output from consumption to investment. Once the capital stock approaches its value in the new steady state, the fact that there is still a larger number of firms operating than in the new steady state implies that consumption begins to overshoot in intermediate periods.

The dynamic of import penetration is muted by the interplay of these same two forces. When consumption is high, the fact that investment is intensively imported means import penetration is high. However, the fact that there are a large number of small firms dampens trade. The import penetration ratio is its highest level in the very first period of the transition when investment is highest (it is 23.35% in the first period, compared to 23.33% in the new steady state). Then in the second period import peneration drops and then converges toward the new steady state value from below.

5.4 Discussion: Overshooting and Undershooting

The fact that the model of capital accumulation and the model of firm entry and exit imply qualitatively different transition paths between steady states requires some explanation. Two crucial factors cause this fundamental difference.

First, while the model with capital accumulation implies that investment is lower in the steady state with high trade costs than in that with low trade costs, the model with firm entry and exit (and no capital) implies the opposite about firm entry. More firms enter in the high trade cost steady state than in the low, so total expenditure on trade costs is higher in the high trade cost steady state than in the low. Therefore, while the model with capital accumulation exhibits a costly transition in which capital is accumulated, the model with firm entry and exit has the opposite transition: they initially have too much of their accumulated factor (firms), which falls during the transition until reaching the new steady state.

Second, the fact that firm sunk costs are irreversible is important for understanding the dynamic in the model with firm entry and exit. If a firm had the option each period to liquidate and recover the value of the fixed cost used to open it, it would do so along the transition. We demonstrate this in Figure 6. For the marginal entrant in the high trade cost steady state, we compute the ratio of

[16] In applying equation (3.6) we treat payment of fixed costs as E_{Ijt}.

its expected present value to the value of the sunk cost to operate.[17] Because the reduction in trade costs happens unexpectedly in period 0, a firm making its entry choice the period before incorrectly believes that the economy will be in the high trade cost steady state forever. The next period, the expected present value of the firm drops as price levels fall and the cost of inputs rise as depicted with the solid line in Figure 6. In that period, if the firm could liquidate and recover the fixed cost it had paid to open, it would do so. Moreover, if it had foreseen the trade cost reduction it would have computed a lower expected present value and not opened. The calculation it would have made if the trade cost reduction was foreseen is given by the dotted line in Figure 6.

The fact that firms cannot be liquidated has a timing effect that is not present in the model with capital accumulation. Suppose that $\eta = 0$ so that the intertemporal elasticity of substitution is infinite. In this case, our baseline model of capital accumulation would transition in one period: the household would simply reduce consumption by enough to increase the capital stock to the new steady state. Likewise, in a model with firm entry and exit, if firms could liquidate themselves the transition would also take place in a single period. Again, the household has no consumption-smoothing motive so moves immediately to the new steady state. However, without liquidation even with linear preferences the transition is slow as firms exit over time. This demonstrates that the irreversibility of firm fixed costs plays an important role in generating the transition in the model with firm entry and exit.

6 Conclusion

This paper studies the relationship between gains from trade cost reductions in static and dynamic models. Dynamic models with endogenous capital contain mechanisms that are missing from static models, such as endogenous changes in factors, shifting composition of imports between consumption and investment goods, different measure trade elasticities and non-trivial consumption paths. We provide a decomposition of these effects to measure their relative importance.

Qualitatively, we find that consumption and import penetration move in opposite directions along a given transition path when investment goods are more intensively imported than consumption goods, as in U.S. data. This is an important caveat to application of static models to measuring gains from trade over short time horizons. If we see initially high rates of import penetration achieved from some reform subside over time, the logic developed from static models implies that this can be interpreted as diminishing gains from trade. We have demonstrated that dynamic models have just the opposite prediction: falling import penetration is consistent with a model of capital accumulation in which consumption is growing. However, this again implies that the relationship between consumption and import penetration is reversed along transition paths, showing that the result from the capital accumulation model is more general than that one setting.

