A long-standing concern is that adjustment costs will dampen the gains to trade in the short run. Firms and workers in industries hit with rising imports will suffer profit and job losses. In this paper, we build a standard model of endogenous growth and trade, providing a tight link between trade liberalizations and increases in the long-run growth rate. Motivated by recent empirical evidence which suggests that increased low-cost import competition stimulated innovation at affected firms, we also incorporate "trapped factors:" short-run adjustment costs that restrict the movement of inputs across firms. In this model, trade liberalizations with low-cost countries like China cause a reduction in the opportunity cost of fixed inputs at shocked firms, giving them an incentive to redeploy those inputs away from producing old goods and towards innovative activity to develop and produce new goods. The presence of trapped factors leads to a permanent increase in the level of patents or varieties in the economy, as well as output and consumption, relative to an economy without adjustment costs. This actually generates an increase in welfare, suggesting that models ignoring trapped factors underestimate the gains from trade liberalization.

I. Empirical Motivation

Business case studies have long suggested that bad news in the form of increased import competition from low-cost countries can cause firms to "innovate or die." For example, Freeman and Kleiner (2005) describe how a US shoe maker responded to rising Chinese imports by halting production of mass-market men’s shoes that were no longer profitable. Rather than simply idle its factory, skilled employees, brand capital and organizational resources, the firm introduced new types of shoes for smaller niche markets. One specially designed batch of boots, run off for a local construction firm, had metal hoops in the soles that made it easier for workers to rapidly climb ladders. Making these boots took skilled engineers and R&D. The new design earned a patent. Bartel, Ichinowski and Shaw (2007) report a similar story from US valve manufacturers. After losing the market for low-cost valves to Chinese competitors they switched to inventing and producing smaller runs of innovative valves. This required enlarging their engineering team and increasing R&D directed towards new products.

Note: Data from 23,000 firms across 12 European countries from 2000 to 2007. Source: Bloom, Draca and Van Reenen (2012). IT intensity defined as computers per employee, Chinese import growth defined as the change in China’s share of all European imports.

The behavior reported in these case studies has also been confirmed in an econometric analysis on large panel data samples of firms in 12 European countries by Bloom, Draca and Van...
Reenen (2012). Firms that experienced a large increase in import competition after China’s accession to the WTO rapidly increased their R&D expenditure, patenting and adoption of IT (see Figure 1). These changes were not merely the result of reallocation toward more innovative firms. Individual firms that faced more import competition exhibited a bigger increase in innovation. Nor did the results simply reflect the pro-innovation “escape competition” effects that arise in quality ladder models (e.g. Aghion, et al (2005)) as increased competition from high-cost OECD countries (like Japan) did not lead to a similar increase in innovation.

The first challenge that these results pose is to explain the difference in the behavior of an individual firm before and after a trade shock. Why is it that they innovate after something bad has happened to them? The usual presumption is that a negative shock will reduce investment, because it signals either lower expected returns or higher expected costs from more reliance on external finance. The second challenge is to explain the cross-sectional difference in the behavior between firms after the shock hits. The move to a more open trade regime could raise the return to innovation, as models of trade and growth suggest. In this case, the incentive to innovate should be higher for all firms. Once again, the usual presumption would be that the firms that face a significant loss in revenue would be no more likely, and perhaps much less likely, to take advantage of the new opportunities. Why then do the results show just the opposite, that it is the firms that face more competition from imports that undertake relatively more innovation? The final challenge is why does this increase in innovation arise in response to low-cost export competition from China but not from high-cost export competition from countries like Japan?

The dynamic general equilibrium model fully developed with details available in Bloom, et. al. (2012) shows that adversity can indeed increase the rate of innovation if factors of production are trapped inside a firm. For the shoe company mentioned above, its workers might be trapped because they have human capital that is specific to the firm and which will be lost if they move to other firms. The firm’s physical capital might also be costly to uproot and sell. After the trade shock reduces the price for one of the goods that the firm had been producing, the opportunity cost goes down for inputs that are trapped within the firm. The firm does more innovation, not because of an increase in the value of a newly designed good, but rather because of a fall in the opportunity cost of the inputs used to design and produce new goods.

II. A Model of Growth and Trade

Our model of growth extends the lab-equipment model of growth and trade proposed in Rivera-Batiz and Romer (1991), which builds on the closed-economy model in Romer (1987). We assume a West-East model of the product cycle in which all innovation takes place in the West. (The West-East axis now seems a better way to capture trade flows between high- and low-wage countries than the traditional North-South axis.) Our extension allows not just for the extremes of autarky and free trade, but also for a continuum of intermediate degrees of trade integration indexed by a parameter $\phi$, which measures the fraction of goods that are allowed to trade freely. Consistent with previous results on growth and trade, an increase in trade integration ($\phi$) also raises the returns to innovation and increases the rate of growth of patents and the rate of growth of output, which benefits both regions.

