Escaping the Losses from Trade: The Impact of Heterogeneity on Skill Acquisition*

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Abstract

Future generations of workers can invest in education and avoid the negative consequences of trade openness for low-skilled workers. We exploit variation in exposure to import penetration shocks across space in the United States to show that greater exposure (i) deteriorated labor market conditions for workers without a college education, (ii) increased overall college enrollment, and (iii) that the increase in enrollment is entirely driven by students in richer households. To analyze the welfare implications of the effects of trade openness on college enrollment, we propose a dynamic model of international trade with heterogeneous households. The model features incomplete credit markets and costly endogenous skill acquisition by new cohorts of workers. We calibrate the model to match trends in aggregate trade data for the United States between the late 1980s and 2010. A decline in import barriers for manufacturing goods generates increased college enrollment and positive welfare gains for all workers in the long-run, but significant losses for workers in manufacturing in the short-run, particularly for those without a college education. Even though college enrollment for new cohorts increases over time, low-wealth/low-income generations of households take the longest to acquire skills. They are therefore the last to experience positive gains from trade openness, and in some cases may not realize any gains within a life-time.

*The views in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

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1 Introduction

Trade openness affects workers unevenly. By shifting economic activity across occupations, firms, or industries, freer trade generates gains for specific groups of workers, but also significant losses for others. For instance, over the last few decades, trade openness has lead to a decline in the income of workers without a college education—or lower skills—relative to the income of college-educated workers.[1] These distributional consequences generate incentives for affected workers to adjust over time, thus leading to different effects in the short and long term. While existing literature has focused on understanding how current generations of workers adjust to freer trade by switching occupations, firms, industries, or regions, recent work has overlooked skill acquisition decisions by future generations of workers, particularly college enrollment, as another margin of adjustment to trade openness.

There are two key forces driving the effects of trade openness on skill acquisition decisions: incentives and resources. On one hand, trade openness increases the income premium for all skilled workers which will incentivize future generations of workers to invest in education and eventually benefit from their high-skill.[2] Hence, potential low-skilled workers that could experience any adverse effect of trade openness can escape any possible losses by investing in skill acquisition if they find it beneficial. On the other hand, even if future workers find beneficial to invest in education, they may lack the resources to make that investment. Thus, potential workers with similar ability but different wealth may pursue alternative education investment decisions and experience heterogeneous effects of trade openness.[3] Consequently, trade openness not only has consequences on inequality going forward, but such consequences can also be shaped by initial income and wealth inequality.

In this paper, we explore the effects of trade openness on welfare and inequality by taking into account these two key forces. Our analysis consists of two parts. In the first part of our analysis we study empirically how trade shocks have affected college enrollment decisions. To do so, we follow a similar strategy as Autor et al. (2013) and exploit variation in exposure to trade shocks across space in the United States between 1990 and 2007. We show empirically that greater import penetration increases college enrollment. We provide such evidence by showing that import penetration (i) deteriorated labor market conditions for workers without a college education (Autor et al., 2013; Kim and Vogel, 2018), (ii) increased overall college enrollment, and (iii) that the increase generated in college enrollment is driven by future workers in richer households. Our results imply that a \$1,000 increase in import penetration increased the fraction of 18 to 25 year olds enrolled in their

[1] Autor et al. (2016) and Kim and Vogel (2018) provide evidence of the unequal effects of trade openness on different groups of worker in the United States. Burstein et al. (2013) and Burstein et al. (2016); Burstein and Vogel (2017) focus on the effects of trade on the college wage premium.

[2] See Findlay and Kierzkowski (1983) for a theoretical account of this mechanism and Atkin (2016) and Greenland and Lopresti (2016) for empirical analyses of the effects of trade on incentives for school attendance and completion.

[3] The importance of liquidity constraints on education attainment has been subject of multiple studies going back to (Becker, 1975). Belley and Lochner (2007) show that parental financial resources mattered significantly for college attendance in the 2000s. See Heckman and Mosso (2014) for a survey of the literature. Even in the absence of such constraints, introducing the possibility to acquire skill into the analysis of the effects of trade on workers poses important challenges associated with the intrinsic dynamics associated with the intertemporal tradeoff of consumption entailed in acquiring costly education

first year of college by 19 basis points. However, while this effect is not significantly different from zero for the lowest income quartile, it is of 35 basis points for the highest income quartile. In the second part of our analysis we study the welfare consequences of trade openness in the presence of endogenous skill acquisition decisions. To do so, we build a dynamic life-cycle international trade model of a multi-region small open economy (SOE) with heterogeneous households and incomplete credit markets. The model features costly endogenous skill acquisition and idiosyncratic uninsurable risk (Aiyagari, 1994), which, together with a stochastic evolution of skills, induces an equilibrium wealth distribution. These features result key to understand the short- and long-run implications of trade openness. In the model, trade liberalization results in a higher wage premium, which leads households to invest more in education.[4] However, the pace at which households invest depends not only on their productivity, but also on their wealth: Poor households will take the longest to acquire skills and, therefore, will be the last to experience positive gains from trade openness and, in some cases, they might not even experience these gains. Thus, wealth heterogeneity is key to understand why, even allowing for endogenous skill acquisition, workers might lose from trade. Moreover, the model includes heterogeneity across regions which allow us to consider the effects of exogenous import penetration shocks that affect regions differently, exactly as the type of shocks that we exploit in our empirical analysis. Hence, we obtain a clear mapping between the data and the model.

We calibrate the model to a single region or "island" representing the U.S. economy, and consider a trade shock that reduces the cost of importing manufacturing goods which are domestically produced by the sector that is intensive in low-skilled labor.[5] The trade shocks we choose are such that the model matches the decline in the home-bias of the manufacturing sector observed in the United States between the late 1980s and 2010. We derive three main results from our analysis. First, trade liberalization increases everyones welfare in the long-run. This is not only because of the productivity gains from lower trade costs reflected on the lower overall prices of consumption goods, but also because of endogenous skill acquisition decisions as an additional margin of adjustment for future generations of workers. However, and second, many workers lose from trade openness in the short-run. In particular, those who were initially low-skilled and too poor to afford skill acquisition. Importantly, the initial distribution of wealth across low-skilled workers determines how long it will take for these workers to experience gains from trade. Third, because heterogeneity of wealth matters for skill acquisition, we find that heterogeneity in wealth amplifies the effects of trade openness on between-group inequality. In particular, trade openness sharply increases inequality in the short run, but it eventually converges to lower levels of inequality although larger than the ones the economy had initially.

We carry out a detailed analysis of the model to derive the three main results of this paper. First we analyze the two steady states of the economy—before and after a shock leading to a decline trade barriers, which we label as closed and open economies respectively. We show that the drop in trade

[4] See Findlay and Kierzkowski (1983) and Danziger (2017) among others.

[5] The calibration and analysis of the model for an economy with multiple interconnected regions is currently work in progress.

costs leads to a long-run increase in the wage premium of 0.2 percent across steady states. The higher wage premium induces households to invest more in education and the measure of skilled workers increases by 0.6 percentage points. This increase in high-skilled workers results from a change in optimal education policies, such that poorer households are more likely to acquire skills in the open economy. Interestingly, we find that the wealth distributions for both high-skill and low-skill workers shift to the right, implying that in the open economy every worker is richer than in the closed economy, and therefore, all new generations are better off in the long-run.

The long-run results mask important difference in the wage premium and welfare gains from trade along the transition from the closed steady state to the open one. Along the transition, the wage premium initially overshoots the open economy level and then converges gradually as more workers decide to invest in education. On impact, the college-wage premium increase by approximately 10 times the increase in such premia across steady states. After twenty years, the wage premium—and therefore also the income premium in the model—is 1.5 percentage points above its level in the closed economy steady state. These 1.5 percentage points are comparable to our empirical estimate of an interquartile effect of import penetration shocks on the income of college graduates relative to high school graduate of approximately 1 percentage points (see column (1) in Table 2). However, this comparison must be made with caution given that we are considering an "island" economy. The share of workers with a college degree also overshoots, increasing sharply initially and eventually declining to reach the new steady state level. Consequently, trade openness in the short-run is beneficial for high-skilled-wealthy households but detrimental for low-skilled-poor ones, a finding that extends the classic *Stolper-Samuelson* theorem to the case of endogenous skill acquisition and welath heterogeneity.

Why do low-skilled workers not invest in education and benefit from high-skilled wages? Because education investment is costly and poor households cannot afford it, thus they endure the transition towards the open economy. This is a key mechanism in the model, which lies in the interaction of endogenous skill acquisitions and an equilibrium wealth distribution. As we show, losses from trade for poor households can be substantial: up to 5 percent of life-time consumption and lasting as long as ten years.

Related Literature This paper is related to multiple strands of literature in International Trade and Macroeconomics. First, the paper is related to the relatively scarce literature on the effects of trade on skill acquisition. Findlay and Kierzkowski (1983) incorporate the formation of human capital into the two-factor, two-good model of international trade and show that the implications of the model are consistent with the empirical evidence on the role of human capital in explaining patterns of comparative advantage. Danziger (2017) considers a dynamic two-symmetric-country Melitz-type trade model with endogenous skill demand and supply and calibrates it to show that ignoring adjustments in skill supply leads to a substantial bias in the quantitative assessment of trade liberalization. Atkin (2016) presents empirical evidence that the growth of export manufacturing in Mexico during a period of major trade reforms altered the distribution of education. Greenland and Lopresti (2016) show empirically that high school graduation rates increased in regions that suffer greater import penetration shocks cause"China Shock". We contribute to this literature by providing evidence of the increase in college enrollment generated by trade openness and proposing a quantitative trade model with heterogeneous agents whose consumption can differ from earnings. Our models allows us to carry out welfare calculations.

The previous contribution puts this paper very close to recent literature exploiting heterogeneous agents macro models to understand the effects of trade shocks. Lyon and Waugh (2017) and Lyon and Waugh (2018) embed the trade model of Dornbusch et al. (1977) in which each sector represents a local labor market into a small open economy setting with heterogeneous agents and incomplete markets to study redistribution policies and quantify the losses form trade, respectively. This paper contributes to this strand of literature by considering differences in endogenously determined skill levels in a life-cycle setting.

The paper also contributes to the quantitative literature on the effects of trade between different groups of workers. Kim and Vogel (2018) explore the different margins of adjustment along which groups of current workers adjust to import penetration shocks across regions in the United States. Burstein et al. (2016) quantify the impact of computers, occupations, and international trade on U.S. between-group inequality and show that moving to autarky in equipment goods and occupation services in 2003 reduces the skill premium by 2.2 and 6.5 percentage points, respectively; Burstein and Vogel (2017) introduce firm and sector heterogeneity into the standard Heckscher-Ohlin framework and find that reductions in trade costs increase the skill premium in almost all countries. We contribute to this literature not only by examining changes in skill acquisition induced by the initial changes in the skill premium caused by lower trade costs, but also by adding the important dimension of wealth heterogeneity in order to understand the impact of trade.

The paper also contributes to the literature on the effects of trade shocks on labor markets. Autor et al. (2013) and Pierce and Schott (2016) provide empirical evidence on the effects of trade shocks on labor markets. Autor et al. (2013) provide evidence of a negative effect on earnings and employment in labor markets relatively more exposed to import competition shocks. Pierce and Schott (2016) also show the industries that we relatively more exposed to import competition form China also saw greater declines in employment after China joined the WTO.[6] We contribute to this literature by bringing in the wealth heterogeneity dimension into the picture and showing that the initial distribution of wealth matters for how trade shocks affect workers differently. In this sense this paper also relate to the more general literature on trade and inequality (Helpman et al., 2010, 2017; Burstein et al., 2013; Antràs et al., 2017).

Roadmap The rest of the paper is organized as follows. In Section 2 we conduct our empirical exercise and estimate the effects of trade shocks on college enrollment. In Section 3 we lay down the model and in section 4 we discuss some analytical results related to our model that are well-known in the international trade literature. Section 5 provides the quantitative evaluation our main exercise. Section 6 discusses policy implication, and Section 7 concludes.

