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, acquire skill and avoid the negative consequences of trade openness for low-skilled workers. However, not all members of these future generations might have the resources required to make such investments. In this paper we exploit variation in exposure to import penetration shocks across space in the United States to show that greater import penetration increases college enrollment and that this increase is driven by future workers in richer households. To analyze the welfare implications of the effects of trade openness on college enrollment, we propose a dynamic multi-region model of international trade with heterogeneous agents. The model features incomplete credit markets and costly endogenous skill acquisition. We calibrate the model to match changes in aggregate trade data for the United States and differential import exposure across U.S. regions. Lower import barriers generate increased college enrollment and welfare gains for all workers in the long-run. However, these gains are concentrated on workers with a college education, whose welfare gains are twice as large as those of non-college workers. While all workers in the manufacturing sector lose from grater trade openness, a small number of college educated workers in manufacturing with low wealth experience the greatest losses. Increasing college enrollment for new cohorts over time plays a crucial role in allowing new generations of workers to escape the potential welfare losses form trade. However, poor dynasties take the longest to acquire skills. They are therefore the last to experience positive gains from trade openness, and entire generations 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

Globalization affects workers unevenly. By shifting economic activity across occupations, firms, or industries, freer trade not only generates gains for specific groups of workers, but also losses for others. In the case of workers with different education levels, the differential effects of trade openness are evident. Freer trade has led to a decline in the income of workers without a college education—or lower skills—relative to the income of college-educated workers in multiple countries.[1] These distributional consequences generate incentives for workers with different education levels to adjust over time. While existing literature has focused on understanding how current generations of workers adjust to trade openness—for instance, by switching occupations, firms, industries, or regions in which they work—recent work has overlooked margins of adjustment available to future generations of workers like acquiring skill by enrolling into college.

Two key forces drive the effects of trade openness on skill acquisition decisions: incentives and resources. On one hand, if opening to trade increases the income premium for college-educated workers, future generations of workers are incentivized to invest in a college education and benefit from high skills.[2] Hence, future generations of workers making skill acquisition decisions can escape any potential losses from trade by investing in skill if they find it beneficial. On the other hand, even if future workers find the investment in college beneficial, 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 differential effects from trade openness.[3] Consequently, trade openness not only has consequences for inequality, but such consequences can also be shaped by initial inequality in income or wealth.

In this paper, we explore how trade openness affects college enrollment and its implications for welfare and inequality by taking into account the two key forces previously mentioned. Our analysis consists of two parts. In the first part of the paper we study empirically how trade shocks affect college enrollment decisions. We follow a similar strategy to Autor et al. (2013) and exploit variation in exposure to trade shocks across space in the United States between 1990 and 2007. We show that greater import penetration increases college enrollment and that this increase is driven by potential college students in richer households. More specifically, we show that import penetration (i) deteriorated labor market conditions for workers without a college education (Autor et al., 2013; Kim and Vogel, 2018) and (ii) increased overall college enrollment, while (iii) the increase in college enrollment is driven by future workers in richer households. Our results imply that a $1,000 increase in import penetration across regions increased the fraction of 18 to 25 year olds enrolled in their first year of college in more exposed region by 19 basis points relative to less exposed regions. However,

[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.

while this effect is not significantly different from zero for the lowest income quartile, it is 35 basis points and statistically significant for the highest income quartile.

In the second part of the paper we study the welfare consequences of trade openness in the presence of endogenous skill acquisition decisions an incomplete credit markets. To do so, we build a dynamic life-cycle international trade model. The model consists of a small open economy (SOE) composed of multiple regions and heterogeneous agents. The model features costly endogenous skill acquisition and idiosyncratic uninsurable risk—incomplete financial markets—(Aiyagari, 1994), which, together with a stochastic evolution of ability, induces an equilibrium wealth distribution. These features are 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 agents to invest more in college education. However, the decision to invest by agents depends not only on their abilities, but also on their wealth: Poor agents will take the longest to acquire skills and, therefore, will be the last to experience the gains from trade, and in some cases might not ever experience these gains. Thus, even allowing for endogenous skill acquisition, future generations of workers might lose from trade because of wealth heterogeneity. The model also allows for worker mobility across local labor markets defined by region-sector pairs. This feature allow us to asses the relevance of college enrollment as a margin of adjustment relative to other margins, as well as to consider the effects of exogenous import penetration shocks that affect regions differently. This is the type of shocks that we exploit in our empirical analysis; hence, we obtain a direct mapping between the data and the model.

We rely on a particulate parametrization of our model to conduct quantitative analysis. We calibrate the model to three regions or "islands" representing local labor markets the U.S. that differ in import exposure, 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.[4] 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 in 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, particularly college workers in manufacturing that are poor. 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. Inequality eventually converges to a level that is lower than the immediate aftermath of the shock, but higher than the pre-shock level.

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 in trade barriers. We show that the permanent drop in trade barriers leads to an increase in the

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

skilled wage premium of 0.2 percent in the long-run and that this increase differs substantially across regions. The higher wage premium induces future generations of workers to go to college leading to an increase in the number of skilled workers of 0.3 percentage points on average, while this measure increases by more than twice (0.7 percentage points) in highly exposed regions. The increase in the number of high-skilled workers results from a change in optimal education decisions, such that all future workers are more likely to go to college in the new steady state. Interestingly, we find that the wealth distributions for both high-skill and low-skill workers shift to the right, implying that in the new steady state every worker is richer than in the initial one, and therefore, all new generations are better off in the long-run.

The long-run results mask important differences in the wage premium and welfare gains from trade along the transition between steady states. 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 increases by approximately 10 times the steady state increase. After twenty years, the wage premium—and therefore also the income premium in the model—is 0.8 percent above its level in the average region of the new steady state. However, the wage premium across the high- and low-exposed regions still differs by 1.5 percentage points after twenty years. These 1.5 percentage points are comparable to our empirical estimate of the interquartile effect of import penetration shocks on the income of college graduates relative to high school graduates of approximately 1 percentage points (see column (1) in Table 2). 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 agents but detrimental for low-skilled-poor ones, a finding that extends the classic *Stolper-Samuelson* theorem to the case of endogenous skill acquisition and wealth heterogeneity.

Why do low-skilled workers not invest in education and benefit from high-skilled wages? Because education investment is costly and poor agents cannot afford it. Thus, low-skilled workers suffer during the transition towards the open economy. This is a key mechanism in the model, which lies in the interaction of endogenous skill acquisition and the equilibrium wealth distribution. As we show, losses from trade for poor agents can be substantial, amounting to 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 studying the effects of trade on skill acquisition taking both theoretical (Findlay and Kierzkowski, 1983; Danziger, 2017) and empirical (Atkin, 2016; Greenland and Lopresti, 2016; Blanchard and Olney, 2017) approaches. We contribute to this literature by providing evidence of the increase and heterogeneity 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 on labor markets, inequality and other macroeconomic outcomes. (Lyon and Waugh, 2017, 2018; Carroll and Hur, 2019) 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 literature on the effects of trade shocks on labor markets. (Autor et al., 2013; Pierce and Schott, 2016) Our empirical analysis is closely related to Autor et al. (2013) who provide evidence of a negative effects of an import penetration shock on earnings and employment in labor markets relatively more exposed to import competition. We contribute to this literature by providing evidence of the effects of import penetration shocks on college enrollment that differ across households' income distribution. From a structural perspective, this paper is closely related to the literature on structural trade models with labor market dynamics. (Artuç et al., 2010; Coçar et al., 2016; Dix-Carneiro, 2014; Caliendo et al., 2015) We contribute to this literature by bringing in the wealth heterogeneity dimension into models of labor market dynamics 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).

Lastly, this paper also contributes to the quantitative literature on the effects of trade between different groups of workers (Kim and Vogel, 2018; Burstein et al., 2016; Burstein and Vogel, 2017). 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.

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.

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.[5] 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,

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

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.[6]

We consider changes in import penetration over the periods spanning form 1990 to 2000 (1990-2000) 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.[7] 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.[8] In addition, conducting this analysis allows us to contrast our results with those

[6]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.

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

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

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

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

decisions.

[9] 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.

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).

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 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.[10]

[10] 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

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).

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 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

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.

remain only with a high school education. Hence, we now proceed to estimate the direct effects of these shocks on college enrollment decisions.[11] 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.[12]

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.[13] 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 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 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

[11] 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.

[12] 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.

[13] 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.

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 1st-Year College (2)	Enrolled in College (3)	Enrolled in 1st-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).