In this analysis, although we assumed the levels of trade were different for consumption and investment goods, we assumed that their trade elasticities were the same. Verifying this assumption is beyond the scope of this paper, but it could matter for our results. In particular, if the elasticity for investment goods was much lower than for consumption goods, it could be the case that import penetration for consumption goods is higher than for investment goods in the steady state with low

[17] The marginal entrant is the firm with productivity such that equation (5.8) holds with equality. That is, it is the lowest productivity operating firm from the high trade cost steady state.

trade costs. This would imply that both import penetration and consumption rise along the transition path. Determining whether or not these elasticities are different, or if the difference is large enough to give that result is an important area for future research.

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A Appendix – model characterization

In this Appendix we characterize of equilibria for each of the models presented in section 2 and the model from section 5. We consider the symmetric country cases in all three.

A.1 Dynamic model

An equilibrium for the dynamic model with capital accumulation consists of allocations $\{c_t, c_{ht}, c_{ft}, x_t, x_{ht}, x_{ft}, y_t, l_t, k_{t+1}\}_{t=0}^{\infty}$ as described in section 2.1. Here we remove j subscripts that denote country because they are symmetric.

The investment choice for the household is given by the following Euler equation:

$$\left(\frac{c_t}{c_{t+1}}\right)^{-\sigma} = \frac{A_{t+1}\alpha k_{t+1}^{\alpha-1} + (1-\delta)\nu^{\frac{1-\rho}{\rho}}\left(1+\frac{\nu}{1-\nu}\tau_{t+1}^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}}}{\nu^{\frac{1-\rho}{\rho}}\left(1+\frac{\nu}{1-\nu}\tau_t^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}}} \times \beta\left(\frac{1+\frac{\mu}{1-\mu}\left(p_{t+1}\tau_{t+1}\right)^{\frac{\rho}{\rho-1}}}{1+\frac{\mu}{1-\mu}\tau_t^{\frac{\rho}{\rho-1}}}\right)^{\frac{1-\rho}{\rho}}, \tag{A.1}$$

The intra-temporal decision for consumption is:

$$c_{f,t} = c_{h,t}\tau_t^{\frac{-1}{1-\rho}}\frac{\mu}{1-\mu}, \tag{A.2}$$

The intra-temporal decision for investment is:

$$x_{f,t} = x_{h,t}\tau_t^{\frac{-1}{1-\rho}}\frac{\nu}{1-\nu}, \tag{A.3}$$

The consolidated budget constraint implies:

$$c_{h,t} + x_{h,t} + \tau_t(c_{f,t} + x_{f,t}) = y_t, \tag{A.4}$$

The capital accumulation equation is:

$$k_{t+1} = (1-\delta)k_t + x_{h,t}\nu^{\frac{\rho-1}{\rho}}\left(1+\frac{\nu}{1-\nu}\tau_t^{\frac{\rho}{\rho-1}}\right)^{\frac{1}{\rho}}, \tag{A.5}$$

Lastly, labor market and the definitions of output, consumption and investment imply:

$$\begin{aligned} l_t &= L, \\ y_t &= A_t k_t^{\alpha} l_t^{1-\alpha}, \\ c_t &= \left(\mu^{\rho-1}c_{ht}^{\rho} + (1-\mu)^{\rho-1}c_{ft}^{\rho}\right)^{\frac{1}{\rho}}, \\ x_t &= \left(\nu^{\rho-1}x_{ht}^{\rho} + (1-\nu)^{\rho-1}x_{ft}^{\rho}\right)^{\frac{1}{\rho}}, \\ p_t &= 1 \end{aligned} \tag{A.6}$$

The steady state of the dynamic model can be fully solved in closed form, which we characterization here explicitly.

