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The Cost of Adjustment to Green Growth Policies

Lessons from Trade Adjustment Costs

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Abstract

Green growth policies confront firms and workers with adjustments that may create welfare costs for different segments of the population and cause reductions in near-term actual versus potential gross domestic product. There is little evidence on the cost of adjustment to climate change measures, and only limited evidence for more general environmental policies, especially in developing countries. Therefore, this paper canvasses the research on adjustment costs to trade policies to draw analogies and highlight differences compared with the potential impacts of green growth policies. Trade policies affect prices and work directly on technology choice. In the presence of adjustment costs, firms may experience impacts on wages, employment, and incentives to adopt alternative technologies. Both types of trade policy impacts may be amplified by technology availability and credit constraints.

Many green growth policies are likely to work via the same mechanisms, that is, taxes on emissions or changes in technology requirements. However, trade liberalization is typically seen as offering higher total incomes, albeit with winners and losers. Green growth policies are thought of as welfare-enhancing at the collective level but may not be income-enhancing at the individual level. This implies much more difficulty in measuring the potential gains associated with green growth policies.

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The Cost of Adjustment to Green Growth Policies:
Lessons from Trade Adjustment Costs*

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1. Introduction

The need for policies to mitigate climate change and reduce more local environmental damages has been established and many countries are actively pursuing their implementation. It is acknowledged, however, that firms and workers face costs of adjustments that may create welfare costs for different segments of the population and thus cause reductions in near-term actual versus potential GDP. Having little evidence on the cost of adjustment to climate change and only limited evidence for more general environmental policies, especially in developing countries, the objective of this note is to assess what can be learnt from the trade literature. To this end, I canvass research on adjustment costs to trade policies and draw analogies and highlight differences with potential impacts of green growth policies.

Broadly speaking, I identify two mechanisms via which trade policies affect adjustment. The first is the price mechanism. Trade policy, such as tariffs, quotas, quantitative restrictions, alters the price of goods (and inputs). Faced with changed prices, firms want to adjust employment, wages, capital (investment). In the presence of adjustment costs (of labor, capital), firms may be unable to react and this may have an impact on wages, employment, welfare, and so on. In addition, the changes in prices caused by trade policy may affect the overall incentives of the firms and, for instance, induce them to adopt alternative technologies (via R&D, or to supply higher quality goods for the export market which may require a different composition of skilled to unskilled labor). This implies a different kind of adjustment that may be hindered by other factors such as credit constraints.

The second mechanism works directly on technology choice. Policies such as standards of quality or of labor (i.e., fair labor) are in practice requirements imposed on producers that affect the technologies needed to take advantage of export opportunities. These adjustments may be costly and may be hindered by factors like technology availability, credit constraints, and so on.

Many green growth policies are likely to work via the same mechanisms. Taxes on emissions, for instance, affect prices. Other policies may affect the costs of operating the currently available technology and these are akin to changes in input prices. Changes in technology requirements (such as, for example, restrictions on technologies using fossil fuels) are analogue to standards or labor requirement policies in trade. In the setting, there appear to be valid analogies between trade policies and green growth policies, and thus useful lessons from the literature on adjustment costs could be drawn.

There will also be differences that need to be considered. One important issue is that trade liberalization is typically thought of as welfare-enhancing at the individual level, meaning that firms stand to gain higher profits, workers stand to earn higher wages, and so on. There is clearly a redistributive issue, with winners and losers, but, in the aggregate, total private income and welfare both increase. Green growth policies may or may not be welfare-enhancing at the individual level but they are thought of as welfare-enhancing at a collective level. This may affect the validity of some of the analogies to be made. In particular, it is much more difficult to measure the potential gains, especially the social gains, associated with green growth policies and, as such, it may be harder to assess GG reforms. For instance, I show below that the costs of adjustment to trade liberalization are only a (small) fraction of the total gains from trade. This result provides strong evidence to advocate trade reforms. Without similar measures of the (somewhat more intangible) gains (including social) from GG policies, a similar advocacy is harder to sustain. On the other hand, the social gains may prove to be massive and, if they are, this advocacy may be perhaps easier than in the case of trade policy. In addition, there may be differences in incentives to exploit export opportunities vis-à-vis green growth opportunities, and this differences need to be assessed.