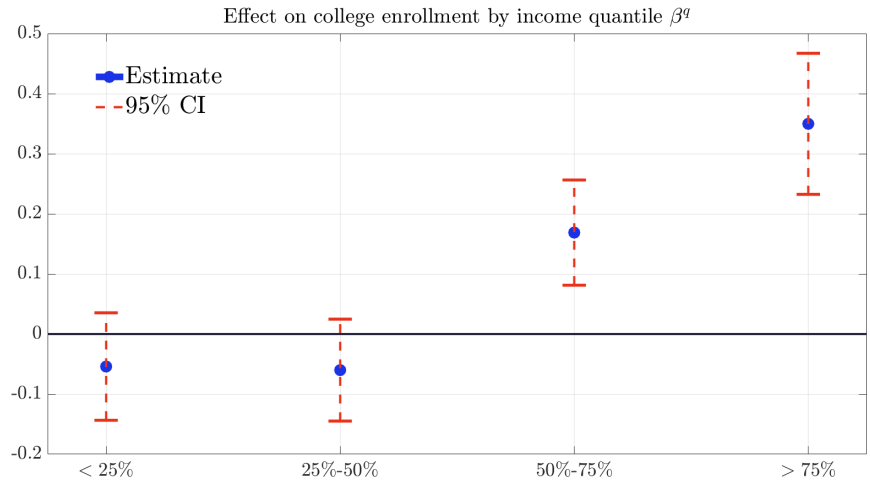
points. Hence, differences of 90 basis points across regions can explain a significant part of the aggregate change. These results point in the same direction as previous findings by Greenland and Lopresti (2016) who carry out a similar exercise, but looking at high school completion rates. Hence, our 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 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.[14] 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

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

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.

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 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

We consider a small open economy (SOE) composed of multiple regions indexed by $r \in \mathcal{R}$. Time is discrete, infinite, and periods are indexed by $t = 0, 1, 2, \ldots$. Production in each region r of the economy consists of two sectors—manufacturing and services—indexed by $i \in \{s, m\}$. The SOE is inhabited by a continuum of finitely-lived agents who live for J_R periods. Newborns are born

when agents reach age $J_k < J_R$, the age at which they become parents. Parents care about their off-spring, which generates a bequest motive.

At the beginning of their lives, agents decide whether to go to college or not. This is a one-time irreversible decision. Each agent corresponds to a worker, and we refer to agents that make the education investment as *college* workers, and those who do not make the investment as *non-college* workers.

We think of a labor market m as the region and industry pair $m = (r, i)$. At the end of each period, workers can choose to switch from one labor market to another, subject to a random utility cost. Newborns are born in the same regions as their parents, but they can also decide to move to another region at the begging of their life. Thus, the model allows for regional migration and industry switching.

Agents 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 bond is the only financial asset agents have access to. Borrowing and saving happens in international financial markets, at a gross interest rate R^* which the SOE takes as given.[15]

In each region r, 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 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 in an Armington fashion. The SOE assumption implies that domestic demand for imports is always met by foreigners at exogenously given world prices. We also assume an exogenously given foreign demand for domestic exports.

We start by discussing firms in the economy and then move to workers. 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 no 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.

3.1 Firms

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

$$F_{rit}(L_{crit}, L_{nrit}) = Z_{rit} \left(\gamma_i L_{crit}^{\frac{\sigma_i - 1}{\sigma_i}} + (1 - \gamma_i) L_{nrit}^{\frac{\sigma_i - 1}{\sigma_i}} \right)^{\frac{\sigma_i}{\sigma_i - 1}}, \tag{5}$$

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

where L_{crit} is *college* labor and L_{nrit} is *non-college* labor used in sector i, region r 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 we will assume is that manufacturing is relatively more intensive in *non-college* workers. That is, we assume $\gamma_s > \gamma_m$ for all regions r. 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 sectoral productivity may vary across regions, as captured by productivity Z_{rit}. Regional heterogeneity in productivity Z_{rit} implies different initial patterns of sectoral specialization across regions, and thus different effects of country-wide trade openness.

Intermediate goods firms' profit maximization reads

$$\max_{L_{crit}, L_{nrit}} \{p_{rit} F_{rit}(L_{crit}, L_{nrit}) - w_{crit} L_{crit} - w_{nrit} L_{nrit}\} \tag{6}$$
$$\text{subject to (5)}$$

where p_{rit} is the price of the tradable good in sector i, region r, at period t, and w_{crit} and w_{nrit} stand for *college* and *non-college* wages in the same region, industry and period, respectively. Notice that the wages of *college*/*non-college* workers may not equalize across sectors since workers are not fully mobile.

Solving problem (5) we obtain the optimality condition

$$\frac{w_{crit}}{w_{nrit}} = \frac{\gamma_i}{1-\gamma_i} \left(\frac{L_{crit}}{L_{nrit}} \right)^{-\frac{1}{\sigma}}. \tag{7}$$

Equation (7) shows that the wage premium in a given region and sector —w_{crit}/w_{nrit}— 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 matters for the determination of the skill premium, and this allocation will depend on comparative advantage, the world prices of tradable goods and sectoral productivity differences.[16]

Final Non-Tradable Goods Producers Final goods in each region $r \in \mathcal{R}$ are produced by combining domestic intermediate goods from each region as well as imported intermediate goods. For each sector $j = \{s, m\}$ and region r, final good producers aggregate intermediate goods using a nested Armington structure given by

$$Q_{rit} = \left[\omega_i^{\frac{1}{\eta_i}} D_{rit}^{\frac{\eta_i - 1}{\eta_i}} + (1-\omega_i)^{\frac{1}{\eta_i}} \left(D^*_{rit}\right)^{\frac{\eta_i - 1}{\eta_i}} \right]^{\frac{\eta_i}{\eta_i - 1}} \tag{8}$$

[16]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.

where D^*_{rit} is the imported intermediate good, and D_{rit} is an Armington aggregate combining domestic goods from all regions as follows

$$D_{rit} = \left(\sum_{\tilde{r} \in \mathcal{R}} \alpha_{ri\tilde{r}}^{\frac{1}{\theta_i}} \mathcal{Y}_{ri\tilde{r}t}^{\frac{\theta_i - 1}{\theta_i}} \right)^{\frac{\theta_i}{\theta_i - 1}}, \tag{9}$$

where $\mathcal{Y}_{jrlt}$ denotes the amount of intermediate goods demanded by sector j in region r from region l in period t. We assume that shipping goods across regions and internationally is costly.

In equation (8), η_i denotes the elasticity of substitution between domestic and imported inputs, and ω_i is a shifter affecting sector-specific home-bias in trade. We allow both the trade elasticity, η_i, and home-bias shifters to vary across sectors. Analogously for equation (9), θ_i denotes the elasticity of substitution across domestic intermediate goods from different regions, and $\alpha_{ri\tilde{r}}$ is the demand shifter in region r towards goods produced in region $\tilde{r}$. This model structure nests multiple models in the literature depending on the parameter choices. For instance, if $\alpha_{ri\tilde{r}} = 0 \ \forall \tilde{r} \neq r$, then there is no trade across regions and the model boils down to an "island model" in which, given the supply of the types of labor, 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 reads

$$\max_{\{\mathcal{Y}_{ri\tilde{r}t}\}_{\tilde{r} \in \mathcal{R}}, D^*_{rit}} \left\{ q_{rit} Q_{rit} - \sum_{\tilde{r} \in \mathcal{R}} \tau_{ri\tilde{r}t} p_{\tilde{r}it} \mathcal{Y}_{ri\tilde{r}t} - \tau^*_{rit} p^*_{it} D^*_{rit} \right\} \tag{10}$$

subject to (8)-(9)

where q_{rit} is the price of the final good bundle Q_{rit} in region r, $\tau_{ri\tilde{r}t} \geq 1$ is the iceberg cost of moving goods from region $\tilde{r}$ to r, and τ^*_{rit} is the cost of importing the good to region r.[17] Notice that we allow iceberg-type costs to vary over time, thus generating changes in trade openness.

Optimal demands are given by

$$\mathcal{Y}_{ri\tilde{r}t} = \alpha_{ri\tilde{r}} \left(\frac{\tau_{ri\tilde{r}t} p_{\tilde{r}it}}{\bar{p}_{\tilde{r}it}} \right)^{-\theta_i}, \tag{11}$$

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

$$D^*_{rit} = (1 - \omega_i) \left(\frac{\tau^*_{rit} p^*_{it}}{q_{rit}} \right)^{-\eta_i} Q_{rit}, \tag{13}$$

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

$$\bar{p}_{rit} = \left(\sum_{\tilde{r}} \alpha_{ri\tilde{r}} \left(\tau_{ri\tilde{r}t} p_{\tilde{r}it} \right)^{1-\theta} \right)^{\frac{1}{1-\theta_i}} \tag{14}$$

[17] Notice that we allow for iceberg-type trade barrier across regions in line with the literature on spatial economics.

and q_{rit} satisfies

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

3.2 Workers

There is a continuum of finitely-lived worker of ages $j = 1, \ldots, J_R$. Workers derive utility from consuming a bundle composed of services, c_s, and manufactures, c_m, and we denote this bundle by $c = \mathcal{C}(c_s, c_m)$. Each worker is endowed with $\bar{h}$ hours. Their labor productivity x evolves stochastically according to a Markov process with transition probabilities given by $\Pi_x(x', x)$. Workers can only save in risk-free bonds denominated in units of the final consumption bundle and with returns determined in world financial markets. At age J_k agents become parents. We assume workers care about their offspring and allow for *intervivos* transfers.