[6] Other work related to this literature has focused on structural trade models with labor dynamics like Artuç et al. (2010), Coçar et al. (2016), Dix-Carneiro (2014) and Caliendo et al. (2015).

2 Effects of Import Penetration on College Enrollment

In this section we investigate empirically how greater trade openness has affected skill acquisition decisions in the United States. To do so, we estimate the effects of import penetration shocks on both labor market outcomes across different education levels and on college enrollment. We proceed with our analysis in two steps. First, we estimate the effects of import penetration shocks across local labor markets on (i) aggregate labor market opportunities for different education levels and (ii) college enrollment.[7] In the second part of our analysis we focus on individual enrollment outcomes and their interaction with individual income levels. In this part of our analysis, the effects of the import penetration shock in isolation is still identified off of differences across local labor markets, but the identification of the interaction between trade shocks and individual income relies on within local labor market variation.

Our empirical analysis follows Autor et al. (2013) by exploiting variation in trade exposure across space to estimate the effects of trade shocks on labor market opportunities and college enrollment in the United States. We consider commuting zones in the United States as the regions corresponding to units of observation which we denote by r. These regions are characterized by strong commuting links within each region, but weak commuting links between regions. There are 722 commuting zones. For each of of these zones we construct a measure of import penetration in a given time period t as follows:

$$\Delta IPW_{rt} = \sum_j \frac{L_{rjt}}{L_{rt}} \frac{\Delta M_{jt}}{L_{jt}}, \tag{1}$$

where r denotes the commuting zone, j the industry, ΔM_{jt} the change in Chinese imports into the United States in industry j between periods t and $t-1$, and L_{rjt} the number of workers employed in that industry. Notice that the changes in imports are not only scaled by the number of workers employed in the corresponding industry, but sectoral changes in imports are also weighted by the share of total industry j workers working in region r, where $L_{rt} = \sum_j L_{rjt}$ and $L_{jt} = \sum_i L_{rjt}$.

The import penetration measure in equation (1) provides a proxy for trade shocks at the regional level. To estimate the effects of trade on skill acquisition, we simply correlate import penetration with (i) changes in labor market outcomes potentially affecting skill acquisition decisions, and (ii) directly with measures of college enrollment. However, we must first account for any concerns of endogeneity if we want to correctly identify the effect of trade shocks on labor market outcomes and college enrollment. To do so, we follow Autor et al. (2013) and instrument U.S. imports from China by those of other high-income countries.[8]

We consider changes in import penetration over the periods spanning form 1990 to 2000 (1990-

[7]The empirical strategy we follow in this step is very similar to Autor et al. (2013).

[8]The actual instrument we consider for region r and period t is given by

$$\Delta IPW_{ort} = \sum_j \frac{L_{rjt-1}}{L_{rt-1}} \frac{\Delta M_{ojt}}{L_{jt-1}}, \tag{2}$$

where M_{ojt} are Chinese's imports from other advanced countries and we consider lagged values of employment.

2000) and 2000 to 2007 (2000-2007). These measures of import penetration across commuting zones have a median of \$1,140 for 1990-2000 and \$2,600 for 2000-2007, as well as inter-quartile ranges of \$600 for 1990-2000 and \$1,500 for 2000-2007.[9] Hence, import penetration across U.S. regions became more pronounced and dispersed after the year 2000.

As previously noted, in the first part of our empirical analysis we estimate both the direct effect of trade shocks on college enrollment as well as the effect of these shocks on labor market outcomes of different education groups. We do this because, in principle, differential changes in education-specific labor market conditions should matter for skill acquisition decisions of new cohorts with potential college students.[10] In addition, conducting this analysis allows us to contrast our results with those by Autor et al. (2013) and investigate any differences. Hence, to estimate the effect of ΔIPW_{rt} on variable y_{rt} we consider the empirical specification

$$\Delta y_{rt} = \gamma_t + \beta \Delta IPW_{rt} + \delta X_{rt} + u_{rt} \tag{3}$$

where Δy_{rt} will denote either changes in employment, labor income or college enrollment. When we investigate how these effects vary across education groups we consider a set of group-specific controls, X_{rt}, that include labor force characteristics and regional dummies among others. We cluster residuals at the state level. To carry out our estimation we consider data from the American Community Survey (ACS) obtained through Integrated Public Use Microdata Series (IPUMS).

In the second part of our analysis we consider individual level data on education from the Current Population Survey (CPS) and merge it with commuting zone aggregate measures computed using the ACS. For this part of our analysis, we focus on a linear probability model specified by

$$e_{irt} = \sum_q \beta^q \mathbb{I}_{\{Y_{irt} \in q\}} \Delta IPW_{rt} + \delta_X X_{rt} + \delta_e \sum_q \mathbb{I}_{\{Y_{irt} \in q\}} \bar{e}^q_{rt-1} + \theta Y_{irt} + u_{irt} \tag{4}$$

where e_{irt} denotes an indicator equal to one if individual i in enrolled in college, $\mathbb{I}_{\{Y_{irt} \in q\}}$ denotes an indicator function equal to one whenever individual i's household income, Y_{irt}, is in quartile $q \in \{0\text{-}25, 25\text{-}50, 50\text{-}75, 75\text{-}100\}$ of the overall income distribution, and $\bar{e}^q_{rt-1}$ denotes the fraction enrolled in college at $t-1$ in commuting zone r and quartile q.

2.1 Labor Market Outcomes

In order to understand how trade might affect college enrollment decisions, we first focus on the effects of changes in import penetration on income per capita of adults. In this case, we focus on the specification in (3), where Δy_{it} denotes the change in income per adult of population of ages 30 to 55.[11] We focus on workers ages 30-55 because we believe labor market conditions for these workers are the ones considered as relevant by younger cohorts making education decisions. Table 1

[9] These quantities are all expressed in yearly changes.

[10] Charles et al. (2015) follow a similar strategy to identify the effects of housing booms and busts on education decisions.

[11] Table 1 is the equivalent to Table 3 in Autor et al. (2013), but with income of adults of ages 30-55 as the dependent variable, rather then employment by all working age population.

presents our results when we include the different sets of controls considered by Autor et al. (2013). The values in parentheses report standard errors.

Table 1: Imports from China and Change in Income per Capita for Workers Ages 30-55 within CZ, 1990-2007: 2SLS Estimates

Dependent variable: 10 × annual change in the log of income per adult ages 30-55 (in % pts)

	1990-2007 stacked first differences					
	(1)	(2)	(3)	(4)	(5)	(6)
(Δ imports from China to US)/ worker	-1.322*** (0.354)	-0.479 (0.418)	-0.628 (0.413)	-0.666* (0.374)	-0.865** (0.393)	-0.917** (0.391)
manufacturing share$_{-1}$		-0.275*** (0.081)	-0.252*** (0.061)	-0.195*** (0.066)	-0.195* (0.074)	-0.107 (0.074)
college share$_{-1}$				0.142** (0.070)		0.213** (0.097)
foreign born share$_{-1}$				-0.009 (0.035)		0.030 (0.041)
routine occupation share$_{-1}$					-0.560** (0.213)	-0.504** (0.200)
average offshorability$_{-1}$					3.422** (1.356)	0.602 (1.268)
Census division FE	No	No	Yes	Yes	Yes	Yes

Notes: N = 1,444 (722 CZs by two time periods). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. All control variables are the same as the baseline controls in Autor et al. (2013).

For the specification including all control variables in the baseline specification of Autor et al. (2013) (column (6)), our estimates show that import penetration decreases labor income per person. More specifically, an increase in relative import penetration of $1,000 decreases labor income by approximately 1 percent. These results are in line with those in Autor et al. (2013).

Table 1 estimates the effects of import penetration shocks on the average income of all adults of ages 30-55. However, this result masks the heterogeneous effects of these shocks across individuals with different levels of education. Column (1) in in Table 2 shows the estimates corresponding to the first row of Table 1 for subgroups of 30-55 year olds with different education levels. Panel A of Table 2 considers the effects on all individuals without any college education and on individuals with a high school degree. Panel B presents the estimates for individuals with some college education, and those with a 2-year or a 4-year college degree. Column (1) clearly shows that the income effects of import shocks are concentrated among workers without a college education. A $1,000 greater increase in imports reduced the income of low-skilled workers by 1.4 percent, while the same shock does not have a statistically significant effect on the income of high-skilled workers. These results clearly point in the direction of the import penetration shock increasing the opportunity cost of not going to college for new generations of workers.

Columns (2) and (3) of Table 2 also show the estimates of the effects of import shocks on total employment and on the share of workers employed in manufacturing. For the case of total employment, column (2) shows that there is statistically significant negative effect for all worker

Table 2: Imports from China and Labor Market Opportunities across Education Levels for Workers Ages 30-55 within CZ, 1990-2007: 2SLS Estimates

	1990-2007 stacked first differences		
	Income per Capita (1)	Employment per Capita (2)	Employment Share in Manufacturing (3)
Panel A			
High School or Less			
ΔIPW_{rt}	-1.365**	-1.062***	-0.520***
	(0.521)	(0.304)	(0.131)
High School			
ΔIPW_{rt}	-1.409***	-1.129***	-0.642***
	(0.449)	(0.306)	(0.142)
Panel B			
Some College			
ΔIPW_{rt}	-0.547	-0.466***	-0.422***
	(0.356)	(0.133)	(0.117)
2-year College Degree			
ΔIPW_{rt}	-0.445	-0.450**	-0.688***
	(0.639)	(0.180)	(0.148)
4-year College Degree			
ΔIPW_{rt}	-0.365	-0.308**	-0.277**
	(0.404)	(0.122)	(0.122)
Observations	1,444	1,444	1,444
Baseline Controls	Yes	Yes	Yes

Notes: Dependent variables denote 10 × annual change in (1) the log of income per person of adults ages 30-55, (2) the share of all adults ages 30-55 employed and (3) the share of adults ages 30-55 employed in manufacturing (in % pts); * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. All control variables are the same as the baseline controls in Autor et al. (2013).

independently of their education level. However, the effects are significantly greater for workers without a college education. While a $1,000 greater import shock leads to a 0.47 percentage point decrease in employment of those individuals with some college education, the share of workers without any college education suffer more than a twice as large drop in employment (1.06 percentage points). Turning to the share of workers employed in manufacturing, column (3) shows a large decline in this share across all education levels. This last result implies that, in general, employment in the manufacturing sector in those commuting zones facing greater import penetration shocks shrunk relatively more the in other regions.[12]

The results in Table 2 point in the direction of an sizable statistically significant increase in the opportunity cost of not going to college caused by the import penetration shock. In the following

[12] Autor et al. (2013) also find that and increase in import penetration (i) does not lead to migration across regions, (ii) leads to a modest decline in local non-manufacturing employment, (iii) leads to a sharp rise in labor force non-participants, and (iv) leads to employment reductions equally concentrated among young, mid-career and older workers, but employment losses are relatively more concentrated in manufacturing among the young and in non-manufacturing among the old.

subsection we turn to the direct effect of the import shocks on college enrollment.

2.2 College Enrollment

The previous results point in the direction of trade shocks affecting labor market outcomes that matter for skill acquisition decisions by individuals deciding whether to pursue a college education or not. Results in Table 2 suggest that import penetration shocks increased the marginal benefit of having a college education: Employment status and income of workers with some college education were either less affected or not negatively affected at all by trade induced shocks. These effects also suggest that we should expect the marginal individual deciding to enroll in college rather than remain only with a high school education. Hence, we now proceed to estimate the direct effects of these shocks on college enrollment decisions.[13] However, there are multiple issues that arise when trying to identify these effects. A particularly relevant challenge arises because many individuals ages 18-25 migrate across regions to enroll in college. Hence, we need to deal with this issue in order to correctly identify the effect of import penetration on college enrollment.[14]

The vast majority of individuals enrolling in college are in the age range of 18-25. However, individuals in this age range are also very mobile, particularly because they migrate to go to college in many cases.[15] Unfortunately, a disadvantage of using the ACS instead of the CPS is that it does not include households who leave for college, unlike the CPS. Therefore, it is difficult to link college students to their regions of origin. However, we can partially account for this issue if we have information on the location of college students previous to enrolling. The ACS does report individuals' last year region of location. Hence, to partially control for this issue, in one case we restrict attention to the effects on individuals ages 18-25 in college with at most one year of college finished and we link these individuals to the trade shock corresponding to their region in the previous year. It is important to underline that this is one reason why we identify the effects of trade on enrollment rather than on college completion. Still, one drawback of our strategy to identify the parameter is that using the ACS we cannot see the individuals' household income once they are no longer living in the same household. To overcome this issue we turn to CPS data and individual levels regressions in the next subsection.