Given a constant productivity A and trade costs τ, the steady state is characterized by:

$$
\begin{aligned}
k^{SS} &= \left(\frac{\beta\alpha A}{\left(1-\beta(1-\delta)\nu^{\frac{1-\rho}{\rho}}\right)\left(1+\frac{\nu}{1-\nu}(p\tau)^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}}} \right)^{\frac{1}{1-\alpha}}, \\
l^{SS} &= 1, \\
y^{SS} &= A\left(k^{SS}\right)^{\alpha}, \\
x^{SS} &= \delta k^{SS}, \\
x_h^{SS} &= x^{SS}\nu^{\frac{1-\rho}{\rho}}\left(1+\frac{\nu}{1-\nu}(p\tau)^{\frac{-\rho}{1-\rho}}\right)^{-\frac{1}{\rho}}, \\
x_f^{SS} &= x_h^{SS}(p\tau)^{\frac{-1}{1-\rho}}\frac{\nu}{1-\nu}, \\
c_h^{SS} &= \frac{y^{SS}-x_h^{SS}-p\tau x_f^{SS}}{1+(p\tau)^{\frac{\rho}{\rho-1}}\frac{\mu}{1-\mu}}, \\
c_f^{SS} &= c_h^{SS}(p\tau)^{\frac{-1}{1-\rho}}\frac{\mu}{1-\mu}, \\
c^{SS} &= c_h^{SS}\mu^{\frac{\rho-1}{\rho}}\left(1+\frac{\mu}{1-\mu}(p\tau)^{\frac{\rho}{\rho-1}}\right)^{\frac{1}{\rho}}.
\end{aligned}
\tag{A.7}
$$

A.2 Static model

An equilibrium for the model presented in section 2.2 consists of allocations:

$$
\begin{aligned}
y &= Ak^{\alpha}, \\
l &= 1, \\
c_h &= y\left(1+(p\tau)^{\frac{\rho}{\rho-1}}\frac{\mu}{1-\mu}\right)^{-1}, \\
c_f &= y\left(\frac{1-\mu}{\mu}(p\tau)^{\frac{-1}{\rho-1}}+p\tau\right)^{-1}.
\end{aligned}
\tag{A.8}
$$

B Intermediate goods case

B.1 Static model with intermediate goods

In this appendix we develop a static version of the model from section 2.1 in which the production process involves the production of an intermediate good combining domestic and foreign intermediate goods.[18]

The problem that households in country j solve is:

$$
\begin{aligned}
\max_{\{c_j,c_{hj},c_{fj}\}} \quad & u(c_j), \\
\text{subject to:} \quad & p_{hj}(c_{hj}+x_{hj})+p_{fj}\tau(c_{fj}+x_{fj}) = w_jL_j+q_jm_j, \\
& c_j = (\mu^{\rho-1}c_{hj}^{\rho}+(1-\mu)^{\rho-1}c_{fj}^{\rho})^{1/\rho}, \\
& m_j = (\nu^{\rho-1}x_{hj}^{\rho}+(1-\nu)^{\rho-1}x_{fj}^{\rho})^{1/\rho}.
\end{aligned}
\tag{B.1}
$$

[18] The model is similar to the one presented in section 3.4 of Costinot and Rodríguez-Clare (2014).

Firms

The firm in country j solves:

$$\max_{y_j, m_j, l_j} \quad p_{hj} y_j - w_j l_j - q_j m_j, \qquad \text{subject to:} \quad y_j \leq A_j m_j^{\alpha} l_j^{1-\alpha}. \tag{B.2}$$

Finally, prices are determined by market clearing conditions that are similar to those of the dynamic model, but without time subscripts. Namely,

$$\text{Labor Market:} \qquad l_j = L_j, \tag{B.3}$$

$$\text{Trade Balance:} \quad y_j - c_{hj} - m_{hj} = p\tau(c_{fj} + m_{fj}). \tag{B.4}$$

Competitive equilibrium in the static economy with intermediates

Next, we define what an equilibrium is in this economy.

Definition B.1. An equilibrium in this economy are prices $\{w_j, r_j, p\}_{j\in\{h,f\}}$ and allocations $\{c_j, c_{hj}, c_{fj}, x_{hj}, x_{fj}, k_j, y_j, l_j$ such that the household solves the problem (B.1), the firm solves problem (B.2), labor markets clear, equation (B.3), and trade balances, equation (B.4).