We consider a dynastic framework with three main stages: pre-education, education and a working stage. During the pre-education stage, newborns choose their education—to attend college or not—and a region-sector pair—a labor market—for their education stage. During the pre-education stage, agents are subject to idiosyncratic education- and region-sector-specific taste shocks that affect their education and location decisions. Furthermore, attending college and switching locations are both costly decisions. At the end of every period, workers can migrate from regions and/or switch industries, subject to a random taste shock. Next, we describe an agent's problem at the different stages of her life-cycle.

Let $V_t^j(a, x, r, i, e)$ be the maximum attainable life-time utility by an agent of age j, at time t, holding a units of the risk-free bond, with productivity x, working in sector i, with a level of education $e \in \{c, n\}$ and living in region r.

Working stage During the working stage, the value to a worker is

$$\begin{aligned}
V_t^j(a, x, r, i, e, j) &= \max_{c_s, c_m, a'} \left\{ U(c) + \mathbb{E}\left[\max_{m'} \left\{\epsilon_{m'} - \psi_{je}(m, m') + \beta V_{t+1}^{j+1}(a', x', r', i', e)\right\} | x\right]\right\} \quad (16)\\
q_{rst} c_s &+ q_{rmt} c_m + q_{rt} a' \leq w_{riet} x \bar{h} + R^* q_{rt} a \\
c &= \mathcal{C}(c_s, c_m) \\
a' &\geq \underline{a}_{je} \\
m &= (r, i) \\
\Omega_{t+1} &= \mathcal{H}(\Omega_t).
\end{aligned}$$

Here, $\epsilon_{m'}$ is the agent's idiosyncratic labor market-specific taste shock and $\psi_{je}(m, m')$ denotes the—age and education specific—cost of switching from labor market $m = (r, i)$ to labor market $m' = (r', i')$ at the end of period t. 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, and $q_{rt} \equiv \mathcal{Q}(q_{srt}, q_{mrt})$ denotes the ideal price index for a unit of the final consumption bundle, $c = \mathcal{C}(c_s, c_m)$. Notice that

education, e does not change during the working stage, but region r and indurty i may change.

The labor market-specific idiosyncratic shocks $\epsilon_{m'}$ are realized at the end of period t, after the agent has made consumption (c_s and c_m) and saving (a') decisions. It is after this shock is realized that agents choose the labor market where they will start next period, m'. We assume that these idiosyncratic sector-specific shocks are *iid* across time and workers, and follow an age and education-specific Gumbel distribution $\epsilon_{m'} \sim Gumbel\,(-\rho_{je}\gamma, \rho_{je})$.

Education stage College takes the first two periods of life, ages $j = 1, 2$. The cost of college per period in region r is denominated in terms of services and is given by κ_r. Education also requires time, and agents can only work part-time while attending college. Agents can borrow to pay for college, and the borrowing limit is looser for a few periods if an agent goes to college. Let $\underline{a}_{je}$ denote the borrowing limit for an individual of age j with education e. We assume that the borrowing limit does not vary across regions. If a newborn chooses not to go to college, they start their life in the working stage.

For ages $j = 1, 2$, the value for a newborn who attends college ($e = c$) in region r is given by

$$\begin{aligned}
V_t^j(a, x, r, i, c) &= \max_{c_s, c_m, a'} \left\{ U(c) + \mathbb{E}\left[\max_{m'} \left\{ \epsilon_{m'} - \psi_{je}(m, m') + \beta V_{t+1}^{j+1}(a', x', r', i', c) \right\} |x \right] \right\} \quad (17) \\
q_{rst}c_s + q_{rmt}c_m &+ q_{rt}a' + q_{rst}\kappa_r \leq w_{rint}x\frac{\bar{h}}{2} + R^* q_{rt}a \\
c &= \mathcal{C}(c_s, c_m) \\
a' &\geq \underline{a}_{jc} \\
m &= (r, i) \\
\Omega_{t+1} &= \mathcal{H}(\Omega_t)
\end{aligned}$$

Three comments are worth mentioning about problem (17). First, the cost of attending college is assumed to be denominated in terms of services. Second, while in college, agents can only work part-time and earn the *non-college* wage of their industry i only. Third, similar to the working stage of their life-cycle, workers can move across regions and industries, subject to a utility cost, during their education stage.

Pre-education stage Newborns have to choose their education and labor market at age $j = 1$, before production takes place. We refer to this stage as the *pre-education* stage and assume that education and labor market choices are made sequentially as specified next. At the beginning of age $j = 1$, which we refer to as age $j = 0$, an individual is born in their parent's region, observes parents's productivity and education, and receives a transfer from their parents. After receiving the transfer, newborns make education decisions. Finally, at the end of age $j = 0$, idiosyncratic taste shocks are realized and newborns choose the labor market—a region-sector pair—where they will go to school and work at age $j = 1$. Idiosyncratic labor productivity is realized at the very beginning of age $j = 1$.

To describe the newborns' optimal decisions, we'll the decisions at age $j = 0$ backwards. We start with labor-market choice, then move to education choice, and finally discuss the optimal transfers decision.

At the end age $j = 0$, a newborn already made an education decision e and must now chose a labor market m where to go. The maximum attainable life-time utility if born in region r_p (p for parents), who received transfer a, with parents' productivity x_p and sector i_p respectively, is given by

$$V_t^{0^+}(a, x_p, r_p, i_p, e) = \mathbb{E}_{\epsilon_m}\left[\max_m \left\{\epsilon_m - \psi_{0e}(m_p, m) + \mathbb{E}_x\left[V_t^1(a, x, r, i, e)|x_p\right]\right\}\right] \tag{18}$$

where ϵ_m is the idiosyncratic labor market-specific shock that is realized at the end of age $j = 0$ and $\psi_{0e}(m_p, m)$ is the education-specific cost of relocating and switching industries relative the newborn parents labor market. At this point, the newborn idiosyncratic productivity x has not yet been realized but it's distribution depends on the parents' productivity x_p with *cdf* $F_x(x_p)$.

Let's move one step back to the education choice. At the beginning of age $j = 0$, the value of a newborn in region r_p, who received transfer a, and with parent's productivity, sector and education x_p, i_p, and r_p respectively, is given by

$$V_t^{0^-}(a, x_p, r_p, i_p, e_p) = \mathbb{E}_\phi\left[\max\left\{V_t^{0^+}(a, x_p, r_p, i_p, c) - \phi, V_t^{0^+}(a, x_p, r_p, i_p, n)\right\}\right] \tag{19}$$

where ϕ is a random variable distributed according to a *cdf* $F_\phi(e_p)$ that depends on the parent's education.

The optimal education policy e is obtained from solving (19) and the initial labor market choice $m = (r, i)$ is obtained from (18), which determines the measure $\mu_t^1(r, i, e)$ of workers age $j = 1$ in region r, industry i, and education e at time t.

Inter-generational transfers At age J_k, workers choose the transfers to their newborns. The amount Φ to be transferred is given as

$$\max_{\Phi \geq 0}\left\{V_t^{J_k}(a - \Phi, x_p, r_p, i_p, e_p) + \hat{\lambda} V_t^{0^-}(\Phi, x_p, r_p, i_p, e_p)\right\} \tag{20}$$

where $\hat{\lambda}$ is how much parents discount their newborns' utility.

The agents' problem previously defined generates a set of policy functions defined next. For ages $j \geq 1$, let $\mathbf{c}_{st}^j(a, x, r, i, e)$, $\mathbf{c}_{mt}^j(a, x, r, i, e)$, $\mathbf{a}'^j_t(a, x, r, i, e)$ denote agents' optimal policies for services consumption, manufacturing consumption, and saving, respectively; and by $\mathbf{m}'^j_t(a, x, r, i, e, m')$, the probability of switching from labor market m to labor market m' at the end of period t. For age $j = 0$, let $\mathbf{m}_t^0(a, x_p, r_p, i_p, e, m)$ denote the probability that a newborn chooses labor market m, and $\mathbf{e}_t^0(a, x_p, r_p, i_p, e_p, e)$ denote the probabilities that a newborn chooses education e.

3.3 Market Clearing and Equilibrium Definition

Next, we discuss market clearing. In addition, we aggregate agents' 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 $\mu_t^j(a, x, r, i, e)$ be the measure of agents age j, in region r, in period t, with foreign holdings a, productivity x and education level e, working in sector i. We normalize the measure to unity: $\sum_r \sum_{j=1}^{J_R} \sum_{i,e} \int_{\mathcal{B}} d\mu_t^j(a, x, r, i, e) = 1$ for all t. For later computations, denote by $\mu_t^{0^-}(r) = \sum_{i,e} \int_{\mathcal{B}} d\mu_t^{J_k}(a, x, r, i, e)$ the measure of newborns in region r *before* the education and labor-market decisions.