A change in $\phi$ also induces a change in the terms of trade. When $\phi$, which can be interpreted as a quota, is low enough to impose binding restrictions on the pattern of trade, the exchange rate, measured as the cost in units of output in the West of a unit of output from the East, is less than one. As one would expect from traditional trade models, an increase in $\phi$ leads to a worldwide increase in the level of output. Here, the level gains are concentrated in the East. It has a cost advantage in producing any goods that are off patent. When the trade restriction is loosened, it exports more to the West. To balance trade, the exchange rate increases toward 1, the value that would prevail under free trade. So the increase in $\phi$ changes the terms of trade in favor of the East.

Let $g(\phi)$ denote the steady-state growth rate associated with a given level of trade integration. We calibrate the model to the US experience in the last few decades and find that the increase in the growth rate associated with a change in $\phi$ is moderate. Increased trade with developing
countries such as China could boost the world-wide steady-state growth rate by about 0.1 percentage points, so \( g(\phi') - g(\phi) \approx 0.1\% \). In our baseline this means that growth rises from 2.0 to 2.1 percentage points per annum (a 5% rise in global growth).

For convenience, we work with an endogenous growth model in which a change in policy leads to this kind of change in the steady-state growth rate. We do this because it is easier to capture the effects of policy changes if most of the analysis takes the form of a comparison of different steady-state growth rates. Small parameter changes could convert the model into a semi-endogenous growth model of the type proposed by Jones (1995b) without any fundamental changes in the conclusions of our model. As Jones argues (1995a), the semi-endogenous growth model provides a better fit to date over horizons long enough for the stock of human capital to increase substantially. In those models, policy can also have a potentially long-lasting effect on the rate of growth, which in turn has a permanent effect on future levels of the variables that grow.

To further limit the importance of any transition dynamics, we also minimize the persistence in the model. In particular, we assume that durable inputs in production last for only one period and that patents also last for only one period. With these assumptions, it takes only a few periods to converge to a new, slightly higher steady-state growth rate after an unexpected change in \( \phi \).

### III. Trapped Factors

We then add trapped factors, adjustment costs preventing movement of inputs across firms within the period of a trade shock, and assume that the new import competition is concentrated in a subset of firms.

This feature can then reproduce the cross-sectional results from Bloom, Draca and Van Reenen (2012) that firms hit with increasing trade competition increase innovation. Suppose there is an increase from \( \phi \) to \( \phi' \), that is a sudden rise in the range of goods that are allowed as imports from the low-cost East. Assume this impacts only the goods that are made by a subset of firms, so some firms experience more trade competition while others do not. Let \( g(S) \) for “Shocked”) denote the rate of growth of patents at firms that face this trade shock and let \( g^N \) (\( N \) for “No shock”) denote the growth rate of patents at firms that face no new competition for goods that they make. When the shock from \( \phi \) to \( \phi' \) is announced for period \( T \), we find that

\[
g_T^S(\phi') > g_T^N(\phi') > g(\phi)
\]

Moreover, the difference between the two types of firms is large. In our baseline model, the number of new patents developed by a representative \( S \) firm that faces a shock jumps up to a level that is 15.1% higher than for an \( N \) firm with no shock. This cross-sectional impact on patenting rates can be seen in Figure 2, which plots for each industry the flow of new patents in the trapped-factors environment. For convenience, the pre-shock patent flows have been normalized to 1000 patents for each type of firm. The figure also shows the identical rate of growth of patents for the two types of firms when factors are fully mobile.

![Figure 2: Industry patent flows increase with import exposure](image)

Note: A trade shock occurs in period 1. All results in this figure are produced using code available at [http://www.stanford.edu/~nbloom/BRTV.zip](http://www.stanford.edu/~nbloom/BRTV.zip).

To indicate the effect that the trapped factors and trade shock have on the aggregate rate of growth in the impact period which we denote by \( T \) (period 2 in the simulation in Figure 2), let \( g_T^{Trapped} \) be the aggregate rate of growth of patents when factors are trapped and the trade shock is unanticipated. Let \( g_T^{Mobile} \) denote the corresponding rate of growth when all factors...
are fully mobile. We find that
\[ g_{T}^{Trapped} > g_{T}^{Mobile} \]

In our calibrated baseline, this one period growth boost, while strictly positive, is modest, \( g_{T}^{Trapped} - g_{T}^{Mobile} \approx 0.1\% \), about the same size as the change in the balanced growth rates, \( g(\phi^*) - g(\phi) \). This means that in period \( T \) the growth rate is 2.2 percentage points instead of 2.1 percentage points in the fully mobile case (and 2 percentage points in the pre-shock economy). Although the doubling of the trade effect on growth in the initial post-shock period is substantial, because it dies out after one period it is much less important than the standard general equilibrium effect of openness on growth. This one period trapped-factors boost in the growth rate of patents causes a permanent increase in the stock of patents. Because the decentralized rate of innovation in such models is below the social optimum, the temporary boost in the growth rate and the permanent increase in the range of intermediate inputs induced by the interaction of trapped factors and the trade shock causes a correspondingly modest but positive increase in welfare in both the West and the East.

This kind of counter-intuitive “second-best” welfare result helps capture the essence of the predictions in the model. But it does not suggest new policy options such as using legislation to force higher costs on firms that lay off workers or sell off capital. The analysis here is premised on the assumption that the change in \( \phi \) is unanticipated. If policymakers try to trap factors in firms to benefit from anticipated trade shocks, firms will reduce their input demands in response.