B.2 Isolating the transition channel

We denote the total expenditure on intermediate goods:

$$E_{mj} = q_j m_j. \tag{B.5}$$

We can compute real income in the static model with intermediates directly from the equilibrium characterization (see Appendix B.3). Real income is equal to:

$$c_j = (y_j - E_{mj})\mu^{\frac{\rho-1}{\rho}}(\lambda_j^C)^{\frac{1-\rho}{\rho}}. \tag{B.6}$$

The change in real income in this case, Δ_j^I (the superscript I stands for *intermediates*), that a consumer gets from moving from a regime of high trade costs H to a regime of low trade costs L is given by:

$$\Delta_j^I = \left(\frac{\lambda_{jL}^C}{\lambda_{jH}^C}\right)^{\frac{\rho-1}{\rho}} \left(\frac{y_{jL} - E_{mjL}}{y_{jH} - E_{mjH}}\right). \tag{B.7}$$

We see that this equation is substantially different than that from the baseline static model given by equation (3.9). As in the dynamic model, we see that the welfare-relevant measure of imports is the domestic share of expenditure restricted to consumption goods, rather than overall. This captures the *composition channel* discussed in the decomposition before. Likewise, the second term in this equation is the same as the *capital channel* in that it reflects the expenditure on consumption rather than total output.

Finally, the *elasticity channel* is captured in this model in exactly the same way as in the dynamic model if all of the following are true: the trade elasticity and domestic expenditure shares for consumption are the same in both models, consumption as a share of gross output is the same in both models, and the domestic expenditure share of investment in the dynamic model is the same as the domestic expenditure share of intermediates in this static model.[19] This is the version of the model in which intermediate inputs play exactly the same role that the endogenous accumulation of capital plays in the dynamic model.

In that case, the analogue of equation (3.11) is:

$$\frac{\Delta_j^D}{\Delta_j^I} = \left(\sum_{t=0}^{\infty} \beta^t \left(\frac{c_{jt}}{c_{jL}}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}. \tag{B.8}$$

This is exactly the same formula for the *transition channel* discussed before. Moreover, under the set of assumptions made above, we can use exactly the same set of computed results from before to quantify the difference between the dynamic model of capital accumulation and the static model with intermediate goods. On Table 2, if one subtracts the terms in the row labeled “Decomposition” from the row labeled “Dynamic Gains”, that gives the natural logarithm of the change in real income in the static model with intermediate goods. Given that the only remaining channel in this case is the transition, then the fact that transitions from high to low trade costs are always costly in this environment implies that the model with intermediate goods will always have higher gains from trade than the model with capital accumulation.

B.3 Static model with intermediates

An equilibrium for the model presented in section B.1 consists of allocations:

$$\begin{aligned}
&l = 1, \\
&x_h = \left(\alpha A \nu^{\alpha\frac{\rho-1}{\rho}}\right)^{\frac{1}{1-\alpha}} \left(1 + \frac{\nu}{1-\nu}(p\tau)^{\frac{\rho}{\rho-1}}\right)^{\frac{\alpha-\rho}{\rho(1-\alpha)}}, \\
&x_f = x_h \frac{\nu}{1-\nu}(p\tau)^{-\frac{1}{1-\rho}}, \\
&q = x_h \nu^{\frac{\rho-1}{\rho}} \left(1 + \frac{\nu}{1-\nu}(p\tau)^{\frac{\rho}{\rho-1}}\right)^{\frac{1}{\rho}}, \\
&c_h = \alpha^{\frac{\alpha}{1-\alpha}} A^{\frac{1}{1-\alpha}} (1-\alpha) \nu^{\frac{\alpha}{1-\alpha}\frac{1-\rho}{\rho}} \frac{\left(1 + \frac{\nu}{1-\nu}(p\tau)^{\frac{\rho}{\rho-1}}\right)^{\frac{\alpha}{1-\alpha}\frac{1-\rho}{\rho}}}{\left(1 + \frac{\mu}{1-\mu}(p\tau)^{\frac{\rho}{\rho-1}}\right)}, \\
&c_f = c_h \frac{\mu}{1-\mu}(p\tau)^{-\frac{1}{1-\rho}}, \\
&y = A m^{\alpha} L^{1-\alpha}.
\end{aligned} \tag{B.9}$$