Labor Market Let L_{riet} be the optimal labor demand in region r of workers with education e from the intermediate good producers in sector i. The labor market must clear for each type of labor e in each region separately. That is,

$$L_{rint} = \int x\frac{\bar{h}}{2} d\mu_t^1(a, x, r, i, c) + \sum_{j=2}^{J_R} \int x\bar{h} d\mu_t^j(a, x, r, i, n) \qquad \forall r, i, t \tag{21}$$

$$L_{rict} = \sum_{j=3}^{J_R} \int x\bar{h} d\mu_t^j(a, x, r, i, c) \qquad \forall r, i, t \tag{22}$$

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

$$Q_{rst} = C_{rst} + \bar{\kappa}_{rt} \qquad \forall k, t \tag{23}$$

$$Q_{rmt} = C_{rmt} \qquad \forall k, t \tag{24}$$

where $\bar{\kappa}_{rt} = \int \kappa_r \mathbf{e}_t^0(\Phi, x_p, r_p, i_p, e_p) d\mu_t^{J_k}(a_p, x_p, r_p, i_p, e_p)$ denotes total services demanded for education investment, for $\Phi = \Phi(a_p, x_p, r_p, i_p, e_p p)$ the optimal *itervivos* transfer.

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 demand of goods produced in each region r, $B_{rit}^* = \bar{B}_{it}^* (p_{rit})^{-\eta^*}$. The term $\bar{B}_{it}^*$ incorporates multiple factors that could shift the demand for intermediate goods produced domestically. For instance, this term incorporates the effects of iceberg-type trade costs that foreigners pay to purchase goods produced at home. Market clearing for tradable goods then implies

$$Y_{rit} = \sum_{\tilde{l}} \tau_{\tilde{r}irt} \mathcal{Y}_{\tilde{r}irt} + B_{rit}^* \tag{25}$$

where $\mathcal{Y}_{\tilde{r}irt}$ is given in (11).

Agents' 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 $A_{rt+1} = \sum_{j,i,e} \int \mathbf{a}'^j_t(a,x,r,i,e) d\mu^j_t(a,x,r,i,e)$ be the total savings in region r. Then, aggregate asset holdings of agents in region r evolve according to

$$\begin{aligned} A_{rt+1} - A_{rt} &= (R^* - 1)A_{rt} \\ &+ \sum_i \sum_{\tilde{r} \neq r} (\tau_{\tilde{r}irt} p_{rit} \mathcal{Y}_{\tilde{r}irt} - \tau_{ri\tilde{r}t} p_{\tilde{r}it} \mathcal{Y}_{ri\tilde{r}t}) \\ &+ \sum_i (p_{rit} B^*_{rit} - \tau^*_{rit} p^*_{it} D^*_{rit}). \end{aligned} \tag{26}$$

Equation (26) 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 ($\sum_i \sum_{\tilde{r} \neq r} \tau_{\tilde{r}irt} p_{rit} \mathcal{Y}_{\tilde{r}irt}$) is larger than the cost of purchased goods from other regions ($\sum_i \sum_{\tilde{r} \neq r} \tau_{ri\tilde{r}t} p_{\tilde{r}it} \mathcal{Y}_{ri\tilde{r}t}$); and the third line implies an accumulation because of trade with foreigners.

Notice that $\sum_r \sum_i \sum_{\tilde{r} \neq r} (\tau_{\tilde{r}irt} p_{rit} \mathcal{Y}_{\tilde{r}irt} - \tau_{ri\tilde{r}t} p_{\tilde{r}it} \mathcal{Y}_{ri\tilde{r}t}) = 0$. Hence, the economy wide evolution of asset holdings is given by

$$A_{t+1} - A_t = (R^* - 1)A_t + \sum_r \sum_i (p_{rt} B^*_{rit} - \tau^*_{rit} p^*_{it} D^*_{rit}), \tag{27}$$

where $A_t = \sum_r A_{rt}$. Equation (27) is the standard current account identity: foreign assets accumulation in a country is the return on previous assets plus net exports.

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 $|\mathcal{R}| = \infty$, that agents' 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_j for $j \in \{s, m\}$.

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:*

$$\left(\frac{1-\gamma_m}{1-\gamma_s}\right)^{\sigma-1} > \frac{\gamma_m\left(\frac{w_c}{w_n}\right)^{1-\sigma}+(1-\gamma_m)}{\gamma_s\left(\frac{w_c}{w_n}\right)^{1-\sigma}+(1-\gamma_s)}. \tag{28}$$

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.[18] 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.

[18] 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

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

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 our initial quantitative exercise, we consider a version of our model in which each region is an isolated "island", trading with the rest of the world but not with other regions, and where there is no migration.[19] This is, we assume that $\alpha_{rli} = 0\ \forall l \neq r$ and $\psi(e)_{(r_p,j_p),(r,j)} = \infty$ for $r \neq r_p$ for all j. Thus, final good producers use only two types of intermediate goods: foreign and domestic from their own region. We focus on three "islands" and calibrate them to high, average and low exposure to import penetration. The highly exposed region has an initial labor manufacturing share equal to the average of the top half of the commuting zones in the U.S. in terms of labor manufacturing shares, while the low exposed region is equivalent to the bottom half of the distribution. The differences in initial exposure across regions are entirely driven by differences in sectoral productivity. The commuting zones considered are the same geographical units 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^*_{jt}. We consider a period of trade liberalization as a decrease in the cost of imported goods τ^*_{jt}. In particular, we start the economy at a steady-state with a high τ^*_j calibrated to observed trade flows in 1990, and analyze the effect of an (unexpected) drop in τ^*_j leading to trade flows observed around the

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

year 2010. We refer to the high-τ_j^* steady-state as a "closed economy", and the low-τ_j^* steady-state as the "open economy".

We start by describing the calibration of the model. We then analyze how the closed and open economies compare in terms of welfare and inequality. Finally, we analyze the economy transition from the closed to the open economy.

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 $K_R = 25$, that is, agents born at age 18 work for 50 years, until 68; agents become parents at age $K_T = 15$, so that at age 48, their offspring is 18 years old. We assume an annual foreign risk-free rate of $R^* - 1 = 1.6$ percent 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 the altruistic parameter $\hat{\lambda}$ such that annual transfers (intended, bequests, and college payments) amount to about to 30% 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 $\nu_s = 1 - \nu_m = 0.74$ 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 $\sigma_x = 0.25$ at annual frequency (Floden and Lindé, 2001). We convert the process to a two-year duration and discretize it following Tauchen (1986).

Turning to the sector-specific taste shocks, we assume that these shocks are distributed according to a Gumbel distribution with parameters $\rho_\epsilon \nu_\epsilon$ and ν_ϵ. We follow Artuç et al. (2010) to calibrate these parameters. Moreover, we calibrate the switching costs, ψ^u to match an annual sectoral persistence of approximately 97 percent.

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 $q_s \kappa_r$ can be borrowed. This initial loan will have to be repaid in the next 14 years: $a_{k,c} = a_{1,c}\ \forall k \leq 7$, and $a_{k,c} = 0\ \forall k > 7$. Finally, we calibrate κ_r, the cost of education, such that the cost of education is approximately ten percent of total income; each household has two identical children. Turning to the education taste shocks, we follow Daruich (2018) and assume that these shocks are distributed according to a log-normal distribution with mean m_{e_p}, where $e_p \in \{c, n\}$, and variance σ_e^2, that is, $\ln \phi \sim \mathcal{N}(m_{e_p}, \sigma^2)$, for $e_p = \{c, n\}$. We calibrate the parameters of this distribution such that the share of college educated in the steady state is 36 percent, in line with American Community Survey (ACS) data for 1990, and the persistence in inter-generational education is 77 percent.

We use standard values for technology parameters. For the final good technology, we assume identical technologies: $\omega_j = 0.7$ and $\eta_j = 4$. Hence, we consider a trade elasticity in line with the

literature. For intermediate goods technology, we assume $\sigma = 2$. We calibrate the intensity in college workers, γ_j, to match the share of college labor earnings relative to total labor earnings in each sector in the U.S. in 1990. As expected, Table 4 shows that $\gamma_s > \gamma_m$, implying that, on average, services are more intensive in college workers. The college share in services is 49 percent, while it is 31 percent in manufacturing.

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

Table 4 summarizes our calibration and provides data on the moments we target to discipline some of the parameters. Table 5 presents some results for non-targeted moments in the steady state. The model delivers a reasonable wage premium, and a realistic wealth distribution.