Table 3 presents the results for the case in which Δy_{it} denotes the change in the fraction of

[13] Charles et al. (2015) follow a similar strategy to show how housing booms and busts affected labor market opportunities and, therefore, college attendance in the United States during the 2000s. Focusing on the case of changes in education induced by international trade, Atkin (2016) shows that the growth of export manufacturing in Mexico altered the distribution of education. The empirical strategy by Atkin (2016) can be thought of as skipping the step of constructing measures of export expansion, and instead taking a measure of changes in export employment directly as the independent variable.

[14] Greenland and Lopresti (2016) also examine the effects of import penetration on education decisions. However, they focus on the case of high school graduation rates. Given that the vast majority of hight school students still live with their parents, they do not tend to migrate across regions. Hence, Greenland and Lopresti (2016) do not face the challenge posed by migration that we face for identification.

[15] According to the Eagan et al. (2016), 48.4 percent of college freshmen in 1990 enrolled in colleges over 100 miles away from their permanent home. This number remained relatively stable over time and was 50 percent in 2015. Greenland et al. (2019) show that import penetration shocks have a statistically significant effect on migration of 15-34 year olds.

individuals ages 18 to 25 enrolled in college overall or in the first year of college. In this case we control for the same set of variables that are included in column (6) of Table 1.

Table 3: Imports from China and College Enrollment for Individuals Ages 18-25 within CZ, 1990-2007: 2SLS Estimates

Dependent variable: 10 × annual change in the fraction of adults ages 18-25 enrolled

	1990-2007 stacked first differences			
	In current period t		In future period $t+1$	
	Enrolled in College (1)	Enrolled in 1^{st}-Year College (2)	Enrolled in College (3)	Enrolled in 1^{st}-Year College (4)
Adults ages 18-25				
ΔIPW_{rt}	0.878***	0.187**	1.304***	0.355*
	(0.192)	(0.086)	(0.396)	(0.201)
Observations	1,444	1,444	722	722
Baseline Controls	Yes	Yes	Yes	Yes

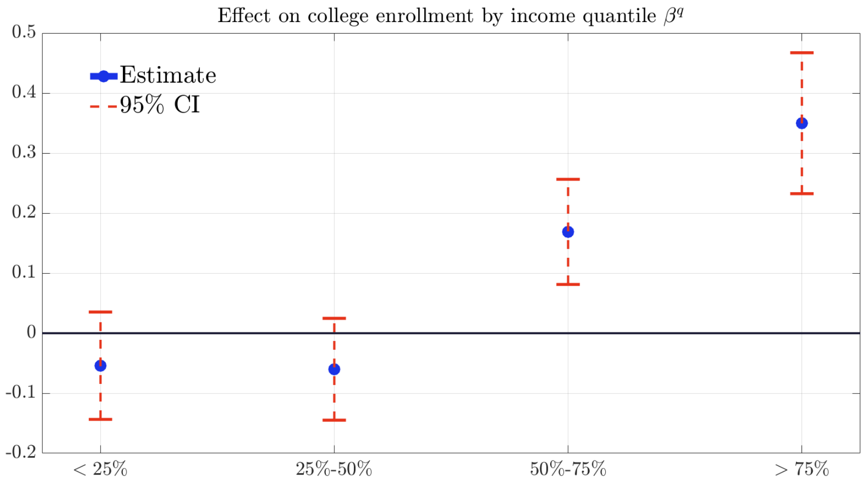
Notes: Dependent variables denote 10 × annual change in the fraction of adults ages 30-55 enrolled in some year of college [columns (1) and (3)] and the fraction of adults ages 18-25 enrolled in their first years of college [columns (3) and (4)] (in % pts); columns (3) and (4) consider lead dependent variables; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; standard errors are clustered by state; the regression analyses are weighted by initial CZ share of national population. All control variables are the same as the baseline controls in Autor et al. (2013).

Table 3 shows that import penetration increases the fraction of individuals enrolled in college overall as well as in the first year of college. In other words, college enrollment, and therefore skill acquisition increases in responses to import competition. Our results imply that a $1,000 increase in import penetration increases the fraction of 18 to 25 year olds enrolled in college by 88 basis points and the fraction of those enrolled in their first year of college by 19 basis points.

These numbers imply that the interquartile difference in enrollment is of approximately 90 basis points and 20 basis points for first year enrollment. To put this number in perspective, the total change in enrollment in the United States during this time period was of approximately 330 basis points. Hence, differences of 90 basis points across regions can explain a significant part of the aggregate change. These results point in the same direction as previous findings by Greenland and Lopresti (2016) who carry out a similar exercise, but looking at high school completion rates. Hence, our point estimates supports the hypothesis that trade shocks have affected education decisions in the United States.

Columns (3) and (4) of Table **??** consider future changes in enrollment as the dependent variable. To the extent that adjusting education decisions takes time, we can think of future enrollment changing in response to previous trade shocks rather than to most recent ones. The data point in the direction of a strong and rather sizable effect of increases in import penetration on future college enrollment. We can easily think of a story in which households slowly learn about aggregate labor market conditions. This sluggishness would imply that it takes a number of new cohorts to internalize the increase in the marginal benefit of education induced by the trade shock. Another story could be related to the ability of new cohorts to immediately pay for the cost of a college

Figure 1: Imports from China and College Enrollment Across Income Quartiles



Notes: Values on the x-axis denote different quartile ranges. Blue points denote point estimates of β^q and red dashed intervals denote 95% confidence intervals.

education. In any case, these are just possibilities that could be driving the strong correlation for future changes in enrollment.

Results in Table 3 show that import penetration shocks have generated an increase in college enrollment. However, going to college is a costly endeavor that not every potential student can afford. There is a ample evidence that an individual household's wealth and access to credit matter for college enrollment decisions.[16] To take these important issues into consideration, we now turn to the second step of our analysis in which we investigate how differences in household income across individuals affect college enrollment decisions given import penetration shocks. To carry out our analysis we turn to individual level data from the CPS and focus on the specification shown in (4). While the sample size of the CPS is considerably smaller than the ACS', implying that we need to rely on individual level regressions, the CPS data allows us to link potential workers to their households' incomes.

We are interested in identifying the coefficients β^q in equation (4). These coefficients are plotted in Figure 1. The figure shows that the increase in enrollment is driven by 18-25 year olds living in the richest households. While $\beta^{0\text{-}25}$ and $\beta^{25\text{-}50}$ arr not statistically significantly different than zero, these coefficients for individuals living in the two top quartiles of the income distribution are positive. Comparing the quartile-specific estimates to out aggregate estimate in column (2) of Table 3, we see that the estimate of 0.187 percentage points is driven by an estimate of 0.172 percentage points for the second highest quartile and 0.35 percentage points for the highest quartile.

Summarizing, our empirical results provide evidence that import penetration shocks (i) increase in the opportunity cost of not going to college, (ii) increase college enrollment, and (iii) that the

[16]See Lochner and Monge-Naranjo (2012) and Solis (2017).

effect of these shocks on college enrollment decisions depends on individual households' income. These pieces of evidence motivate our analysis in the next section where we propose a model to study the effects and welfare implications of import shocks on college enrollment decisions.

3 The Model

Consider a small open economy (SOE) composed by multiple regions indexed by $k \in \mathcal{K}$. Time is discrete, runs forever, and is indexed by $t = 0, 1, 2, \ldots$. Each region is inhabited by a continuum of finitely-lived households who live for J_R periods and are then replaced by a newborn. Households care about their off-spring, which generates a bequest motive. Production in each region k of the economy consists of two sectors—manufacturing and services—indexed by $i \in \{s, m\}$.

At age one—during the first period of life—households decide whether to go to college or not. Simultaneously, they decide the industry i in which they will work. Both the education and the industry choices are a one-time irreversible decisions. Each household corresponds to a worker, and we refer to households that made the education investment as *college* workers, and those who did not make the investment as *non-college* workers. Workers (households) are immobile across regions throughout their life-time.

Households are exposed to idiosyncratic labor productivity shocks, and they can only self insure by saving/borrowing in one-period bonds subject to a borrowing limit. We assume this is the only financial asset households have access to. We assume that borrowing/saving happens in international financial markets, at an interest rate r^* which the SOE takes as given.[17]

In each region k, production in sector i is performed by intermediate good producers and final good producers—both operating under perfect competition. Intermediate goods are produced using a constant returns to scale technology in *college* and *non-college* workers, and can be be traded across countries and regions subject to iceberg-type trade barriers. Final goods are non-tradable and produced by combining domestic intermediate goods from all regions as well as imported intermediate goods. The SOE assumption implies that domestic demand for imports is always met by foreigners at exogenously given world prices. We also consider and exogenously given foreign demand for domestic exports.

We start by discussing firms in the economy and then move to households. Since our focus is on transitional dynamics, we describe the economy in a generic period t where all aggregate states are contained in Ω_t. When we carry out the analysis of an equilibrium, we will first consider the economy in a stationary state with not aggregate uncertainty, and then study the transition dynamics given an increase in trade-openness. We carry out this analysis in Section 5. From here on, when we refer to any variable z, we will be actually referring formally to $z_t = z(\Omega_t)$ except if otherwise stated.

[17] Adding trade in financial assets across regions in the same country would be inconsequential given our SOE assumption.

3.1 Firms

Intermediate Tradable Goods Producers The tradable intermediate good in region k and sector $i \in \{s, m\}$ is produced with labor according to the following technology

$$F_{kit}(L_{kict}, L_{kint}) = Z_{kit} \left(\gamma_{ki} L_{kict}^{\frac{\sigma_{ki}-1}{\sigma_{ki}}} + (1-\gamma_{ki}) L_{kint}^{\frac{\sigma_{ki}-1}{\sigma_{ki}}} \right)^{\frac{\sigma_{ki}}{\sigma_{ki}-1}}, \tag{5}$$

where L_{kict} is *college* labor and L_{kint} is *non-college* labor used in sector i, region k and period t.

There are two important features—across sectors and regions—about the production technology that are worth highlighting. First, across sectors, a key difference is that we will assume is that manufacturing is relatively more intensive in *non-college* workers. This is, we assume $\gamma_{ks} > \gamma_{km}$ for all regions k. Consequently, in line with Heckscher-Ohlin (HO) models of trade, an increase (decrease) in the relative price of intermediate services (manufactures) will increase the relative demand for *college* versus *non-college* workers, and—ceteris paribus—the wage premium. Second, we assume that some regions may be more productive than others in a given sector, as captured by productivity Z_{kit}. Regional heterogeneity in productivity Z_{kit} implies different initial patterns of sectoral specialization across regions, and thus different effects of country-wide trade openness.

Intermediate goods firms' profit maximization reads

$$\begin{aligned} &\max_{L_{kict}, L_{kint}} \{p_{kit} F_{kit}(L_{kict}, L_{kint}) - w_{kcit} L_{kict} - w_{knit} L_{kint}\} \\ &\text{subject to (5)} \end{aligned} \tag{6}$$

where p_{kit} is the price of the tradable good in sector i, region k, at period t, and w_{kcit} and w_{knit} stand for *college* and *non-college* wages in the same region, industry and period, respectively. Notice that the wage of *college/non-college* may not equalize across sectors since workers are immobile in the short-run.