[19] Under these assumptions, it can be shown that ν, μ, and ρ are the same in both models. This can be proven using the characterizations in Appendix A.1 and A.3.

Table 1: Parameters in Calibrated Model

Parameter	Baseline, 25% Cut	Recalibrated to Fix Trade Elasticity 5% Cut	10% Cut	40% Cut	50% Cut
Capital Share, α	0.3414	0.3412	0.3412	0.3415	0.3416
Discount Factor, β	0.96	0.96	0.96	0.96	0.96
Domestic Labor, L_1	1	1	1	1	1
Foreign Labor, L_2	1	1	1	1	1
Initial Trade Cost, τ^H	1.50	1.50	1.50	1.50	1.50
Final Trade Cost, τ^L	1.25	1.45	1.40	1.10	1.00
Import Weight (Consumption), μ	0.4085	0.4063	0.4068	0.4102	0.4111
Import Weight (Investment), ν	0.6094	0.6073	0.6078	0.6111	0.6120
Substitutability of Goods, ρ	0.8361	0.8355	0.8356	0.8365	0.8368
Preference Parameter, η	0.5	0.5	0.5	0.5	0.5
Capital Depreciation, δ	0.1	0.1	0.1	0.1	0.1

Table 2: Gains from Trade and Decomposition

	Baseline,	Constant ρ				Recalibrated to Fix Trade Elasticity			
	25% Cut	5% Cut	10% Cut	40% Cut	50% Cut	5% Cut	10% Cut	40% Cut	50% Cut
Initial λ_j	89.9%	89.9%	89.9%	89.9%	89.9%	89.9%	89.9%	89.9%	89.9%
Final λ_j	78.3%	88.2%	86.3%	66.2%	55.6%	88.3%	86.3%	65.4%	54.0%
Trade Elasticity	5.000	5.022	5.017	4.983	4.975	5.000	5.000	5.000	5.000
ACR Gains	2.79%	0.37%	0.81%	6.34%	10.14%	0.37%	0.82%	6.56%	10.72%
Dynamic Gains	3.69%	0.48%	1.07%	8.43%	13.54%	0.48%	1.08%	8.82%	14.57%
Log-Difference	0.90%	0.12%	0.26%	2.09%	3.40%	0.11%	0.26%	2.12%	3.48%
Decomposition:									
Transition	-0.88%	-0.12%	-0.27%	-1.88%	-2.84%	-0.12%	-0.26%	-1.86%	-2.81%
Capital	2.29%	0.31%	0.68%	5.01%	7.72%	0.31%	0.68%	5.15%	8.07%
Composition	-0.46%	-0.07%	-0.15%	-0.90%	-1.24%	-0.07%	-0.15%	-0.89%	-1.23%
Elasticity	-0.05%	-0.01%	-0.01%	-0.15%	-0.25%	-0.01%	-0.01%	-0.15%	-0.25%

Table 3: Parameters in Alternative Cases

Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Capital Share, α	0.3414	0.3414	0.3032	0.3488	0.3414	0.3414	0.3201
Discount Factor, β	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Domestic Labor, L_1	1	1	1	1	1	1	1
Foreign Labor, L_2	1	1	1	1	1	1	3.3861
Initial Trade Cost, τ^H	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Final Trade Cost, τ^L	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Import Weight (Consumption), μ	0.4085	0.6094	0.2312	0.8478	0.4085	0.4085	0.2595
Import Weight (Investment), ν	0.4085	0.4085	0.4046	0.9264	0.6094	0.6094	0.4420
Substitutability of Goods, ρ	0.8361	0.8361	0.7531	0.9111	0.8361	0.8361	0.8296
Preference Parameter, η	0.5	0.5	0.5	0.5	0.33	10	0.5
Capital Depreciation, δ	0.1	0.1	0.1	0.1	0.1	0.1	0.1