However, the existence of trapped factors does change the trade-offs faced by policymakers considering trade liberalization. In the spirit of specific factors models of international trade in the short run as introduced by, for example, Jones (1971) and Samuelson (1971), the short-run impact of trade liberalization along the transition path can differ from the long-run impact. However, the novel increase in innovation observed on impact of the trade shock in our trapped-factors framework suggests that models without trapped factors underestimate the variety and welfare gains from trade liberalization.

IV. Magnitudes of Trapped-Factor Approaches

The magnitudes of the growth and welfare effects identified here are also sensitive to a crucial parameter in the model. For a calibrated version of a model like this to fit actual data, there must be some short-run decreasing returns in the technology that converts inputs into new patents. Increasing the quantities of inputs that are devoted to innovation in a period by some factor \( \lambda \) should not lead to an increase in the number of patents by the same factor. Following Jones and Williams (2000), we assume that patents increase instead by the factor \( \lambda^{1/2} \). A simple way to understand the source of these diminishing returns is to think of innovation as a search process. If a larger team is engaged in search, the difficulties of coordinating the search effort means that there is a higher probability that different groups make redundant discoveries. With two independent discoveries of something like a long-lasting light bulb, the number of new goods goes up by only one.

The key issue here is whether the challenge of avoiding redundant discoveries is entirely internal to a firm or extends across firms. It will be largely internal if different firms naturally specialize in separate parts of search space. It will be at least partly external to an individual firm if all firms tend to search in the same parts of search space. Patent race models typically assume the extreme case of costs that are entirely external, in which case the production function for new designs exhibits a form of Marshallian external diminishing returns.

To capture the entire range of possibilities, the model allows for a parameter \( \eta \) that indexes the continuum of possibilities ranging from fully internal to fully external costs. The baseline specification described above, has \( \eta = 1 \), which implies that the costs are fully internal. In an alternative specification that allows for external costs, the magnitude of the trapped-factors boost to growth should be smaller because the higher research costs (or equivalently the lower productivity of research) caused by more innovation at the shocked firms leads to an increase in the innovation cost at the no-shock firms, hence a reduction in the innovation they undertake. For example, in a specification that allows for \( \eta = 0.5 \), hence a 50-50 split between internal
and external costs, we find that the magnitude of the difference $g_{T}^{\text{Trapped}} - g_{T}^{\text{Mobile}}$ is about half as large as in our baseline. But, since the estimates of technology spillovers uncovered by Bloom, Schankerman and Van Reenen (forthcoming) cannot reject the hypothesis that the costs of innovation are fully internal ($\eta = 1$), we use this as our benchmark.

We conclude that the model suggests the combination of trapped factors and asymmetric trade shocks causes a modest boost to welfare and growth, but quantifying this effect with precision requires much more work.

V. Micro Evidence and Macro Effects

We close with a discussion of what one could infer about aggregate effects from a microeconomic analysis like the one undertaken by Bloom, Draca and Van Reenen (2012). As applied to data generated by our model, their approach would involve running a regression of the log of the number of new patents developed by the two types of firms on year dummies that pick up the trends and a shocked-firm dummy that picks up the difference between the $S$ (shocked) and $N$ (non-shocked) firms. Using data from the model, this regression would show a higher rate of patenting for the $S$ firms in the impact period, $T$.

With large numbers of firms and no other macro shocks, this difference could be precisely estimated. The year dummies could also be used to estimate the aggregate impact - they would have magnitudes that grow at the rate $g(\phi)$ before the shock, $g^{T} (\phi')$ during the impact period, and $g(\phi')$ after the shock. However, other factors (like the business cycle for example) are likely to cause year-to-year fluctuations in innovation, so aggregate values are likely to contain too much noise to measure the effect of increasing Chinese trade.

Helpfully, the cross-sectional differences $g_{T}^{S} - g_{T}^{N}$ do provide some additional information for the type of general equilibrium model developed here. So extending models to capture these empirically important cross-sectional effects leads to tighter predictions about the aggregate effects. In this sense, our conclusion is more positive about the value of micro evidence in predicting aggregate behavior than the conclusions reached, for example, by Arkolakis, Demidova, Klenow and Rodríguez-Clare (2008), Atkeson and Burstein (2010) and Arkolakis, Costinot and Rodríguez-Clare (2012).

VI. Conclusions

We build a standard model of endogenous growth and trade, providing a tight link between trade liberalizations and increases in the long-run growth rate. Motivated by empirical evidence which suggests that increased low-cost import competition stimulated innovation at affected firms, we incorporate short-run trapped factors which prevent movement of inputs across firms. Reductions in the opportunity cost of fixed inputs at shocked firms in the period of a trade liberalization yield an increase in innovative activity at those firms using these inputs. The presence of trapped factors leads to a permanent increase in the level of patents or varieties in the economy, as well as output and consumption, relative to an economy without adjustment costs, as well as an increase in welfare, suggesting that models ignoring trapped factors underestimate the gains from trade liberalization.

VII. References