From optimality conditions we obtain

$$\frac{w_{kct}}{w_{knt}} = \frac{\gamma_{ki}}{1-\gamma_{ki}} \left(\frac{L_{kict}}{L_{kint}} \right)^{-\frac{1}{\sigma_{ki}}}. \tag{7}$$

Equation (7) shows that the wage premium in a given region $-w_{kct}/w_{knt}-$ is not simply determined by the relative aggregate supply of skills in that region. The allocation of aggregate skills across sectors within the region also matter for the determination of the skill premium, and these allocation will depend on comparative advantage and the world prices of tradable goods.[18]

Final Non-Tradable Goods Producers Final goods in each region $k \in \mathcal{K}$ are produced by combining domestic intermediate goods from each region as well as imported intermediate goods. For

[18]Skill-biased technical change can easily be incorporated into this framework. We abstract from this feature in order to focus on the effects of trade openness on skill acquisition.

each sector $i = \{s, m\}$ and region k, final good producers aggregate intermediate goods using a nested Armington structure as

$$Q_{kit} = \left[\omega_{ki}^{\frac{1}{\eta_i}} D_{kit}^{\frac{\eta_i - 1}{\eta_i}} + (1 - \omega_{ki})^{\frac{1}{\eta_i}} (D_{kit}^*)^{\frac{\eta_i - 1}{\eta_i}}\right]^{\frac{\eta_i}{\eta_i - 1}} \tag{8}$$

where D_{kit}^* is the imported intermediate good, and D_{kit} is an Armington aggregate combining domestic goods from all regions as:

$$D_{kit} = \left(\sum_{l \in \mathcal{K}} \theta_{kli}^{\frac{1}{\epsilon}} \mathcal{Y}_{klit}^{\frac{\epsilon - 1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon - 1}}. \tag{9}$$

$\mathcal{Y}_{klit}$ denotes the amount intermediate goods demanded by region k from region l in period t.

In equation (8), η_i denotes the elasticity of substitution between domestic and imported inputs, and ω_{ki} is a shifter affecting region-biases—including home-bias in trade. The trade elasticity, η_i, can only vary across sectors, but shifters are allowed to vary across both sectors and regions. Analogously for equation (9), ϵ_i denotes the elasticity of substitution across domestic intermediate goods from different regions, and θ_{kli} is the demand shifter in region k towards goods produced in region l. This model structure nests multiple particular models in the literature depending on the parameter choices. For instance, if $\theta_{kli} = 0 \ \forall l \neq k$, then there is no trade across regions and the model boils down to an "island model" in which each region ("island") can be analyzed in isolation. In addition, if we assume that $\eta_i \to \infty$, then we obtain the standard SOE-HO model with two sectors.

The profit maximization problem of the final good producer is

$$\max_{\{\mathcal{Y}_{klit}\}_{l \in \mathcal{K}}, D_{kit}^*} \left\{ q_{kit} Q_{kit} - \sum_{l \in \mathcal{K}} \tau_{klit} p_{ilt} \mathcal{Y}_{klit} - \tau_{kit}^* p_{it}^* D_{kit}^* \right\} \tag{10}$$

subject to (8)-(9)

where q_{kit} is the price of the final good bundle Q_{kit} in region k, $\tau_{kli} \geq 1$ is the iceberg cost of moving goods from region l to k, and τ_{kit}^* is the cost of importing the good to region k.[19] Notice that we allow iceberg-type costs to vary over time, thus generating changes in trade openness.

Optimal demands are given by

$$\mathcal{Y}_{klit} = \theta_{kli} \left(\frac{\tau_{klit} p_{ilt}}{\bar{p}_{kit}}\right)^{-\epsilon_i}, \tag{11}$$

$$D_{kit} = \omega_{ki} \left(\frac{\bar{p}_{kit}}{q_{kit}}\right)^{-\eta_i} Q_{kit}, \text{ and} \tag{12}$$

$$D_{kit}^* = (1 - \omega_{ki}) \left(\frac{\tau_{kit}^* p_{it}^*}{q_{kit}}\right)^{-\eta_i} Q_{kit}, \tag{13}$$

[19] Notice that we allow for iceberg-type trade barrier across regions in line with the literature on Spatial Economics.

where $\bar{p}_{kit}$ is the ideal price index of goods across regions given by

$$\bar{p}_{kit} = \left(\sum_{l} \theta_{kli} \left(\tau_{klit} p_{ilt} \right)^{1-\epsilon_i} \right)^{\frac{1}{1-\epsilon_i}} \tag{14}$$

and q_{kit} satisfies

$$q_{kit} = \left[\omega_{ki} \bar{p}_{kit}^{1-\eta_i} + (1-\omega_{ki}) \left(\tau^*_{kit} p^*_{it} \right)^{1-\eta_i} \right]^{\frac{1}{1-\eta_i}} . \tag{15}$$

3.2 Households

Households live for ages $j = 1, \ldots, J_R$, and are replaced by a newborn at age J_R. Households derive utility from consuming bundle composed of non-tradable services, c_s, and manufactures, c_m. Let $c = \mathcal{C}(c_s, c_m)$ denote this bundle. Each household is endowed with $\bar{h}$ hours of work, and an idiosyncratic labor productivity x which evolves stochastically as a Markov process $\pi_x(x', x)$. Next, we describe the household's problem at the different stages of their life.

Education stage Obtaining a college degree takes two periods of life. The average cost of college per period in region k is κ_k, but the actual cost paid is $\kappa_k u$, where u is a bounded shock with mean one and distribution ϕ_u.[20] Education also requires time, and households can only work part-time as a *non-college* worker while attending college. Households can borrow to pay for college, and the borrowing limit is looser for a few periods if a household goes to college. Let $\underline{a}_{j,e}$ denote the borrowing limit for a household of age j with education e. We assume that the borrowing limit does not vary across regions.

Let $V^j_{kt}(a, x, e, i, u)$ be the maximum attainable life-time utility to a household of age j in region k, at time t, who works in industry i, holds a units of the foreign bond, has productivity x, faces an education cost shock u, and education level e. The value for a newborn ($j = 1, 2$) who goes to college ($e = c$) in region k is given by

$$\begin{aligned} V^j_{kt}(a, x, c, i, u) &= \max_{c_s, c_m, a'} \left\{ u(c) + \beta \mathbb{E} \left[V^{j+1}_{kt+1}(a', x', c, i, u) | x \right] \right\} \\ q_{kst} c_s + q_{kmt} c_m &+ a' + q_{kst} \kappa_k u \leq w_{knit} x \frac{\bar{h}}{2} + (1 + r^*) a \\ c &= \mathcal{C}(c_s, c_m) \\ a' &\geq \underline{a}_{jc} \\ \Omega_{t+1} &= \mathcal{H}(\Omega_t) \end{aligned} \tag{16}$$

where the function $\mathcal{H}$ specifies the law of motion of the aggregate state Ω_t, which is summarized by subscript t in the value function and prices.

Two comments are worth mentioning about the problem in equation . First, the cost of education is assumed to be paid in services goods, but the total payment depends on the realization of the

[20] Adding the shock u makes the household problem quantitatively more tractable.

shock u—a lower u being a cheaper tuition. Second, while in college the household only works half her time, and perceives the *non-college* wage of her industry i.

Working stage The value for household currently in the labor market is given as

$$
\begin{aligned}
V^j_{kt}(a,x,e,i) &= \max_{c_s,c_m,a'} \left\{ u(c) + \beta \mathbb{E}\left[V^{j+1}_{kt+1}(a',x',e,i)|x \right] \right\} \\
q_{kst}c_s &+ q_{kmt}c_m + a' \leq w_{keit}x\bar{h} + (1+r^*)a \\
c &= \mathcal{C}(c_s,c_m) \\
a' &\geq \underline{a}_{je} \\
\Omega_{t+1} &= \mathcal{H}(\Omega_t)
\end{aligned}
\tag{17}
$$

Notice that education e and sector i do not change during a household's life-time,

College and industry choice At age $j = 1$, households make the education and industry choice. Let $V^0_{kt}(a,x,u)$ be the value of a newborn in region k and period t, with state (a,x) and education cost shock u. Thus

$$
V^0_{kt}(a,x,u) = \max_{e\in\{c,n\},\ i\in\{s,m\}} \left\{ V^1_{kt}(a,x,e,i,u) \right\}
\tag{18}
$$

The optimal policies e and i obtained from (18) determined the measure of households with each education level at each industry. If a household is indifferent across industries, as is the case in a steady-state, we assume that she chooses i randomly. In this case, we set the probability of choosing each sector as to clear labor markets.

Inter-generational transfers A newborn household inherits the wealth of her parents, and draws a random labor productivity which is correlated with the parents' one. In turn the terminal condition in (17) is given as

$$
V^{J_R+1}_{kt+1}(a,x,e,i) = \hat{\beta}\mathbb{E}_u[V^0_{kt}(a,x,u)]
\tag{19}
$$

where $\hat{\beta}$ is how much parents discount their kids utility.

Notice that the value on equation (19) is actually independent of the parents education and industry. Thus, parents can only affect their kid's life-time utility because of the wealth they decide to transfer—and also exogenously because the kid's productivity distribution depends on the parent's one.

Let $\mathbf{c}^j_{kst}(a,x,e,i)$, $\mathbf{c}^j_{kmt}(a,x,e,i)$, $\mathbf{a}^{j\prime}_{kt}(a,x,e,i)$ denote households' optimal policies for services consumption, manufacturing consumption and saving, respectively.[21] And let $\mathbf{e}_{kt}(a,x,u)$ and $\mathbf{i}_{kt}(a,x,u)$ the (binary) education and sector policies, respectively.

[21] For $j = 1$, these policies actually also depend on the realization of the shock u.

3.3 Market Clearing and Equilibrium Definition

Next, we discuss market clearing and the definition of an equilibrium. In addition, we aggregate households' policies to describe international flows of debt and goods. Let $\mathcal{A}$ be the space of asset levels and $\mathcal{X}$ the space of productivities. Define the state space $\mathcal{S} = \mathcal{A} \times \mathcal{X}$ and $\mathcal{B}$ the Borel σ-algebra induced by $\mathcal{S}$.

Measure Let $\mu_{kt}^{j}(a, x, e, i)$ be the measure of households of age j in region k, period t, with foreign holdings a, productivity x and education level e working in sector i. Since we do not allow for migration, we have $\sum_{j=1}^{J_R} \sum_{e,i} \int_{\mathcal{B}} d\mu_{kt,j}(a, x, e, i) = 1 \ \forall k, t$.[22] For later computations, denote $\mu_{kt}^{-} = \sum_{e,i} \mu_{kt,1}^{1}(a, x, e, i)$ be the measure of newborns *before* the education and sector decision.

Labor Market Let L_{kiet} be the optimal labor demand in region k of workers with education e from the intermediate good producer in sector i. Labor market must clear for each type of labor e in each region separately. This is

$$L_{kint} = \int x \frac{\bar{h}}{2} d\mu_{kt}^{1}(a, x, c, i) + \sum_{j=2}^{J_R} \int x \bar{h} d\mu_{kt}^{j}(a, x, n, i) \qquad \forall k, i, t \tag{20}$$

$$L_{kict} = \sum_{j=1}^{J_R} \int x \bar{h} d\mu_{kt}^{j}(a, x, e, i) \qquad \forall k, i, t \tag{21}$$

Final Non-Tradable Goods Let $C_{kit} = \sum_{j=1}^{J_R} \sum_{e,i} \int \mathbf{c}_{kit}^{j} d\mu_{kt,j}(a, x, e, i)$ be aggregate consumption of the final good $i \in \{s, m\}$ in region k. The final good market must clear for each sector i and region k, this is

$$Q_{kst} = C_{kst} + \bar{\kappa}_{kt} \qquad \forall k, t \tag{22}$$

$$Q_{kmt} = C_{kmt} \qquad \forall k, t \tag{23}$$

where $\bar{\kappa}_{kt} = \int \int_u u \kappa_k \mathbf{e}_{kt}(a, x, u) d\phi(u) d\mu_{kt}^{-}(a, x)$ is the total services goods demanded for education investment.