Table 4: Calibration: External Parameters and Internal with Targeted Moments

	Parameters		Target	Data	Model
Preferences	ν_s	0.74	*External*	—	—
	ρ	0.5	*External*	—	—
Education	$\underline{a}_{1c}$	-0.10	Share of cost that can be borrowed $(-q\underline{a}_{1c}/q_s\kappa)$	0.50	0.48
	κ	0.19	Cost of college as mean of income	0.20	0.39
Savings	β	0.98	Wealth to income ratio	4	3.05
	$\hat{\lambda}$	0.45	Transfers to wealth ratio		0.30
Technologies	σ	2	*External*	—	—
	γ_s	0.55	Wages of non-college workers in services	0.41	0.38
	γ_m	0.40	Wages of college workers in manufacturing	0.07	0.06
			Wages of non-college workers in manufacturing	0.16	0.17
			Wages of non-college workers in services	0.37	0.39
Trade	τ_s	4.39	Home bias in services	0.98	0.98
	τ_m	2.17	Home bias in manufacturing	0.90	0.90
	B_s	0.01	Export share in services	0.02	0.02
	B_m	0.02	Export share in manufacturing	0.09	0.09

5.2 Education Policy in Steady State

The solid lines in Figure 2 show the probability of attending college (left axis) as a function of the parent's transfer, Φ, for different levels of the parent's productivity. Below a certain transfer threshold, newborns do not acquire a college education simply because it is impossible for them to pay for it. At a certain threshold, the probability of attending college increases drastically, and this threshold is lower for newborns with highly productive parents. Given that productivity of a newborn is positively correlated with that of her parents, newborns of productive parents are

Table 5: Calibration: Non-targeted Moments

Moment		Model	Data
Wage premium (raw)		1.39	
Wage premium (adjusted)		1.52	
Trade balance (share of GDP)		-0.03	≈ -0.012
Wealth distribution	1st quintile	0.00	
	2nd quintile	0.04	
	2nd quintile	0.10	
	2nd quintile	0.21	
	2nd quintile	0.65	

expected to see a greater increase in wages by acquiring a college education. This also implies that it is easier for them to pay for the education investment in the future without sacrificing much consumption. Hence, these newborn decide to attend college for lower transfer levels. Interestingly, the increase in the probability of attending college is more drastic for newborns of less productive parents. The more drastic increase occurs because, once transfers are large enough to pay for a college education, the increase in wages due to skill upgrading is more beneficial for newborns of less productive parents. Acquiring skill is their only margin to upgrade the low productivity inherited.

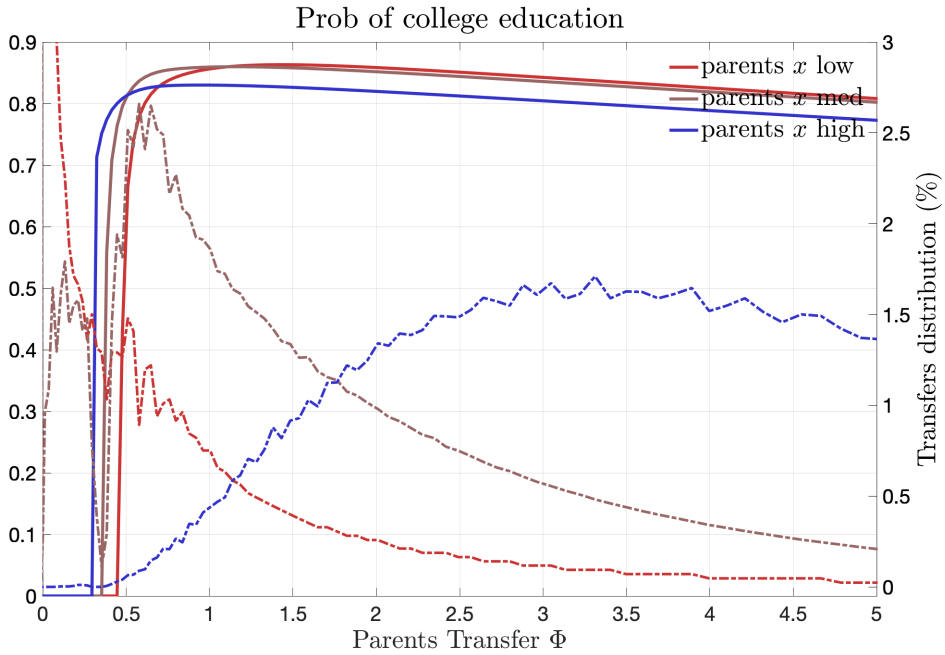
Another interesting feature of the policies is that the likelihood of attending college for the newborns of less productive parents remains higher for high transfers surpassing the wealth region of the drastic increase. For high levels of transfers, the probability of attending college decreases with increasing transfers because, once the education investment can be paid, large transfers can be used to smooth consumption along a newborn's life-cycle without having to attend college which can be really disliked by agents. These income effect is also a driver of the milder increase in the probability of going to college for the newborns of more productive parents.

Even though these policies do not look strikingly different across productivity levels, the distribution of transfers across types of newborns are strikingly different. Figure 2 plots the distribution of transfers for different levels of parents' productivities. More productive parents are richer and make larger transfers to their newborns, while less productive parents make smaller transfers that, in most cases, are not enough to pay for a college education. Hence, even though education policies of newborns do not differ markedly across different levels of their parents' productivities, the amount of their transfers do and therefore only the kids of rich agents end up going to college.

5.3 The Dynamic Effects of Trade Openness

Let us now turn to the analysis of the transitional dynamics of the economy after an unexpected decline in the import costs of all regions leads to an increase of imports into the SOE.

Figure 2: Steady State Education Policies

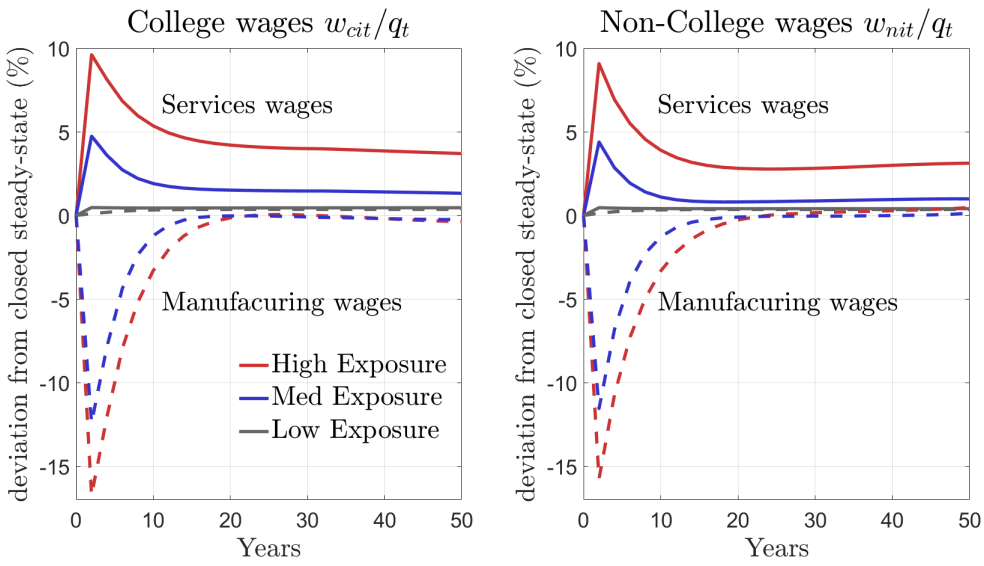


Cross-regional differences In line with our empirical analysis in Section 2, we first study the differences across regions generated by the increase in trade openness. Figure 3 plots the evolution of real wages—wages in terms of the final consumption bundle. The plot shows that, on impact, workers in the manufacturing sector of the average region (labeled as Med Exposure) suffer wage losses of approximately twelve percent independently of their education, while workers in the services sector of the same region experience an increase of approximately four percent. The larger drop in the costs to import manufacturing goods leads to expenditure switching towards foreign manufacturing goods, which generates lower demand for domestically produced manufactures, leading to lower wages in this sector. These effects are amplified by the level of import exposure. In more exposed regions, the changes in wages, both positive and negative, are larger, while these changes are dampened in less exposed regions.

The changes in wages are greatest on impact and dampen over the medium- and long-run. As workers slowly switch sectors, the initial differences in sectoral wages dissipate and the initial increase in service wages is very close to its long-run level of one percent after twenty years. The initial drop in wages in the manufacturing sector has also partially dissipated after twenty years. These results are in line with our empirical results in Section 2.

In summary, the increase in trade openness generates winners and losers in terms of wages. While workers in the manufacturing sector lose, those in the services sector gain. Moreover, these gains and losses are greatest on impact, but become smaller as time evolves and workers switch sectors. These results are in line with previous literature on the effects of switching costs on workers

Figure 3: Evolution of Wages



(Artuç et al., 2010; Dix-Carneiro, 2014; Caliendo et al., 2015).

While these results reveal the relevance of sectoral switching as a margin of adjustment for existing workers at the time of the trade shock, they not tell us anything about the differential effects of trade openness across skill levels. This margin is key for new cohorts of workers rather than existing one, which is the focus of this paper. Hence, we now turn to the effects of the shock across workers with different skills.