The rest of the paper is organized as follows. In section 2, I define what a trade adjustment cost is. In section 3, I describe the imperfect mobility of factors of production (which is the underlying cause of trade adjustment costs). In section 4, I review the literature on trade adjustment costs, with an emphasis on methods and on quantification. I draw analogies and differences between the modeling of TAC the (potential modeling) of green growth adjustment costs (GGAC). Finally, section 5 discusses other relevant adjustments and section 6 briefly reviews the literature on compensation and trade adjustment cost interventions.

2. Trade Adjustment Costs

Trade adjustment costs (TAC) are the costs, in terms of some measure of welfare, associated with imperfect factor adjustments following a trade reform or a trade shock. There are various issues related to this definition that I want to discuss.

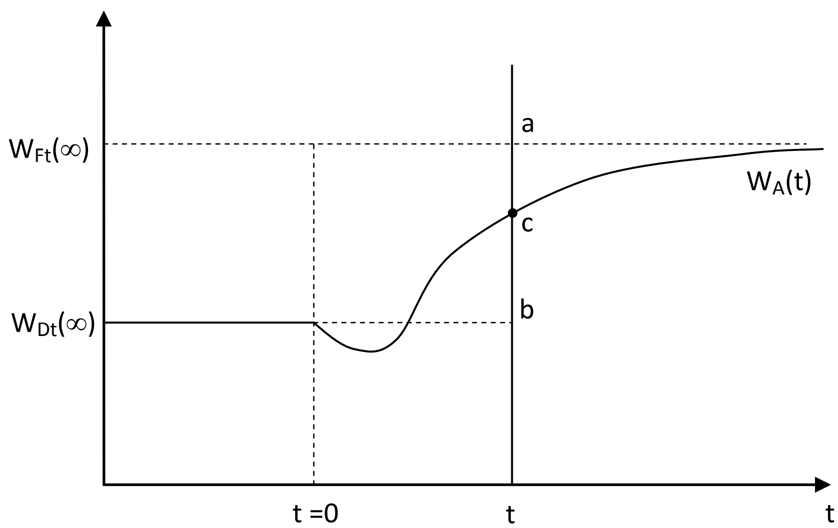
The starting point in this discussion is the recognition that economies adjust to trade shocks. In fact, this adjustment (factor reallocation) is the underlying source of gains from trade. Trade allows countries to specialize in their more productive activities and thus brings about higher output, higher productivity, lower prices and, ultimately, aggregate welfare gains. While there are instances where this may not be the case, it is generally accepted that trade liberalization generates long-term aggregate income and welfare gains for the economy.[1]

The reallocation of factors in response to trade liberalization is likely to create distributional conflict, with winners and losers. This distributional conflict may raise inequality and poverty. Trade theory has shown that, via transfers, taxes, and subsidies, it is in principle possible to compensate the losers with a fraction of the gains of the winners so that trade liberalization can be desirable even in the presence of distributional conflict. The implementation of those transfers, taxes, and subsidies is often not trivial, however. There is, therefore, a need for a detailed and careful discussion of the gains from trade and the distribution of those gains.

The gains from trade can be defined as the difference in present value of welfare before and after trade liberalization (and after factor adjustment). Trade adjustment costs (TAC), in turn, are defined as the difference between the welfare level under liberalization and the welfare level during the transition. To see this, Figure 1 plots hypothetical trends in welfare following a trade reform (see Davidson and Matusz, 2010). In the initial steady state, welfare in the distorted equilibrium is $W_{DT}(\infty)$. At t=0, the economy undergoes a (full) trade liberalization. In a frictionless economy with perfect and immediate factor adjustment, welfare jumps to $W_{FT}(\infty)$. The difference between W_{FT} and W_{DT}, discounted to the present, is the gains from trade.

[1] An important instance when trade can be harmful is when the adjustment increases demand for natural and environmental resources but domestic externality regulation is inadequate.