Intermediate Tradable Goods The tradable domestic good is demanded by final goods producers and by foreign firms. We assume an iso-elastic demand function for foreign's demand of goods produced in region k, $B_{kit}^{*} = \bar{B}_{kit}^{*} \left(p_{kit}\right)^{-\eta^{*}}$. The term $\bar{B}_{kit}^{*}$ incorporates multiple factors that could shift the demand for intermediate goods produced in region k. For instance, this term incorporates the effects of iceberg-type trade costs that foreigners pay to purchase goods produced

[22] Allowing for migration across regions complicates the solution of the model considerably and it is currently work in progress.

at home. Market clearing for tradable goods then reads

$$Y_{kit} = \sum_{l \in \mathcal{K}} \tau_{lkit} \mathcal{Y}_{lkit} + B^*_{kit} \tag{24}$$

where $\mathcal{Y}_{lkit}$ is given in (11).

Households' budget constraints together with market clearing conditions deliver a flow of funds condition describing the evolution of aggregate asset holding in each region, as well as nationally. Let $A_{kt+1} = \sum_{j,e,i} \int \mathbf{a}^{j\prime}_{kt}(a,x,e,i) d\mu^j_{kt}(a,x,e,i)$ be the total savings in region k. Then, aggregate asset holdings of households in region k evolve according to

$$\begin{aligned} A_{kt+1} - A_{kt} &= r^* A_{kt} \\ &+ \sum_i \sum_{l \neq k} (\tau_{lkit} p_{kit} \mathcal{Y}_{lkit} - \tau_{klit} p_{lit} \mathcal{Y}_{klit}) \\ &+ \sum_i (p_{kit} B^*_{kit} - \tau^*_{kit} p^*_{it} D^*_{kit}). \end{aligned} \tag{25}$$

Equation (25) shows that a region can accumulate assets because of three reasons: the first line is accumulation due to return on previous savings; the second line implies an accumulation if the value of goods sold to other regions ($\sum_i \sum_{l \neq k} \tau_{lkit} p_{kit} \mathcal{Y}_{lkit}$) is larger than the cost of purchased goods from other regions ($\sum_i \sum_{l \neq k} \tau_{klit} p_{lit} \mathcal{Y}_{klit}$); and the third line implies an accumulation because of trade with foreigners.

Notice that $\sum_k \sum_i \sum_{l \neq k} (\tau_{lkit} p_{kit} \mathcal{Y}_{lkit} - \tau_{klit} p_{lit} \mathcal{Y}_{klit}) = 0$. Hence, the economy wide evolution of asset holdings is given by

$$A_{t+1} - A_t = r^* A_t + \sum_k \sum_i (p_{kit} B^*_{kit} - \tau_{it} p^*_{it} D^*_{kit}), \tag{26}$$

where $A_t = \sum_k A_{kt}$. Equation (26) is the standard current account identity: foreign assets accumulation in a country is the return on previous assets plus net exports.

3.4 Equilibrium Definition

Next, we provide a formal definition of the economy's stationary equilibrium given values of the model's parameters including iceberg-type trade barriers. We drop time subscript t since outcomes are constant in a stationary equilibrium.

Definition Given world prices of intermediate goods, $\{p^*_i\}_{i \in \{s,m\}}$, and the world interest rate, r^*, a ***recursive stationary equilibrium*** for this economy is defined by region-specific:

- factor prices $\{w_{kc}, w_{kn}\}_{k \in \mathcal{K}}$;

- goods prices $\{q_{ki}, p_{ki},\}_{i \in \{s,m\}, k \in \mathcal{K}}$;

- value functions for households $\{V_{k,j}(a,x,e)\}_{k \in \mathcal{K}}$;

- policies for households $\{\mathbf{c}_{ks,j}(a,x,e), \mathbf{c}_{km,j}(a,x,e), \mathbf{a}'_{k,j}(a,x,e), \mathbf{e}_k(a,x,u)\}_{k\in\mathcal{K}}$;

- policies for intermediate goods firms $\{L_{kic}, L_{kin}\}_{i\in\{s,m\},k\in\mathcal{K}}$;

- policies for final goods firms $\{Q_i, D_i, D_i^*\}_{i\in\{s,m\},k\in\mathcal{K}}$; and

- measures across households states $\{\mu_{k,j}(a,x,e)\}_k \in \mathcal{K}$;

such that, given prices:

(i) Households' policies solve its problem and achieve values $\{V_{k,j}(a,x,e)\}_{k\in\mathcal{K}}$;

(ii) Firms policies maximize their profits;

(iii) Labor markets clear: $\sum_{i\in\{s,m\}} L_{kie} = \sum_j \int x d\mu_{k,j}(a,x,e)$ for $e \in \{c,n\}$;

(iv) Final good market clears:

$$\begin{aligned} Q_{km} &= \sum_{j,e} \int \mathbf{c}_{km,j}(a,x,e) d\mu_{k,j}(a,x,e) \text{ and} \\ Q_{ks} &= \sum_{j,e} \int \mathbf{c}_{ks,j}(a,x,e) d\mu_{k,j}(a,x,e) + \bar{\kappa}_k, \end{aligned}$$

where $\bar{\kappa}_k$ is the total amount of service goods invested in education:

$$\bar{\kappa}_k \equiv \kappa_k \int \left[\int_u \mathbf{1}_{[V_{k,1}(a,x,u,c) > V_{k,1}(a,x,n)]} u df(u) \right] d\mu_1(a,x,c+n);$$

(v) Intermediate goods markets clear; and

(vi) Measures $\{\mu_{k,j}(a,x,e)\}_{k\in\mathcal{K}}$ are stationary and consistent with households policies.

4 Trade Shocks and Skill Acquisition

The rich structure of the model we built in the previous section will allow us to carry out a quantitative analysis of how trade shocks affect workers over time. However, it is worth developing some intuition about the main mechanisms at play in the model before proceeding to the quantitative analysis. In order to do so, we will focus on a simplified version of the static block of the model with a single region, perfect labor mobility across sectors, no foreign demand for goods produced at home and same elasticities of substitution between skills across sectors. More specifically, we assume for the moment that $|\mathcal{K}| = \infty$, that households' savings decisions and skill-acquisition choices have already been made optimally and that $\sigma \equiv \sigma_m = \sigma_s$. This will allow us to rely on two of the main theorems in International Trade to develop intuition, while only referencing to the simple dynamic mechanism telling us that an increase in the return to skill will increase the number of workers that decide to acquire an education. To simplify our exposition, we also assume that the consumption aggregator is given by a Cobb-Douglas function with exponents given by ν_i for $i \in \{s,m\}$.

How do changes in import prices affect the skill premium? Consider a decline in the trade costs that domestic final good producers in sector m pay for intermediate goods produced abroad. Assume that model parameters are such the decline in the price paid by producers leads to expenditure switching across countries and a decline in the relative price of sector m intermediate goods produced in the home country, p_m. The following is a version of the Stolper-Samuelson theorem for this experiment in our model.

Proposition 4.1 (Stolper-Samuelson) *Given a distribution of skills across workers, a decrease in the relative price of the intermediate good produced domestically in sector m will decrease the wage of non-educated workers and increase that of educated workers if non-educated workers are used more intensively in the production of the intermediate good in sector m, that is, whenever the following condition holds given the wage premium, $\frac{w_c}{w_n}$, before the price change:*

$$\left(\frac{1-\gamma_m}{1-\gamma_s}\right)^{\sigma-1} > \frac{\gamma_m\left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)}{\gamma_s\left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)}. \tag{27}$$

Proof See Appendix A.

Consider the case of the United States, for which there is evidence that the manufacturing sector is intensive in non-educated workers.[23] Then, according to Proposition 4.1 a decline the price that final goods producers pay for imported manufacturing goods would lead to an increase in the skill premium given a distribution of skills across workers.

How does an increase in the skill premium affect the distribution of skills across workers and production? Let us briefly turn to the dynamic block of the model. The model tells us that an increase in the skill premium will make the acquisition of education more attractive for new workers. This will in principle lead new generations of workers to become educated, gradually shifting the distribution of skills in the economy towards a more educated economy. This change in the distribution will in turn affect the comparative advantage of the home country, and therefore production, in line with Rybczynski's theorem.

Proposition 4.2 (Rybczynski) *A shift in the distribution of skills in the economy towards more educated workers will increase the output of domestic intermediate goods produced in sector s and decrease the output of the other sector.*

Proof See Appendix B.

[23]See Cravino and Sotelo (2017) for evidence on this feature for multiple countries.

How do changes in output feed back into prices? From preferences we know that in equilibrium

$$\frac{q_m Q_m}{\nu_m} = \frac{q_s Q_s}{\nu_s}.$$

We also know that $p_i Y_i = p_i D_i = \omega_i \left(\frac{p_i}{q_i}\right)^{1-\eta_i} q_i Q_i$. Hence, if κ is not too big, then we obtain that in equilibrium the following condition must hold

$$\frac{Y_m}{Y_s} \approx \frac{\omega_s}{\omega_m} \frac{\nu_m}{\nu_s} \frac{p_s^{\eta_s}}{p_m^{\eta_m}} \frac{q_s^{1-\eta_s}}{q_m^{1-\eta_m}}.$$

For simplicity, let us assume that $\eta \equiv \eta_m = \eta_s$. Then, from the previous condition we obtain that

$$\hat{Y}_m - \hat{Y}_s \approx \eta \left(\hat{p}_s - \hat{p}_m\right) + (1-\eta)\left(\hat{q}_s - \hat{q}_m\right)$$

and if $p_s = 1$ and world prices are given we obtain that

$$\begin{aligned} \eta \hat{p}_m + (1-\eta)\, \hat{q}_m &\approx -\left(\hat{Y}_m - \hat{Y}_s\right) \Leftrightarrow \\ \hat{p}_m \left(\eta + (1-\eta)\,\phi\right) &\approx -\left(\hat{Y}_m - \hat{Y}_s\right) \end{aligned}$$

where ϕ is positive. Therefore, if $\hat{Y}_m - \hat{Y}_s > 0$, then $\hat{p}_m < 0$ which will counteract the initial Stolper-Samuelson forces.

5 Quantitative Exercises

For out initial quantitative exercise, we consider a version of our model in which each region is an "island" trading with the rest of the world, but not with other regions.[24] This is, we assume that $\theta_{kli} = 0 \ \forall l \neq k$. Thus, final good producers use only two types of intermediate goods: foreign and domestic from its own region. We focus on one "island" only, and calibrate it to the average commuting zone in the United States—the geographical unit of observation in our empirical analysis of Section 2.

Trade openness in the model is then determined by the iceberg cost of importing goods τ_{it}^*. We consider a period of trade liberalization as a decrease in the cost of importing goods τ_{it}^*. In particular, we start the economy at a steady-state with a high τ_i^*, and analyze the effect of an (unexpected) drop in τ_i^*. We refer to the high-τ_i^* steady-state as a "closed economy", and the low-τ_i^*steady-state as the "open economy".

We start by describing the calibration of the model, which is mostly done in the "closed economy". We then analyze how the closed and open economies compare in terms of welfare and inequality. Then, we analyze the economy transition from the closed to the open economy.

[24] Carrying out the quantitative exercises with trade across regions is currently work in progress.

5.1 Calibration

We calibrate most parameters to the initial "closed economy". We consider a period to be two years. We assume a working span of $J_R = 15$, that is, 30 years. We assume an annual foreign risk-free rate of 1.6% and we calibrate β to match a mean wealth over annual income ratio of approximately 4, a standard number in the literature. We also calibrate $\hat{\beta}$ such that annual transfers (intended, bequests, and college payments) over wealth amount to close to 1.7% of total mean wealth, as documented in Gale and Scholz (1994).

We assume that the household consumption bundle is given by a CES aggregator over final sectoral goods of the form

$$\mathcal{C}(c_s, c_m) = \left(\sum_{i=s,m} \nu_i^{1/\rho} c_i^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}$$

and set $\nu_s = 1 - \nu_m = 0.6$ and $\rho = 0.5$. These values are standard in the literature and deliver predictions of the model consistent with observed expenditure shares. The idiosyncratic productivity shock x is assumed to follow an AR(1) process in logs with auto-regressive coefficient $\rho_x = 0.9$ and with a standard error of innovations $\sigma_x = 0.20$ at annual frequency (Floden and Lindé, 2001). We convert the process to a two-year duration and discretize it following Tauchen (1986).