(1): Equal Import Weights, (2): Reversed Import Weights, (3): Low Trade Elasticity, (4): High Trade Elasticity, (5): High Intertemporal Elasticity, (6): Low Intertemporal Elasticity, (7): Asymmetric Countries.

Table 4: Gains from Trade and Decomposition in Alternative Cases

	(1)	(2)	(3)	(4)	(5)	(6)	(7a)	(7b)
Dynamic Gains	3.01%	5.15%	2.94%	5.64%	3.70%	3.67%	3.75%	1.16%
ACR Gains	2.28%	3.90%	2.31%	4.22%	2.79%	2.79%	2.76%	0.87%
Log-Difference	0.73%	1.25%	0.64%	1.42%	0.90%	0.88%	0.99%	0.29%
Decomposition:								
Transition	-0.45%	-0.45%	-0.61%	-1.29%	-0.87%	-0.90%	-0.81%	-0.27%
Capital	1.18%	1.18%	1.65%	3.36%	2.29%	2.29%	2.18%	0.79%
Composition	0.00%	0.58%	-0.37%	-0.56%	-0.46%	-0.46%	-0.45%	-0.18%
Elasticity	0.00%	-0.06%	-0.04%	-0.10%	-0.05%	-0.05%	0.07%	-0.05%

(1): Equal Import Weights, (2): Reversed Import Weights, (3): Low Trade Elasticity, (4): High Trade Elasticity, (5): High Intertemporal Elasticity, (6): Low Intertemporal Elasticity, (7): Asymmetric Countries, where a is the small country and b is the large country.

Table 5: Parameters in Models with Firms

Parameter	No Capital	With Capital
Capital Share, α	0	0.2481
Discount Factor, β	0.96	0.96
Domestic Labor, L_1	1	1
Foreign Labor, L_2	1	1
Initial Trade Cost, τ^H	1.25	1.25
Final Trade Cost, τ^L	1	1
Import Weight (Consumption), μ	0.2309	0.2282
Import Weight (Investment), ν	-	0.4006
Substitutability of Goods, σ	5.3478	5.3478
Productivity Distribution, θ	5	5.0888
Preference Parameter, η	0.5	0.5
Capital Depreciation, δ	-	0.1
Fixed Cost to Open, f	1	1
Export Cost, f_x	0.0313	0.0351
Continuation Rate of Firms, δ_f	0.9380	0.9380