Figure 1



More formally, the gains G are

$$G = \sum_{t=0}^{\infty} \rho^t \big(W_{FT}(\infty) - W_{DT}(\infty)\big) = \frac{1}{1-\rho}\big(W_{FT}(\infty) - W_{DT}(\infty)\big)$$

With costly factor adjustment, the economy will not jump to the free trade steady state but rather follow a transition path. Figure 1 plots one possible path, where the economy initially dips and then slowly recovers until the steady state is eventually reached in the long-run. Note that the economy may dip early after the liberalization if, for example, skills are sector-specific and are lost when workers reallocate to expanding sectors so that productivity may decline in the short-run. At a given time during the transition, the cost of adjustment can be measured by the difference between the level of welfare attained in the steady state and the level of welfare attained during the transition. This is the difference between the potential and the actual gains from trade and is in fact a measure of the foregone welfare due to costly factor adjustment. In Figure 1, at time t, the cost of adjustment is given by ab-cb=ac. Summing this up along all the transition path, the formula to compute the costs of adjustment (TAC) is

$$TAC = \frac{1}{1-\rho}\big(W_{FT}(\infty)\big) - \sum_{t=0}^{\infty} \rho^t \big(W_A(t)\big)$$

Note that the issues related to the overall distributional conflict are part of the adjustment to trade, but not of the trade adjustment cost agenda. In other words, if the gains of the winners and the losses of the losers are *permanent*, they are not part of the trade adjustment costs but they are part of the gains from trade. So, for instance, if unskilled workers lose from trade because unskilled wages are reduced by trade, this is a distributional effect but not an adjustment cost. We shall thus not deal with those effects in this note.

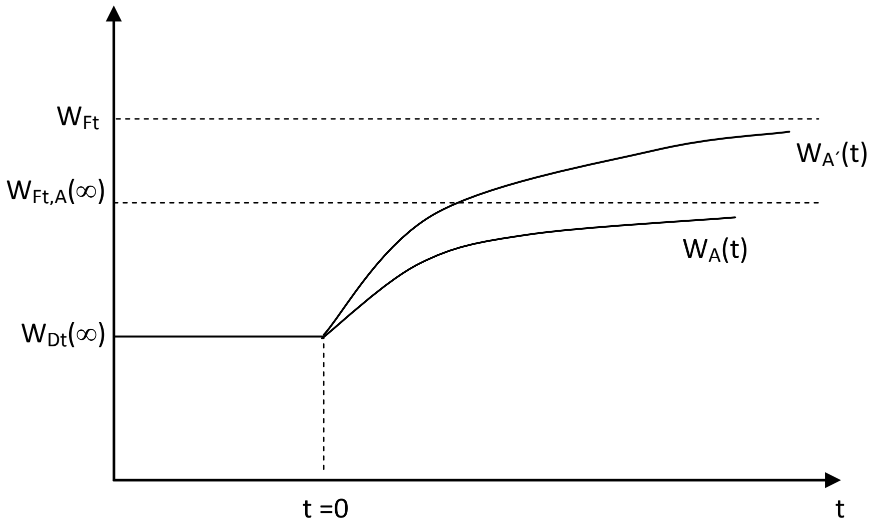
Instead, if for example there is unemployment so that factor reallocation from contracting to expanding sectors is hindered, then the losses of those workers that become unemployed during the transition as well as other general equilibrium effects (e.g., if wages in other sectors do not react fully due to unemployment), even if they affect winners, must be a part of trade adjustment costs.[2]

An important distinction to make is about sources of adjustment costs. In the definition of TAC advanced above, trade adjustment costs appear in the presence of imperfect factor adjustment following a trade reform/shock. If factors reallocate imperfectly and this brings about costs of adjustments to trade, it is important to identify why. This involves, for the most part, an analysis of sources of labor adjustment costs and of capital adjustment costs. In other words, this is an analysis of the proximate sources of adjustment costs such as firing costs, hiring costs, labor mobility costs, reselling and transaction capital costs, etc. It is also important to discuss the ultimate sources of adjustment costs, such as distortions, labor regulations, unions, imperfect credit and capital markets, lack if insurance markets, and so on. This latter analysis can guide policy advice.