The borrowing constraint is set to zero, except for students who go to college. College students can borrow up to $a_{1,c}$, which we calibrate such that 50% of the average cost of education $q_s\kappa$ can be borrowed. [UPDATE]This initial loan will have to be repaid in the next 15 years: $a_{j,c} = a_{1,c}$ for $j = 2, 3$, but $a_{j,c} = 0 \; \forall j > 3$. Finally, we calibrate κ, the cost of education, such that 35% of the labor force has a college degree, in line with American Community Survey (ACS) data for 1990.

We use standard values for most technology parameters. For intermediate goods technology, we assume $\sigma_i = 2$ in both sectors. We calibrate the intensity in college workers in each sector γ_i to match the share of college labor earnings relative to total labor earnings, in each sector in the US in 1990. As expected, we find that $\gamma_s > \gamma_m$. For the final good technology, we assume identical technologies: $\omega_i = 0.7$ and $\eta_i = 4$.

For trade iceberg costs τ_i^*, we chose their values for in the "closed economy" to match home-biases in each sector in 1990, equal to 0.90 in manufacturing and 0.98 in service. For the "open economy", we recalibrate τ_i^* to match a home-bias of 0.75 in manufacturing and equal to 0.98 and in services, which corresponds the US values for 2010. Finally, we calibrate the demand shifter demand shifter $\bar{B}_i^*$ to match exports as a share of total expenditures in each sector in 1990.

Table 4 summarizes the main part of our calibration of the model.

5.2 Steady-State Analysis

We select τ_m to match a home bias in the manufacturing sector of roughly 90% in the closed economy, and about 75% in the open economy. This is similar to the change in home bias observed in the United States between the late 1980s and the year 2010. Table 5 shows results for the open and closed economies, including the home bias.

Table 4: Calibration

Parameter	Value	Description	Model	Target
Households				
β (annual)	0.96	Wealth over annual income	3.56	4
$\hat{\beta}$ (annual)	0.45	Annual transfers over wealth	0.02	0.02
κ	0.14	College workers	0.34	0.35
$a_{c,1}$	-0.22	Relative to college cost	0.50	0.50
Production function				
γ_s	0.55	Wage share to college $i = s$	0.49	0.47
γ_m	0.40	Wage share to college $i = m$	0.30	0.31
Trade				
$\bar{B}_s^*$	0.01	Share of exports $i = s$	0.02	0.02
$\bar{B}_m^*$	0.02	Share of exports $i = m$	0.09	0.09
τ_s	8.18	Home Bias $i = m$	0.98	0.98
τ_m	4.67	Home Bias $i = m$	0.90	0.90

Table 5: Comparison of Main Statistics Across Steady States

	Closed Economy	Open Economy	Difference
Home Bias in Sector m	0.90	0.75	-0.18
Home Bias in Sector s	0.98	0.98	0.00
Wage Premium w_c/w_n	1.3934	1.3937	0.30%
Share of College Workers	0.36	0.37	1.56%
College real wage w_c/q	0.528	0.540	2.18%
Non-college real wage w_n/q	0.379	0.386	1.87%
Average Utility *College*	-11.21	-10.84	3.30%
Average Utility *Non-college*	-20.67	-20.05	2.99%

Wages and Welfare In the long-run, since newborn workers can freely chose an industry, labor is effectively mobile across sector and wages equalize for each education level: $w_{es} = w_{em} = w_e$ $\forall e = c, n$. As Table 5 shows, the drop in trade costs induces a moderate increase in the wage premium w_c/w_n, of about 0.30%. Despite the increase in wage inequality, the purchase power of *non-college* wage $-w_n/q-$ increases by 1.8%. As a result, welfare increases for both type of households. While there are no losses from trade in the long-run, we'll show that is not the case along the transition.

Education Policy Wealthier and more productive households are more likely to invest in education, as Figure ?? shows. Very productive households benefit the most from higher wages, and thus decide to invest in education even if they are very poor. As productivity decreases, only wealthier households find it beneficial to forgo consumption today and invest in education. In the open economy, wage premium increases and so do incentives to obtain a college degree. Consequently, as Figure ?? shows, education policies shift to the left along the wealth dimension implying that it is more likely for workers to acquire an education in the open economy.

The increase in the measure of *college* workers, jointly with higher wages, makes the economy wealthier. As Figure 3 shows, both *college* and *non-college* workers are born in wealthier households in the open economy. Hence, allowing for endogenous skill acquisition implies that every worker—independently of skill—experiences positive welfare gains from trade in the long-run.

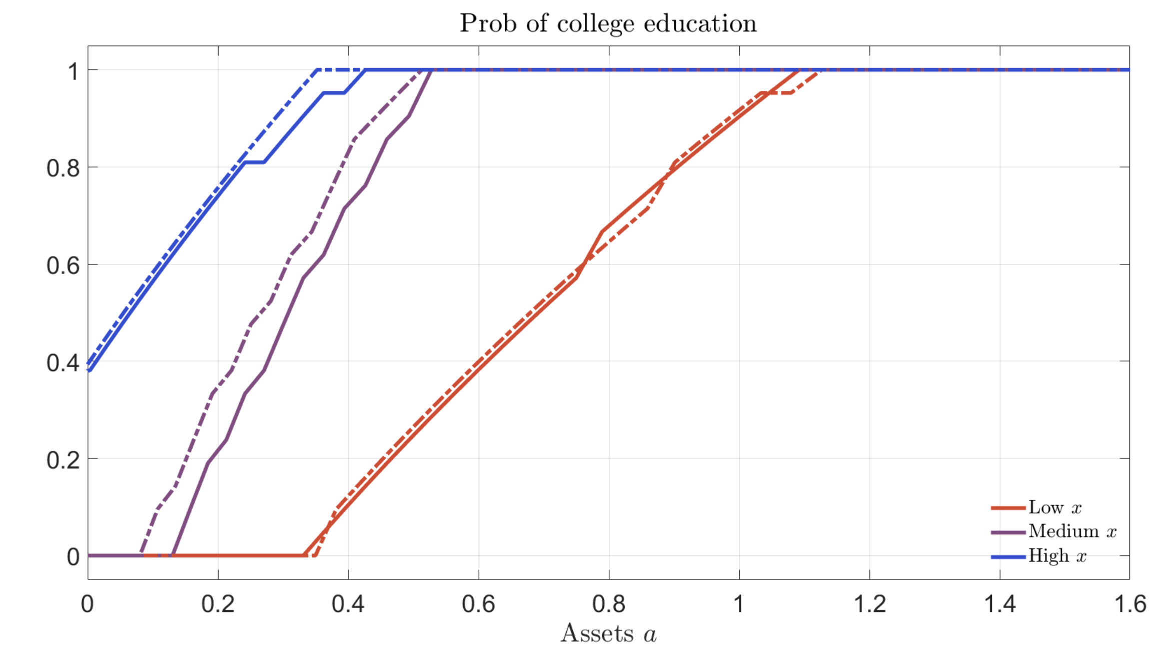


Figure 2: Steady State Education Policies: Closed (solid line) and Open (dashed line) Economies

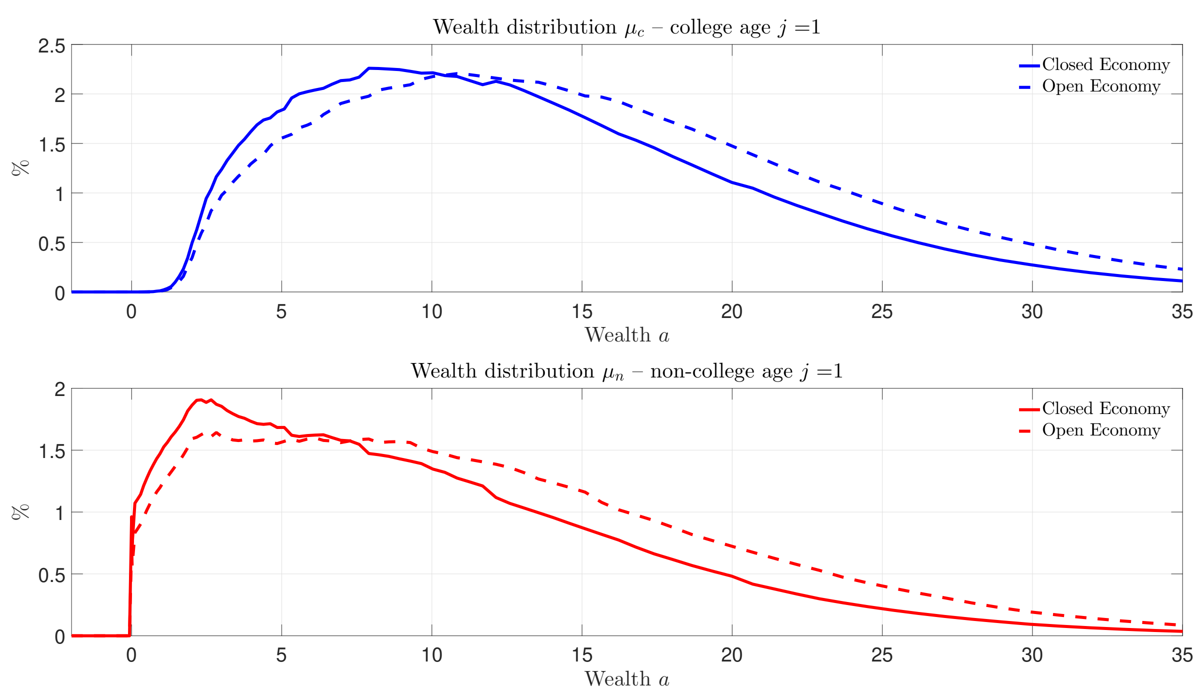


Figure 3: Steady State Wealth Distributions

The key insight of comparing the steady-states is as follows. Households make an effort to save and invest in a college education. This increases their wealth and welfare in the long-run. Thus, in the long-run, the common wisdom that trade openness increases everyone welfare holds. However, as we discuss next, it can take several years to experience these benefits, and the transition towards an open economy may actually be detrimental for several households in the economy.

5.3 Transition

Trade liberalization In this section, we consider the transition between the closed and the open economy. We assume that the iceberg cost τ_{it}^* drops immediately to the "open economy" steady-state level.[25] The largest drop occurs in the manufacturing sector: τ_m^* drops substantially and τ_s^* only mildly—see change in home-bias in Table 5.

Sectoral/Preference shock In order to obtain a smooth transition, we add a preference shock along the transition. In particular, after the newborn makes the education decision, he can only choose the sector i with probability $1 - \xi_e$. With the remaining probability ξ_e, the newborn is allocated to the manufacturing sector. We set ξ_e to be the proportion of households with education e that work in the services sector in the "open economy". We assume the shock lasts for one generation (J_R periods). More details can be found in Appendix B.[26]

Wages and college enrollment In the short-run, trade openness—induced largely by the drop in τ_m^*—reduces the demand for domestic manufactures, which results in lower wages in the manufacturing sector. At the same time, services sector expands, which results in higher wages for the services sector. Figure 4 shows the path for all wages. As can be seen, trade openness not only increases wage inequality, but it also lowers real wages for those in the manufacturing sector. As we show below, this implies life-utility welfare losses.

Since services is expanding, the demand for college labor increases. In turn, college enrollment increases as well, as Figure 5 shows. Why do newborns not invest in education and benefit from higher college wages? Because a college degree is expensive and newborns of poor households cannot afford to invest in education. As Figure 6 shows, about 35% of newborns start with almost no wealth, and thus they cannot afford going to college.

Consequently, trade openness in the short-run is beneficial for those in the services sector, or for those wealthy enough to pay for college. Figure 7 shows this heterogeneity in gains/losses from trade openness by plotting the consumption equivalent variations relative to the closed economy for several wealth levels. Poor workers in the manufacturing sector loose the most.

[25] We consider smoother transitions paths for τ_{it}^* in Appendix C.

[26] A better approach be to have this sectorial/preference shock in steady-state and the transition. This is currently work in progress.