Figure 1: Transition in Model with Capital Accumlation

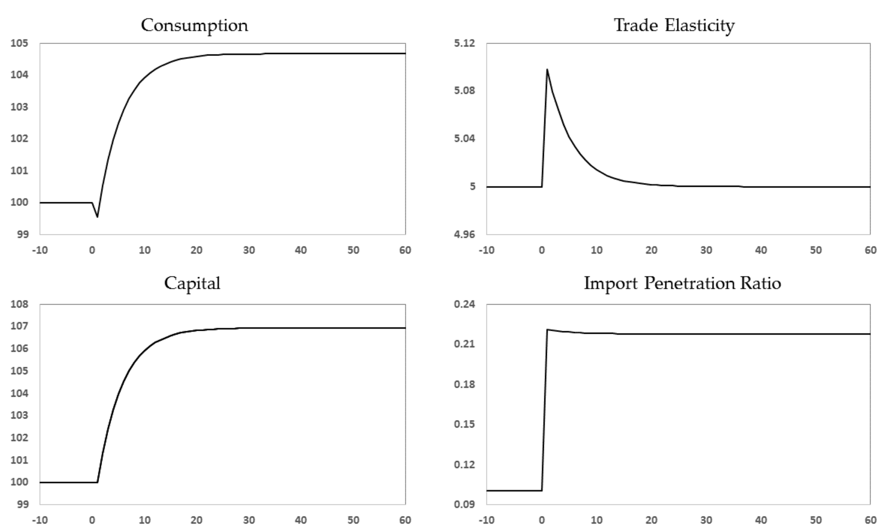
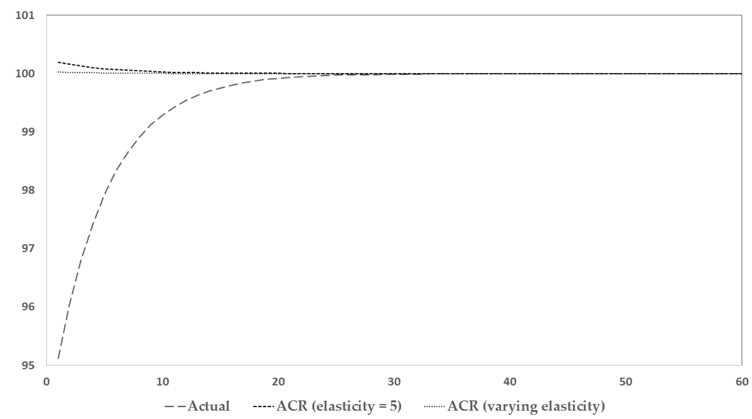
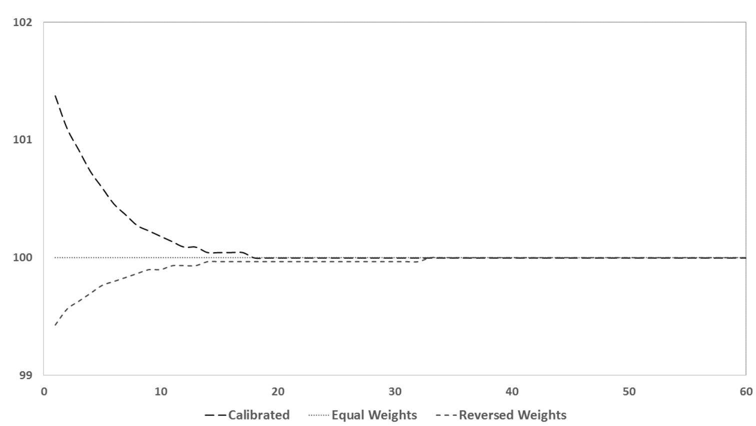


Figure 2: Actual Transition versus ACR Formula



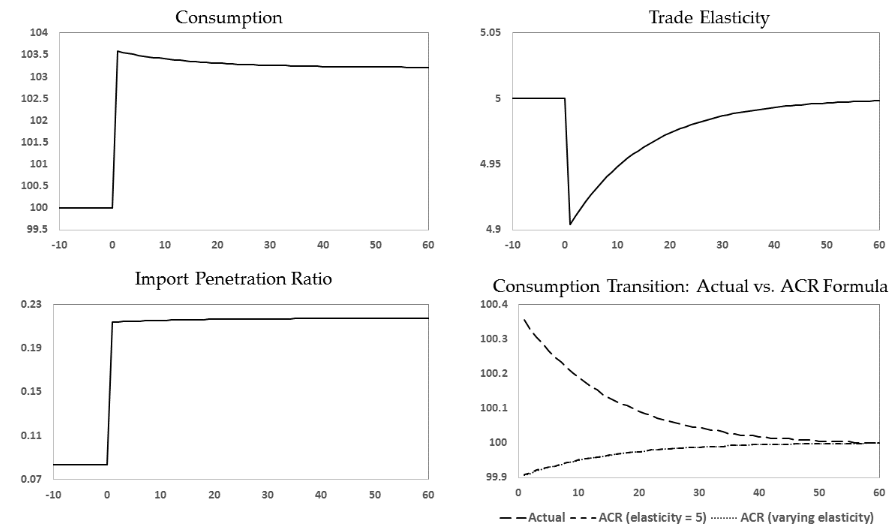
"Actual" gives the transition for consumption with the level of consumption in the low trade cost steady state normalized to 100. The other two series give the dynamic of the ACR formula applied to the time series from the dynamic model period-by-period, again normalized to their long run value. In one case we use the long run elasticity of 5, and in the other we use period-by-period trade elasticity implied by equation (4.1).