Figure 4 plots the evolution of the observed college income premium, which we refer to as the wage premium. The figure shows that, on impact, the increase in the wage premium is sizable in the average region, approximately two percent, and that this increase is almost twice as large in the highly exposed region (3.4 percent). Moreover, the low exposure region does not seem to experience any sizable changes in the wage premium. Hence, the change in the wage premium is amplified by the level of import exposure of a region. After the initial impact, the wage premium starts to decrease as new cohorts of newborns decide to enroll in college because of its higher return, as shown in figure 5. This figure plots the change in the measure of college workers over time. College enrollment increases more in regions that experience larger increases in the college premium. While the average region experiences an increase in the mass of college workers of approximately 0.3 percentage points in the long-run, this effect is more than doubled in the highly exposed region (0.7 percentage points). Interestingly, in the low exposure region, college enrollment decreases even though this region experiences a small increase in its wage premium. This decrease in enrollment is driven by the increase in the relative cost of services, which includes the cost of education.

Even though the aggregate wage premium increases, sector-specific wage premia follow strikingly different paths across sectors, especially in the highly exposed regions. Figure 6 plots the evolution of the wage premium computed for each sector in all three regions. As expected, the wage premium

Figure 4: Evolution of Wage Premium

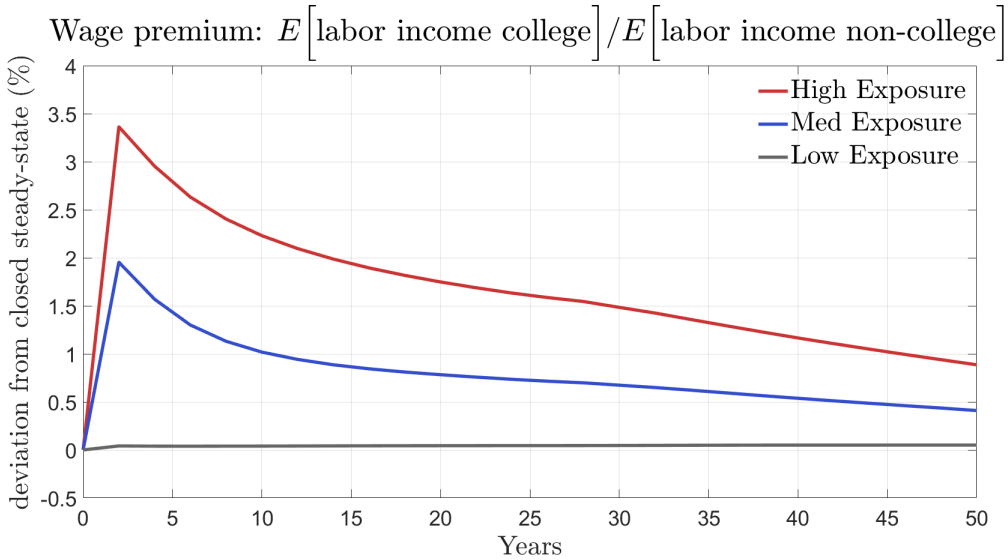


Figure 5: Evolution of College Enrollment

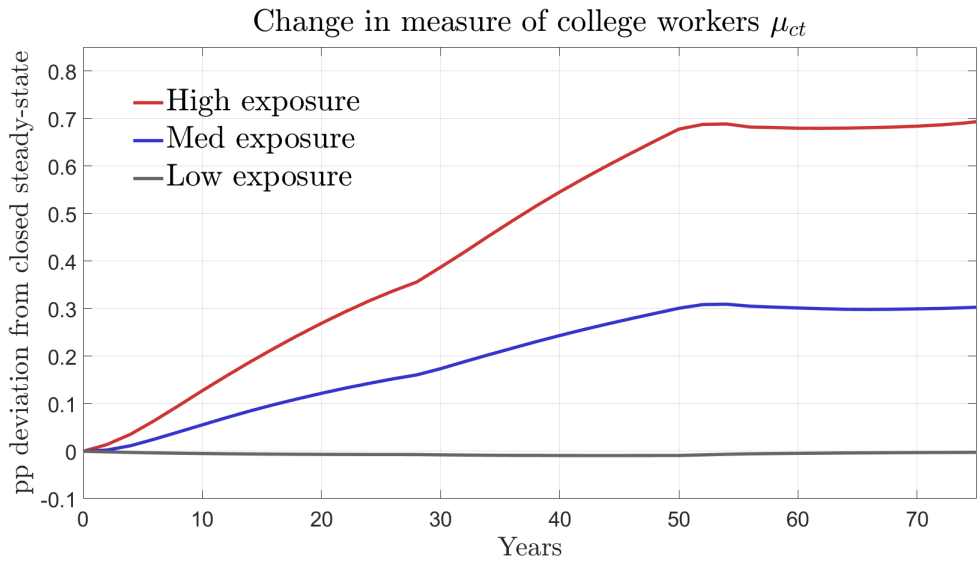
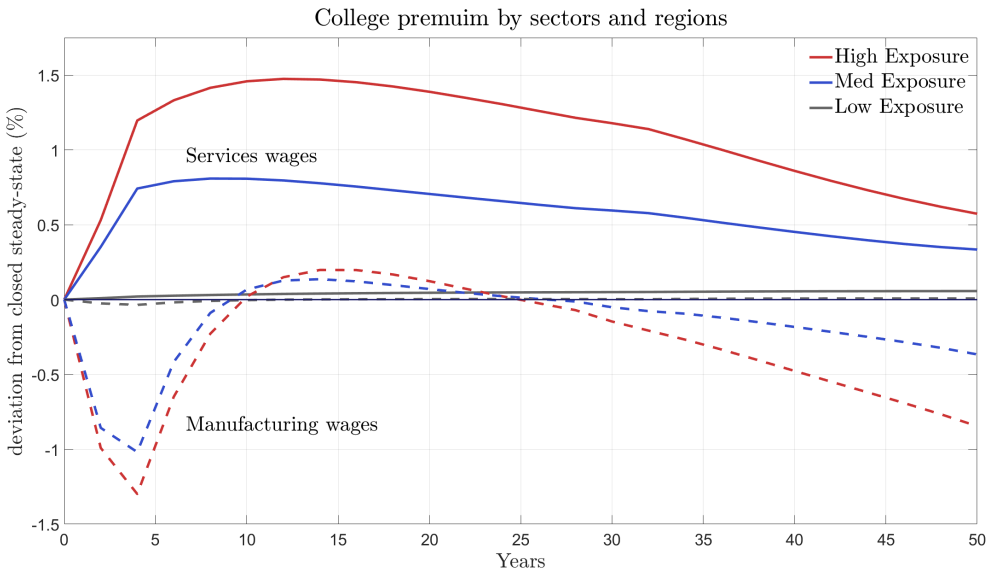


Figure 6: Evolution of Wage Premium by Sector

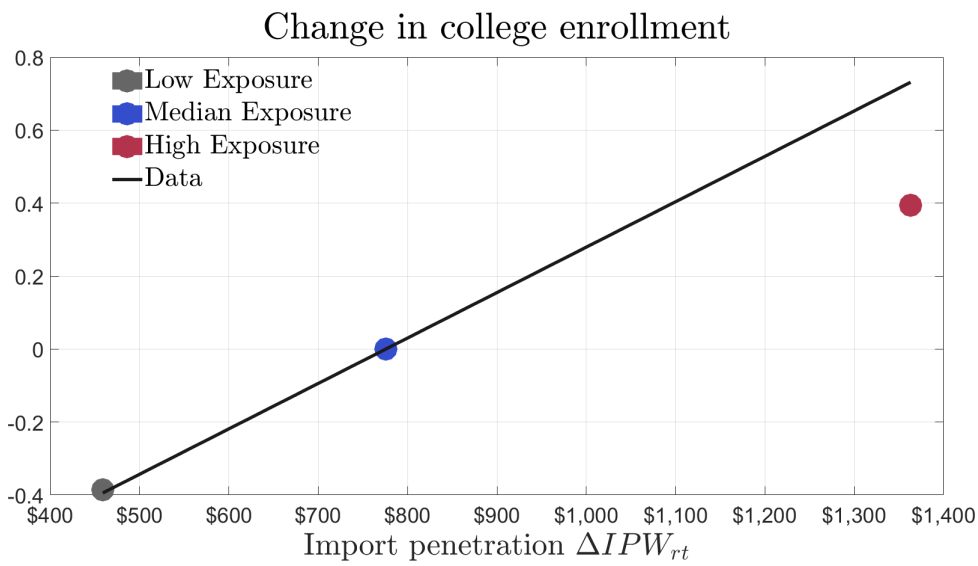


in the services sector increase on impact. However, in contrast to the aggregate wage premium, it keeps increasing for a few period after the initial shock, before reverting towards its new steady state value. Interestingly, the wage premium in the manufacturing sector initially decreases sharply, before following a path similar to the wage premium in services, but with a delay. In a world without costs of switching sectors, wage premia would equalize across sectors and the unique wage premium would increase on impact—because of the Stolper-Samuelson theorem. Hence, the difference in wage premia is driven by the frictions that workers face to reallocate across sectors.