Figure 4: Wage by sector and education over the Transition

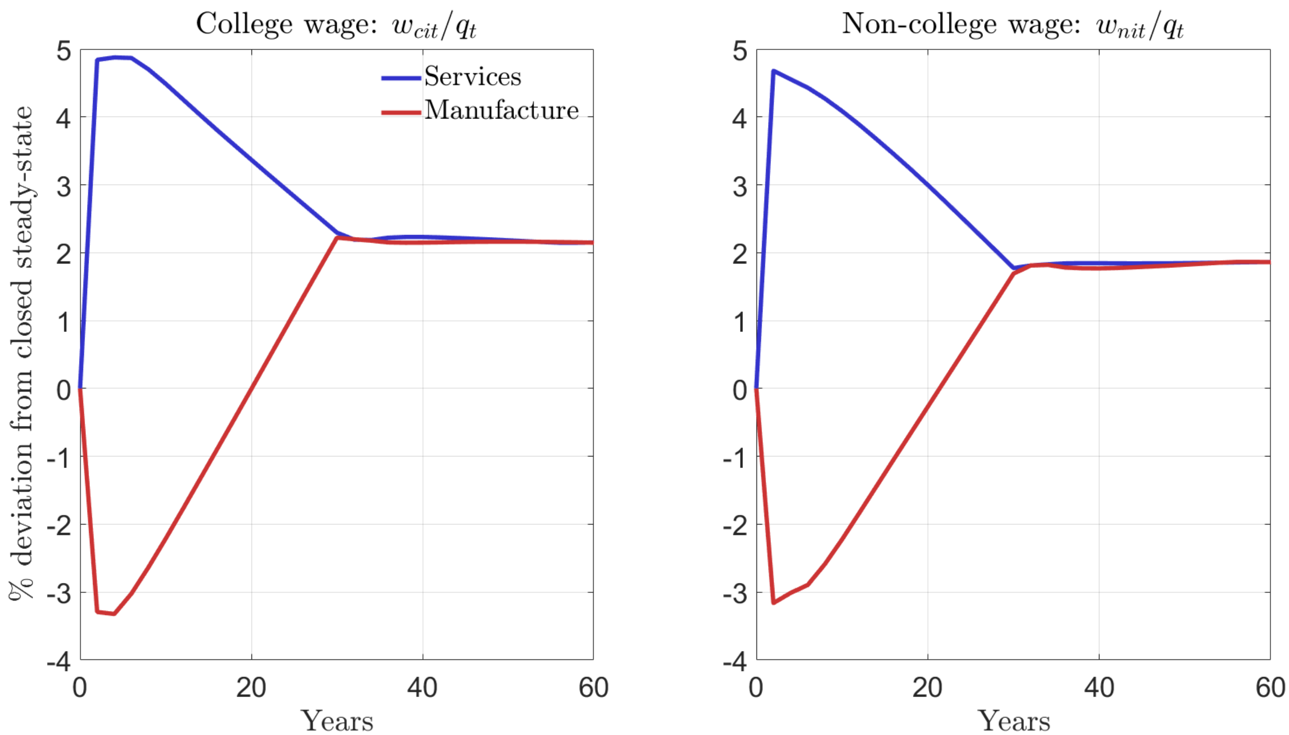


Figure 5: College measure along the transition

Figure 6: College decision by wealth – first period of transition

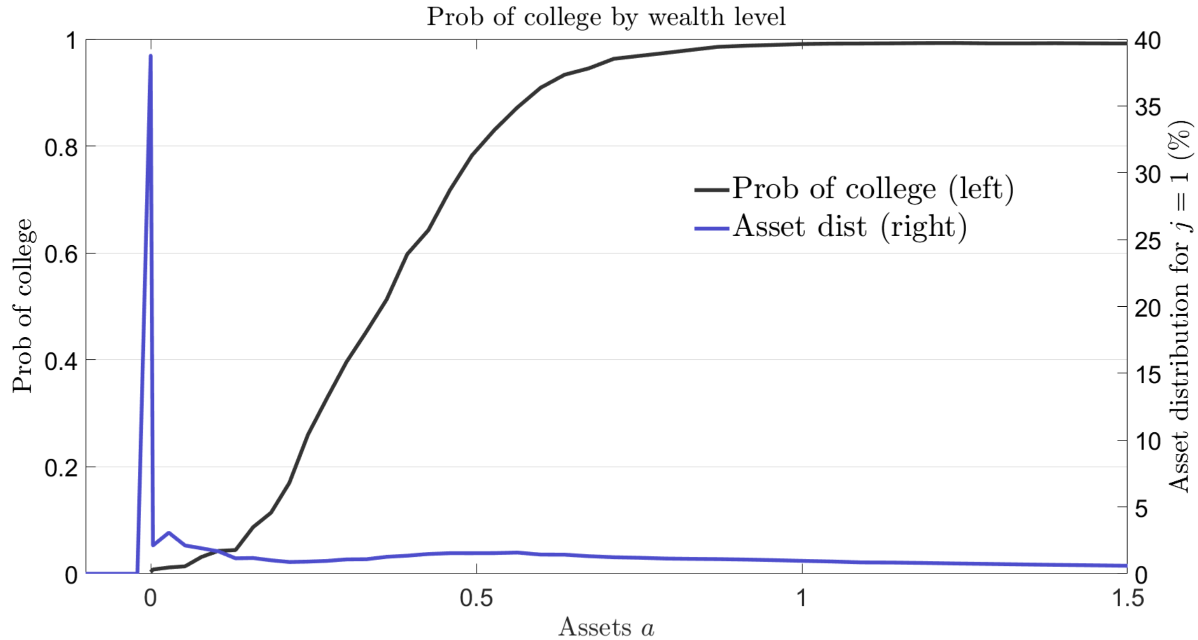
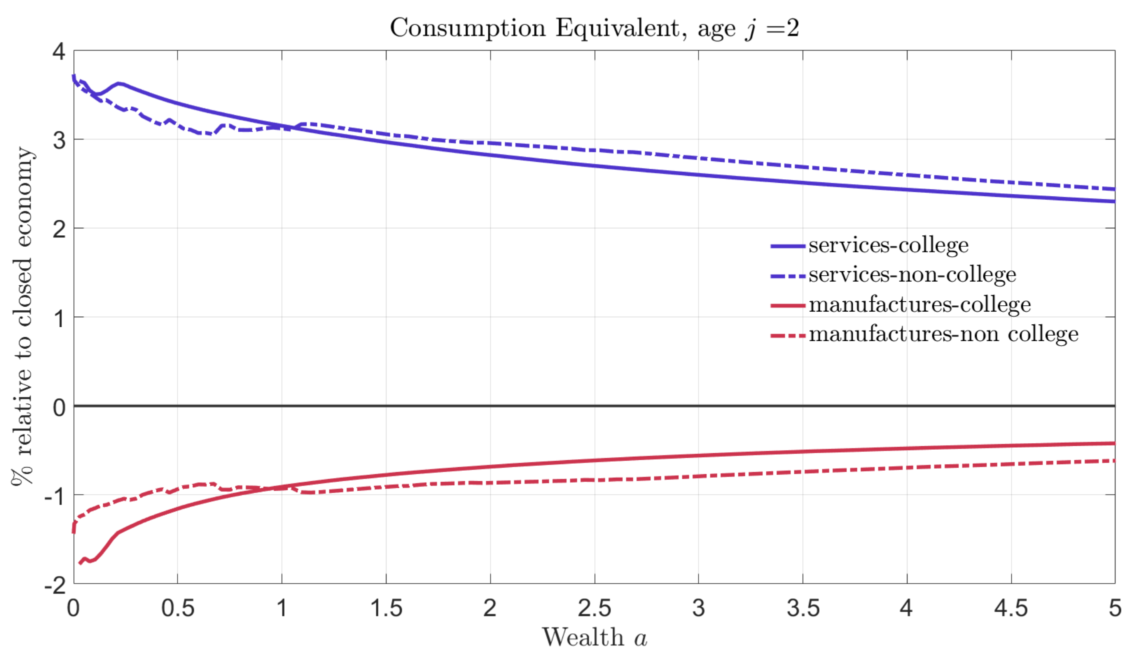


Figure 7: Consumption Equivalents by wealth – first period of transition



6 Policy Implications [TBF]

6.1 Fiscal policy

Trade openness generates temporary distribution concerns which may be addressed by appropriate fiscal policies. In particular, a (Utilitarian) government may consider two types of policies. On the one hand, it may consider speeding up the transition process, in order to reach sooner the new steady-state where everybody gains from trade openness. This view would favor policies to ease the cost of education, such as, loosening the borrowing constraint or subsidizing the cost of education through appropriate fiscal tools. On the other hand, the government may also redistribute to the ones who initially suffer from trade openness, that is, the unskilled workers. This policy would generate immediate welfare gains, but, if financed with a labor tax, it could also reduce incentives to invest in college education. As such, this may slow down the transition.

We present preliminary exercises to quantify each of these forces. Ultimately, we plan to derive the optimal policy mix of education incentives and redistribution to unskilled labor to maximize welfare along the transition.

6.2 Tariffs

The model will allow to compute the "optimal speed" of trade liberalization. We will then find the optimal temporary tariffs in line with this optimal speed.

7 Conclusion

We argued that trade openness can have unequal effects on heterogeneous households, especially in the short-run. An increase in the skill-premium induces households to invest in education, but this decision may be constrained by the household's wealth. In turn, poor-unskilled workers take the longest to acquire skills and are therefore the last to experience positive gains from trade openness. When we calibrate the model to the United States, we find that several households find trade openness detrimental. We explore various policies to address this concern.

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A Appendix

A Proof of Proposition 4.1

For the Armington model consider a shock to p_m^* that leads to expenditure switching and a decline in the price produed at home.

Consider the unit-cost functions:

$$c_i\left(w_c, w_n, r\right) = \min_{L_{i,c}, L_{i,n}, K_i} \left\{ w_c L_{i,c} + w_n L_{i,n} + rK | F_i\left(L_{i,c}, L_{i,n}, K_i\right) \geq 1 \right\},$$

where

$$F_i\left(L_{i,c}, L_{i,n}, K_i\right) = \left(\gamma_i^{\frac{1}{\sigma_i}} L_{i,c}^{\frac{\sigma_i - 1}{\sigma_i}} + \left(1-\gamma_i\right)^{\frac{1}{\sigma_i}} L_{i,n}^{\frac{\sigma_i - 1}{\sigma_i}} \right)^{\left(\frac{\sigma_i}{\sigma_i - 1}\right)\left(1-\alpha_i\right)} K_i^{\alpha_i}.$$

Then we know that in this particular case

$$c_i\left(w_c, w_n, r\right) \propto \left(\gamma_i w_c^{1-\sigma_i} + \left(1-\gamma_i\right) w_n^{1-\sigma_i}\right)^{\left(1-\alpha_i\right)} \left(r\right)^{\alpha_i}$$

and that in general by the "envelope theorem"

$$\frac{\partial c_i\left(w_c, w_n, r\right)}{\partial w_e} = a_{i,L_e}\left(w_c, w_n, r\right)$$
$$\frac{\partial c_i\left(w_c, w_n, r\right)}{\partial r} = a_{i,K}\left(w_c, w_n, r\right)$$

for $e \in \{c, n\}$ where $a_{i,x}$ denotes the optimal choice for factor x as a function of factor prices to produce one unit of the good.