One last point to highlight is that the drivers of trade adjustment costs may themselves affect the economy steady state. One way to think about this is by acknowledging two distortions, one related to trade and the other related to the underlying cause of imperfect factor mobility. As much as the elimination of the trade distortion makes the steady state jump, the elimination of the factor market distortion may play a similar role. This can be seen in Figure 2. There are three relevant steady state levels of welfare. As before, $W_{DT}(\infty)$ is the welfare level in the initial distorted equilibrium and $W_{FT}(\infty)$ is the level of welfare with free trade without the factor market distortion. Finally, $W_{FT,A}(\infty)$ is the level of welfare with free trade but with the factor market distortion. Furthermore, the economy will follow a path after trade liberalization alone that will differ from the path followed after the simultaneous implementation of trade liberalization and factor market reforms (which may not just entail a jump towards the steady-state if there are, for example, other imperfections in the economy).

[2] This distinction is not always clear or obvious. If trade induces an increase in the skill premium (Brambilla, Dix-Carneiro, Lederman, and Porto, 2011), and this induces workers to acquire more education, should this transition be accounted for in the calculation of the trade adjustment costs?

Figure 2



3. Imperfect Factor Mobility

The quantification of trade adjustment costs is difficult and various techniques have been used since the 1970s. I will review those shortly. But before doing that, it is useful to document briefly the prevalence of the underlying cause of TAC, factor immobility, in modern economies.

Two pieces of evidence, direct and indirect, support the presence of labor immobility.[3] Direct evidence on employment reallocation suggests that trade liberalization both destructs and creates of jobs *within* industries but that it induces only limited flows of labor into expanding sectors with comparative advantage. An example is Wacziarg and Wallack (2004) who use cross-country panel data to document little inter-industry flows after liberalization. In turn, Muendler (2010) and Menezes-Filho and Muendler (2007) use the linked employer-employee Brazilian data to show that trade liberalization displaced workers from the de-protected industries but that these workers were only absorbed by the comparative advantage sectors after several years.

Labor immobility is also indirectly suggested by the presence of wage differentials. Various papers have identified large inter-industry wage differentials in both developed and developing countries. The seminal work of Krueger and Summers (1989), for instance, shows that industry effects explain a large fraction of wage heterogeneity across workers. For the U.S., Gaston and Trefler (2004) find a negative correlation between these wage premiums and tariff protection. Attanasio, Goldberg and Pavcnik (2004) and Goldberg and Pavcnik (2005) also find industry-wage premium in Colombia that are, in addition, partly explained by inter-industry tariff differences. For Argentina, Galiani and Porto (2010) document a skill premium at the industry level, thus indicating that both skilled and unskilled labor may be imperfectly mobile. These premiums are also a consequence of inter-industry tariff differences. The industry-skill premiums are also prevalent in a large sample of Latin American countries, as shown by

[3] Since this literature is very large, I review here only a few papers related factor reallocation with trade reforms.

Brambilla, Dix-Carneiro, Lederman and Porto (2011). The authors also show that these skilled premiums can be attributed to differences in industry exports.

4. Quantifying Trade Adjustment Costs

This section will summarize different efforts to quantify the costs of adjustment to trade policy. This summary will review the main results as well as the methods used to obtain those results. Section 4.1 covers the early approach while section 4.2 deals with the more recent, modern, approach.

4.1. The Early Approach

In this section, I review the early estimates of adjustment costs.[4] A summary of the findings in listed in Table 1. One of the first papers to quantify the costs of adjustment to trade for the U.S. is Magee (1972). To measure the adjustment costs of a complete liberalization of trade, Magee calculates the foregone wage earnings of displaced workers. He first estimates the number of workers that would become unemployed due to the elimination of tariff protection (this is done by first calculating the value of displaced domestic production and, second, by transforming the foregone production into employment losses). Then, he approximates the loss of each unemployed worker with his average wage. He makes adjustments for the expected duration of unemployment and he also assumes that all unemployment would be reabsorbed completely within five years. The size of the adjustment costs is mixed, being quite large in the short-run, but relatively small in the longer run. For instance, assuming an intermediate discount rate of 7 percent, the short-run cost of adjustment one year after liberalization is equivalent to 17.5 percent of the gains from liberalization. Five years after liberalization, adjustment costs are equal to 12.2 percent of the gains. In the long-run, the costs of adjustment amount to only 2.8 percent of the total gains from liberalization.[5]