To better understand the dynamics of sector-specific wage premia, we refer to equation (7). This equilibrium condition implies that the wage premium in each sector is determined by labor allocations across sectors for each skill level. The increase in the wage premium in services leads to a decline in L_{csrt}/L_{nsrt}. Given that non-college manufacturing workers suffer the greatest decline in wages, these workers decide to switch to services, reinforcing the direct impact of the trade shock. Interestingly, the increase in the wage premium in services is not sufficient to incentivize enough college workers to reallocate to services, thus resulting in an increase in L_{cmrt}/L_{nmrt}. In summary, on impact, non-college manufacturing workers reallocate a more to services than college workers. This result is also in part driven by the fact that college workers in manufacturing are, on average, richer than non-college workers, which implies that the value of the outside option of switching sectors for the former is lower. However, this reallocation pattern is reverted once the wage premium in services reaches high enough levels. At this point, services attract the majority of the new college educated workers, thus leading to a decline in L_{cmrt}/L_{nmrt}.

How do the results of the model compare to our empirical results? Following our empirical analysis in Section 2, figure 7 considers the change in college enrollment in the three regions after

Figure 7: Cross-regional Regression: Model vs Data



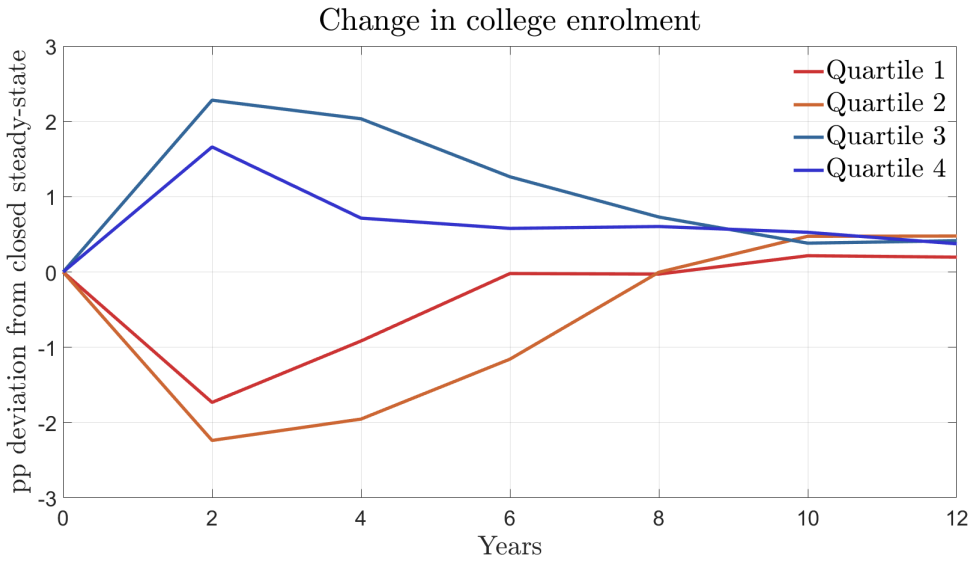
the shock in trade costs, and plots these changes against the change in import penetration in each region. The model generated data is represented by the three dots in the figure. We then consider the estimated coefficient in our empirical analysis and plot the estimated regression line assuming that the y-axis intercept is such that this line is perfectly consistent with the data for the average region. Figure 7 clearly shows that the data generated by the model is able to replicate our empirical results remarkably well.

Who goes more to college? Let us now address which newborns enroll in college. Figure 8 plots the evolution of changes in college enrollment by parental income quartiles in the average region. In summary, parental income matters: enrollment increases only for the children of the two highest parental income quartiles. Moreover, the kids of poorer workers decide not to enroll into college initially. The negative effect of enrollment is partly explained by the increase in the relative price of education services.

The welfare consequences of trade openness Figures 9, 10 and 11 show our results regarding welfare. To measure changes in welfare we rely on measures of consumption equivalent variation for each type of worker and then aggregate them accordingly.

How does welfare change for workers with different skill levels? Figure 9 shows that both types of worker experience welfare gains from trade, but that the gains for college workers are greater by a factor of approximately 2 across all wealth levels. It is worth pointing out that the welfare gains from trade are greater for individuals with lower wealth. The greater gains are explained by two factors. First, agents with lower wealth have lower consumption and therefore exhibit a greater marginal utility of consumption. Second, poor agents have a larger share of labor income in total

Figure 8: Change in College Enrollment



income, which implies that the percentage increase in income because of trade openness is greater. These two factors explain the larger gains by agents with lower wealth.

Even though figure 9 shows that, in the aggregate, both college and non-college workers gain from trade openness, this result masks a significant amount of heterogeneity. Figure 10 shows the welfare changes for workers with different skills and working in different sectors. The figure clearly shows that manufacturing workers are the clear losers from trade. Interestingly, college workers in the manufacturing sector suffer greater losses from trade openness than non-college workers. The difference across skills is clearer for lower levels of wealth. This result derives from the fact that college workers in manufacturing experience a decline in labor income relative to non-college workers as shown in figure 6. Given that labor income is more relevant for poor college workers in manufacturing, this decline affects more these workers than richer ones. College educated workers in manufacturing are still better than non-college workers. Actually, college educated workers in manufacturing are on average richer than college educated in services. However, their decline in welfare is the largest.

It is worth pointing out that under our current calibration, workers' sectors are the key source of heterogeneity driving the emergence of losers from the trade shock. This can be clearly seen in figure 10. However, this result masks the relevance of skill as a source of inequality. The fact that welfare gains are approximately twice as large for college workers is quite striking. This sizable difference implies that the skill acquisition margin should play a key role for new cohorts of workers—independently of their sector—, which are the ones that have access to such a margin of adjustment. One possibility to focus on the gains of the new cohorts of workers, is to compute the welfare gains after a generation of the initial shock, which is precisely what we do next.

How important is the skill-acquisition margin of adjustment? Figure 11 shows welfare gains at