The zero-profit conditions imply that in equilibrium

$$p_m = c_m\left(w_c, w_n, r\right) = \kappa_m \left(\gamma_m w_c^{1-\sigma_m} + \left(1-\gamma_m\right) w_n^{1-\sigma_m}\right)^{\left(\frac{1-\alpha_m}{1-\sigma_m}\right)} \left(r\right)^{\alpha_m},$$
$$p_s = c_s\left(w_c, w_n, r\right) = \kappa_s \left(\gamma_s w_c^{1-\sigma_s} + \left(1-\gamma_s\right) w_n^{1-\sigma_s}\right)^{\left(\frac{1-\alpha_m}{1-\sigma_m}\right)} \left(r\right)^{\alpha_s}.$$

By totally differentiating these conditions we obtain

$$dp_i = a_{i,L_c} dw_c + a_{i,L_n} dw_n + a_{i,K} dr \Rightarrow$$
$$\frac{dp_i}{p_i} = \frac{w_c a_{i,L_c}}{c_i} \frac{dw_c}{w_c} + \frac{w_n a_{i,L_n}}{c_i} \frac{dw_n}{w_n} + \frac{r a_{i,K}}{c_i} \frac{dr}{r}.$$

Define cost shares by $\theta_{i,L_e} \equiv \frac{w_e a_{i,L_e}}{c_i}$ for $e \in \{c, n\}$ and $\theta_{i,K} \equiv \frac{r a_{i,K}}{c_i}$. Then we obtain that

$$\begin{aligned}
\begin{pmatrix} \hat{p}_m \\ \hat{p}_s \end{pmatrix} &= \begin{pmatrix} \theta_{m,L_c} & \theta_{m,L_n} & \theta_{m,K} \\ \theta_{s,L_c} & \theta_{s,L_n} & \theta_{s,K} \end{pmatrix} \begin{pmatrix} \hat{w}_c \\ \hat{w}_n \\ \hat{r} \end{pmatrix} \\
&= \begin{pmatrix} \theta_{m,L_c} & \theta_{m,L_n} \\ \theta_{s,L_c} & \theta_{s,L_n} \end{pmatrix} \begin{pmatrix} \hat{w}_c \\ \hat{w}_n \end{pmatrix} + \begin{pmatrix} \theta_{m,K} \\ \theta_{s,K} \end{pmatrix} \hat{r}
\end{aligned}$$

which implies that

$$\begin{pmatrix} \hat{w}_c \\ \hat{w}_n \end{pmatrix} = \begin{pmatrix} \theta_{m,L_c} & \theta_{m,L_n} \\ \theta_{s,L_c} & \theta_{s,L_n} \end{pmatrix}^{-1} \begin{pmatrix} \hat{p}_m - \theta_{m,K}\hat{r} \\ \hat{p}_s - \theta_{s,K}\hat{r} \end{pmatrix}.$$

Asusmption 1 Assume that only the two types of labor are factors of production, that is, $\alpha_i = 0$ for $i \in \{m, s\}$. Hence, $\theta_{m,K} = \theta_{s,K} = 0$ and $\kappa_i = 1$ for $i \in \{m, s\}$.

We now have that

$$\begin{aligned}
\begin{pmatrix} \hat{w}_c \\ \hat{w}_n \end{pmatrix} &= \begin{pmatrix} \theta_{m,L_c} & \theta_{m,L_n} \\ \theta_{s,L_c} & \theta_{s,L_n} \end{pmatrix}^{-1} \begin{pmatrix} \hat{p}_m \\ \hat{p}_s \end{pmatrix} \\
&= \frac{1}{\det\theta} \begin{pmatrix} \theta_{s,L_n} & -\theta_{m,L_n} \\ -\theta_{s,L_c} & \theta_{m,L_c} \end{pmatrix} \begin{pmatrix} \hat{p}_m \\ \hat{p}_s \end{pmatrix}
\end{aligned}$$

where

$$\begin{aligned}
\det\theta &= \theta_{m,L_c}\theta_{s,L_n} - \theta_{m,L_n}\theta_{s,L_c} \\
&= \theta_{m,L_c}\left(1 - \theta_{s,L_c}\right) - \left(1 - \theta_{m,L_c}\right)\theta_{s,L_c} \\
&= \theta_{m,L_c}\left(1 - \theta_{s,L_c}\right) - \left(1 - \theta_{m,L_c}\right)\theta_{s,L_c} \\
&= \theta_{m,L_c} - \theta_{s,L_c} = \theta_{s,L_n} - \theta_{m,L_n}.
\end{aligned}$$

Therefore, we have that

$$\begin{aligned}
\hat{w}_c &= \frac{\hat{p}_m\theta_{s,L_n} - \hat{p}_s\theta_{m,L_n}}{\theta_{s,L_n} - \theta_{m,L_n}} \\
&= \frac{\left(\theta_{m,L_n} - \theta_{s,L_n}\right)\hat{p}_s + \theta_{s,L_n}\left(\hat{p}_s - \hat{p}_m\right)}{\theta_{m,L_n} - \theta_{s,L_n}}
\end{aligned}$$

and

$$\begin{aligned}
\hat{w}_n &= \frac{\hat{p}_s\theta_{m,L_c} - \hat{p}_m\theta_{s,L_c}}{\theta_{m,L_c} - \theta_{s,L_c}} \\
&= \frac{\left(\theta_{s,L_c} - \theta_{m,L_c}\right)\hat{p}_m - \left(\hat{p}_s - \hat{p}_m\right)\theta_{m,L_c}}{\theta_{s,L_c} - \theta_{m,L_c}}
\end{aligned}$$

Assumption 2 WLOG, assume that the manufacturing sector is intensive in low skilled workers, that is, $\theta_{m,L_n} - \theta_{s,L_n} > 0$, which implies that $\theta_{s,L_c} - \theta_{m,L_c} > 0$ given that $\theta_{i,L_c} + \theta_{i,L_n} = 1$ for $i \in \{m, s\}$.

Suppose that $\hat{p}_s - \hat{p}_m > 0$.

Given the previous assumptions, we obtain Stolper-Samuleson's result that

$$\hat{w}_c > \hat{p}_s > \hat{p}_m > \hat{w}_n.$$

Now, when does the assumption that $\theta_{m,L_n} - \theta_{s,L_n} > 0$ hold? In the case of Cobb-Douglas production functions this is clear. We have that $\theta_{i,L_n} \equiv \frac{w_n a_{i,L_n}}{c_i}$ and

$$a_{i,L_n} = \frac{\partial}{\partial w_n} \left(\gamma_i w_c^{1-\sigma_i} + (1-\gamma_i)\, w_n^{1-\sigma_i}\right)^{\frac{1}{1-\sigma_i}} = (1-\gamma_i) \left(\frac{c_i}{w_n}\right)^{\sigma_i}.$$

Hence,

$$\theta_{m,L_n} - \theta_{s,L_n} = (1-\gamma_m) \left(\frac{c_m}{w_n}\right)^{\sigma_m - 1} - (1-\gamma_s) \left(\frac{c_s}{w_n}\right)^{\sigma_s - 1}.$$

Now, notice that

$$\frac{c_i}{w_n} = \left(\gamma_i \left(\frac{w_c}{w_n}\right)^{1-\sigma_i} + (1-\gamma_i)\right)^{\frac{1}{1-\sigma_i}}.$$

Assumption 3 Skills are gross substitutes in production and their elasticity of substitution is the same across sectors, that is, $\sigma_i > 1$ for $i \in \{m, s\}$ and $\sigma \equiv \sigma_m = \sigma_s$.

Then notice that

$$\begin{aligned}
\frac{c_m}{w_n} &> \frac{c_s}{w_n} \Leftrightarrow \\
\frac{1}{\left(\gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)\right)^{\frac{1}{\sigma-1}}} &> \frac{1}{\left(\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)\right)^{\frac{1}{\sigma-1}}} \Leftrightarrow \\
\left(\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)\right)^{\frac{1}{\sigma-1}} &> \left(\gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)\right)^{\frac{1}{\sigma-1}} \Leftrightarrow \\
\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} - \gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} &> (1-\gamma_m) - (1-\gamma_s) \Leftrightarrow \\
1 &> \left(\frac{w_c}{w_n}\right)^{\sigma-1}.
\end{aligned}$$

Therefore, the only way to assure that $\theta_{m,L_n} - \theta_{s,L_n} > 0$ as long as $\gamma_s > \gamma_m$ is if $\frac{w_c}{w_n} < 1$, which is counter-factual. Hence, if $\frac{w_c}{w_n} > 1$ we need that

$$\frac{1-\gamma_m}{1-\gamma_s} > \frac{c_s}{c_m} = \left(\frac{\gamma_m \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_m)}{\gamma_s \left(\frac{w_c}{w_n}\right)^{1-\sigma} + (1-\gamma_s)}\right)^{\frac{1}{\sigma-1}}$$

which is equivalent to

$$\left(\frac{1-\gamma_m}{1-\gamma_s}\right)^{\sigma-1} > \frac{\gamma_m\left(\frac{w_c}{w_n}\right)^{1-\sigma}+(1-\gamma_m)}{\gamma_s\left(\frac{w_c}{w_n}\right)^{1-\sigma}+(1-\gamma_s)}.$$

B Proof of Proposition 4.2

Let Y_i denote total production of good i. Notice that because of constant marginal costs, then total factors used in the production of good i are $L_{i,c} = a_{i,L_c}Y_i$ and $L_{i,n} = a_{i,L_n}Y_i$. Hence, factor market clearing is given by

$$\begin{aligned} a_{m,L_c}Y_m + a_{s,L_c}Y_s &= L_c, \\ a_{m,L_n}Y_m + a_{s,L_n}Y_s &= L_n. \end{aligned}$$

By totally differentiating this system of equations we obtain

$$\begin{aligned} a_{m,L_c}dY_m + a_{s,L_c}dY_s &= dL_c, \\ a_{m,L_n}dY_m + a_{s,L_n}dY_s &= dL_n, \end{aligned}$$

where we have used the fact that a_{i,L_c} and a_{i,L_n} do not change if prices do not change. Hence, we obtain that

$$\begin{aligned} \frac{a_{m,L_c}Y_m}{L_c}\frac{dY_m}{Y_m} + \frac{a_{s,L_c}Y_s}{L_c}\frac{dY_s}{Y_s} &= \frac{dL_c}{L_c}, \\ \frac{a_{m,L_n}Y_m}{L_n}\frac{dY_m}{Y_m} + \frac{a_{s,L_n}Y_s}{L_n}\frac{dY_s}{Y_s} &= \frac{dL_n}{L_n}, \end{aligned}$$

which we can rewrite as

$$\begin{aligned} \lambda_{m,L_c}\hat{Y}_m + \lambda_{s,L_c}\hat{Y}_s &= \hat{L}_c, \\ \lambda_{m,L_n}\hat{Y}_m + \lambda_{s,L_n}\hat{Y}_s &= \hat{L}_n, \end{aligned}$$

where λ_{i,L_e} measure the fraction of factor L_e employed in industry i.

Inverting this system of equations we obtain

$$\begin{aligned} \begin{pmatrix} \hat{Y}_m \\ \hat{Y}_s \end{pmatrix} &= \begin{pmatrix} \lambda_{m,L_c} & \lambda_{s,L_c} \\ \lambda_{m,L_n} & \lambda_{s,L_n} \end{pmatrix}^{-1} \begin{pmatrix} \hat{L}_c \\ \hat{L}_n \end{pmatrix} \\ &= \frac{1}{\det\lambda}\begin{pmatrix} \lambda_{s,L_n} & -\lambda_{s,L_c} \\ -\lambda_{m,L_n} & \lambda_{m,L_c} \end{pmatrix} \begin{pmatrix} \hat{L}_c \\ \hat{L}_n \end{pmatrix} \end{aligned}$$

where

$$\begin{aligned}
\det \lambda &= \lambda_{m,L_c}\lambda_{s,L_n} - \lambda_{s,L_c}\lambda_{m,L_n} \\
&= \lambda_{m,L_c}\left(1-\lambda_{m,L_n}\right) - \left(1-\lambda_{m,L_c}\right)\lambda_{m,L_n} \\
&= \lambda_{m,L_c} - \lambda_{m,L_n} = \lambda_{s,L_n} - \lambda_{s,L_c}.
\end{aligned}$$

Hence, assuming wlog that $\hat{L}_n = 0$, then

$$\hat{Y}_m = \frac{\lambda_{s,L_n}}{\lambda_{s,L_n} - \lambda_{s,L_c}}\hat{L}_c > \hat{L}_c > 0$$

and

$$\hat{Y}_s = \frac{-\lambda_{m,L_n}}{\det \lambda}\hat{L}_c < 0.$$

B Model Computation

TO BE ADDED

C Model Robustness

TO BE ADDED