Figure 3: Import Intensity of Investment vs. Consumption



This displays the transition dynamic of the import penetration ratio under three parameterizations with the long run value of the import penetration ratio normalized to 100. In the calibrated model, final investment goods have higher import content than final consumption goods. We compare this transition to the cases where the import content of both are equated, and where the calibrated import weights on the two final goods are reversed.

Figure 4: Transition in Model with Firms and No Capital



The lower right panel has the same interpretation as Figure 2.

Figure 5: Transition in Model with Both Firms and Capital

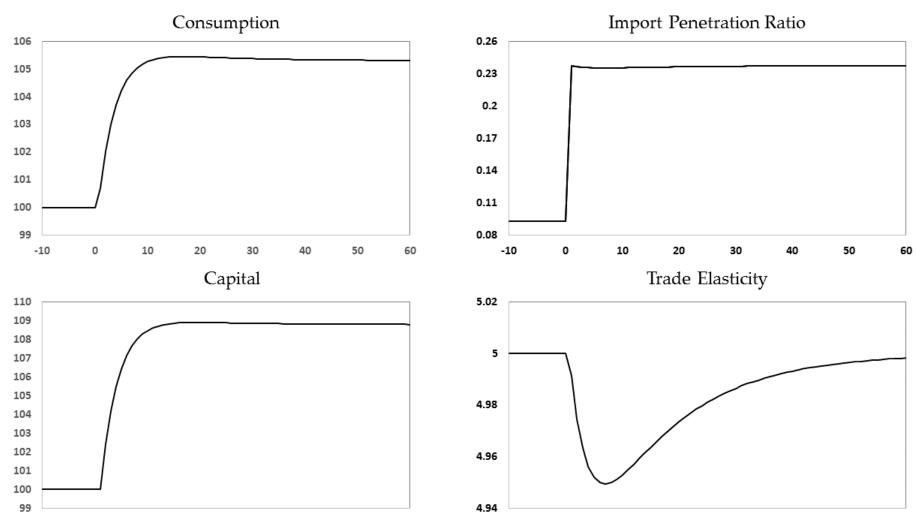
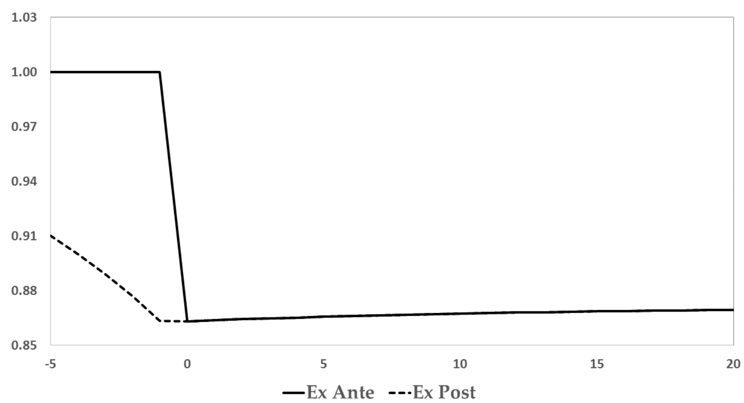


Figure 6: Expected Present Value of a Marginal Firm



For the marginal entrant from the high trade cost steady state, this shows the ratio of the expected present value to the value of the fixed cost paid for it to enter. "Ex Post" values the firm using the fact that the trade cost reduction happens in period zero. "Ex Ante" is evaluated in each period using the information set of the firm. These differ because the trade cost reduction is unforeseen.