Figure 9: Changes in Welfare: Education

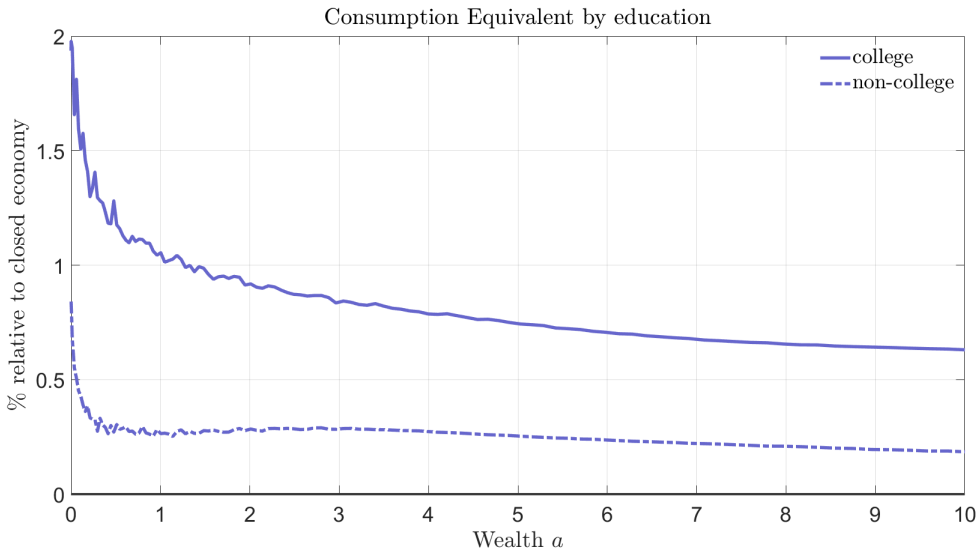


Figure 10: Changes in Welfare: Education and Sector

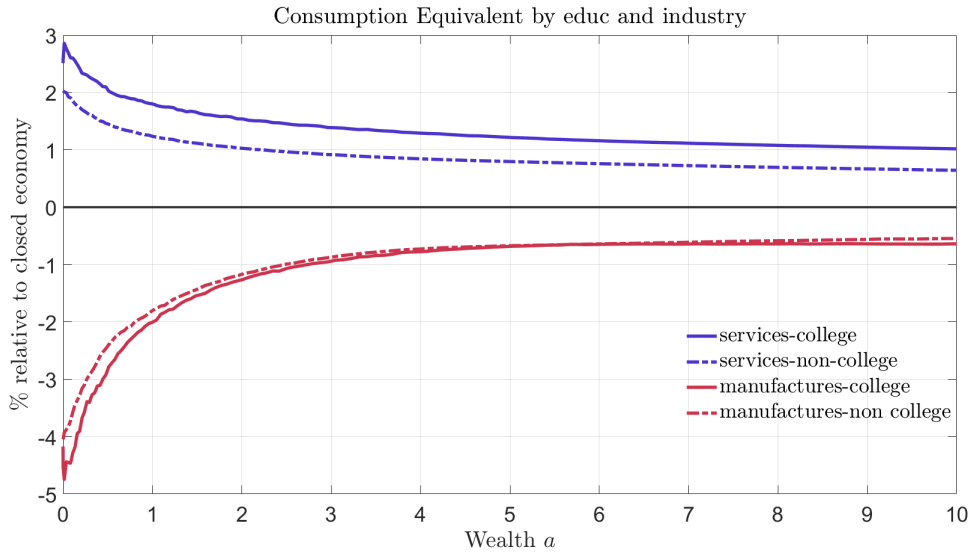
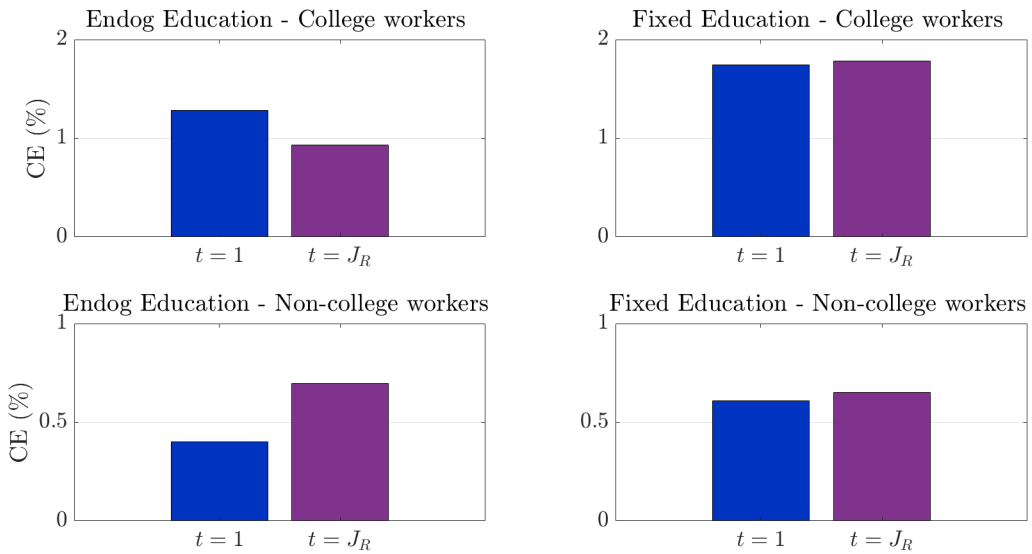


Figure 11: Changes in Welfare: Endogenous vs Fixed Education



two different points in time along the transition with and without considering skill acquisition as a margin of adjustment for new generations of workers. Figure 11 shows that, on impact, we would overestimate the gains from trade for both college and non-college workers if we did not consider this margin of adjustment. We would overestimate the gains of college workers by approximately thirty percent. In the long run, the overestimation would become more pronounced for college workers and we would slightly underestimate the welfare gains for non-college workers.

It is important to focus on the welfare gains after an entire generation because this is the case when every new workers has benefited from the option to adjust their skill level. Notice that after a generation, overlooking the increase in college educated workers would imply that we would overestimate the gains by college workers by a factor of two.

6 Policy Experiments

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 the new steady-state where everybody gains from trade openness more quickly. 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 those 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 us 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.

References

Aiyagari, Rao S, "Uninsured Idiosyncratic Risk and Aggregate Saving," *The Quarterly Journal of Economics*, 1994, *109*, 659–684.

Antràs, Pol, Alonso de Gortari, and Oleg Itskhoki, "Globalization, inequality and welfare," *Journal of International Economics*, 2017, *108*, 387 – 412.

Artuç, Erhan, Shubham Chaudhuri, and John McLaren, "Trade Shocks and Labor Adjustment: A Structural Empirical Approach," *American Economic Review*, June 2010, *100* (3), 1008–45.

Atkin, David, "Endogenous Skill Acquisition and Export Manufacturing in Mexico," *American Economic Review*, August 2016, *106* (8), 2046–85.

Autor, David H., David Dorn, and Gordon H. Hanson, "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," *American Economic Review*, October 2013, *103* (6), 2121–68.

_ , _ , and _ , "The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade," *Annual Review of Economics*, 2016, *8* (1), 205–240.

Becker, Gary S, "Front matter, human capital: a theoretical and empirical analysis, with special reference to education," in "Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education, Second Edition," NBER, 1975, pp. 22–0.

Belley, Philippe and Lance Lochner, "The Changing Role of Family Income and Ability in Determining Educational Achievement," *Journal of Human Capital*, 2007, *1* (1), 37–89.

Blanchard, Emily J. and William W. Olney, "Globalization and human capital investment: Export composition drives educational attainment," *Journal of International Economics*, 2017, *106*, 165 – 183.

Burstein, Ariel and Jonathan Vogel, "International Trade, Technology, and the Skill Premium," *Journal of Political Economy*, 2017, *125* (5), 1356–1412.

_ , Eduardo Morales, and Jonathan Vogel, "Changes in between-group inequality: computers, occupations, and international trade," Manuscript, UCLA 2016.

_ , Javier Cravino, and Jonathan Vogel, "Importing Skill-Biased Technology," *American Economic Journal: Macroeconomics*, April 2013, *5* (2), 32–71.

Caliendo, Lorenzo, Maximiliano Dvorkin, and Fernando Parro, "The Impact of Trade on Labor Market Dynamics," Working Paper 21149, National Bureau of Economic Research May 2015.

Carroll, Daniel and Sewon Hur, "On the Heterogeneous Welfare Gains and Losses from Trade," 2019.

Charles, Kerwin Kofi, Erik Hurst, and Matthew J Notowidigdo, "Housing Booms and Busts, Labor Market Opportunities, and College Attendance," Working Paper 21587, National Bureau of Economic Research September 2015.

Coçar, A. Kerem, Nezih Guner, and James Tybout, "Firm Dynamics, Job Turnover, and Wage Distributions in an Open Economy," *American Economic Review*, March 2016, *106* (3), 625–63.

Cravino, Javier and Sebastian Sotelo, "Trade Induced Structural Change and the Skill Premium," Working Paper 23503, National Bureau of Economic Research June 2017.

Danziger, Eliav, "Skill acquisition and the dynamics of trade-induced inequality," *Journal of International Economics*, 2017, *107*, 60 – 74.

Daruich, Diego, "The macroeconomic consequences of early childhood development policies," *FRB St. Louis Working Paper*, 2018, (2018-29).

Dix-Carneiro, Rafael, "Trade Liberalization and Labor Market Dynamics," *Econometrica*, 2014, *82* (3), 825–885.

Eagan, M. K., E. B. Stolzenberg, J. J. Ramirez, M. C. Aragon, M. R. Suchard, and C. Rios-Aguilar, *The American freshman: Fifty-Year trends, 1966-2015*, Los Angeles: Higher Education Research Institute, UCLA, 2016.

Findlay, Ronald and Henryk Kierzkowski, "International Trade and Human Capital: A Simple General Equilibrium Model," *Journal of Political Economy*, 1983, *91* (6), 957–978.

Floden, Martin and Jesper Lindé, "Idiosyncratic risk in the United States and Sweden: Is there a role for government insurance?," *Review of Economic dynamics*, 2001, *4* (2), 406–437.

Gale, William G. and John Karl Scholz, "Intergenerational Transfers and the Accumulation of Wealth," *Journal of Economic Perspectives*, December 1994, *8* (4), 145–160.

Greenland, Andrew and John Lopresti, "Import exposure and human capital adjustment: Evidence from the U.S.," *Journal of International Economics*, 2016, *100*, 50 – 60.

_ , _ , and Peter McHenry, "Import Competition and Internal Migration," *The Review of Economics and Statistics*, 2019, *101* (1), 44–59.

Heckman, James J. and Stefano Mosso, "The Economics of Human Development and Social Mobility," *Annual Review of Economics*, 2014, *6* (1), 689–733.

Helpman, Elhanan, Oleg Itskhoki, and Stephen Redding, "Inequality and Unemployment in a Global Economy," *Econometrica*, 2010, *78* (4), 1239–1283.

_ , _ , **Marc-Andreas Muendler, and Stephen J. Redding**, "Trade and Inequality: From Theory to Estimation," *The Review of Economic Studies*, 2017, *84* (1), 357–405.

Kim, Ryan and Jonathan Vogel, "Trade and inequality across local labor markets: The margins of adjustment," Manuscript, UCLA 2018.

Lochner, Lance and Alexander Monge-Naranjo, "Credit Constraints in Education," *Annual Review of Economics*, 2012, *4* (1), 225–256.

Lyon, Spencer and Michael Waugh, "Quantifying the Losses from Trad," Manuscript, NYU 2017.

_ **and** _ , "Redistributing the Gains From Trade Through Progressive Taxation," Manuscript, NYU 2018.

Pierce, Justin R. and Peter K. Schott, "The Surprisingly Swift Decline of US Manufacturing Employment," *American Economic Review*, July 2016, *106* (7), 1632–62.

Solis, Alex, "Credit Access and College Enrollment," *Journal of Political Economy*, 2017, *125* (2), 562–622.

Tauchen, George, "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions," *Economic Letters*, 1986, *2* (20), 177–181.

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

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

Then we know that in this particular case

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

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

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

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