Baldwin, Mutti and Richardson (1980) extend Magee's calculations and include the cost of idle capital (analogue to unemployed workers).[6] They use a similar methodology, thus calculating forgone wage income for unemployed workers and forgone output due to idle capital. The authors allow wages to depend on the demographic composition of workers within industries. In consequence, if trade causes a sharper decline in unskilled intensive industries, differences in wages at different skills in different industries (as in Krueger and Summers, 1989; Goldberg and Pavcnik, 2004; Galiani and Porto, 2010; or Brambilla, Dix-Carneiro, Lederman, and Porto, 2011) would play a role in the calculation of the labor adjustment costs. To compute the capital adjustment costs, they first assume a unitary elasticity between industry output and capital utilization so that each percentage point reduction in production due to trade reforms translates into a similar percentage point reduction in capital utilization. Assuming a capital amortization period of 10 years, then 1 percent of the capital stock wears out every 1.2 months. Finally, assuming the oldest capital vanishes first after a reform, each 1 percent of the capital stock that become idle due to trade would carry an income loss equivalent to the value of output produced by that capital in 1.2 months. The findings indicate that, one year after the reform, the costs of adjustment would be equivalent to 41.7 percent of the efficiency gains from trade. In the long-run,

[4] Similar surveys of this literature can be found in Matusz and Tarr (1999) and Francois, Jansen, and Peters (2011).
[5] These estimates depend on the discount rate. For instance, with a discount rate of 10 percent, the costs of adjustment in the long-run are equivalent to 3.8 percent of the gains.
[6] See also Bale (1976) and Monson (1978).

the discounted value of the adjustment costs would be equivalent to 4.17 percent of the discounted value of the gains from trade.

In their experiment, Baldwin, Mutti and Richardon (1980) measure the adjustment costs (for the U.S. economy) associated with a 50 percent multilateral tariff reduction. Note that this is a different exercise form that in Magee (1972), not only because Magee works with full liberalization but also because Baldwin et al. consider multilateral liberalization, as opposed to unilateral liberalization.

Table 1
Estimates of Trade Adjustment Costs

Paper	Notes	Magnitude (as a share of gains)
Magge (1972)	U.S. Economy	1 year: 17.5% TAC: 2.8%
Baldwin, Mutti, and Richardson (1980)	U.S. Economy	1 year: 41.7% TAC: 4.17%
Takacs and Winters (1991)	British Footwear	1 year: 0.65-1.75% TAC: 0.046%
de Melo and Tarr (1990)	U.S. textiles, steel and automobiles	1.5-3.6%
Morkre and Tarr (1980)	U.S. Economy	sugar: 6.25% footwear: 1.47% textiles: 1.75%
Davidson and Matusz (2010)	labor market frictions skill acquisition in un-protected sector	without training costs: 5-25% with training costs: 33-80%
Kambourov (2009)	Chile firing and hiring costs human capital specificity and accumulation	TAC: 7.5%
Dix-Carneiro (2010)	Brazil labor mobility costs sector-specific experience	perfect K mobility: 16% imperfect K mobility: 32%

Notes: See Sections 4 and 5 for details.

Takacs and Winters (1991) use the same approach to compute the income losses due to the elimination of quantitative restrictions on the British footwear industry. This study improves the previous estimating method but the exercise has a more partial equilibrium flavor. Concretely, Takacs and Winters exploit the sectoral employment turnover in the shoe industry so that workers displaced by the removal of quotas are eventually re-employed in the sector as other workers voluntarily leave employment. With an annual turnover rate of 17 percent, and assuming that workers displaced by trade are the first to claim and obtain these vacancies, displaced workers would become re-employed in the industry within 7 weeks. The foregone wage earning is calculated by multiplying this 7-week unemployment transition by the workers' pre-unemployment wage. The findings reveal essentially negligible labor adjustment costs. One year after the removal of the quantitative restrictions, adjustment costs would be equivalent, on average, to only 0.65 percent of the standard efficiency gains. In the most pessimistic scenario, those costs would be equal to 1.75 percent of the gains. Furthermore, using a 10 percent discount rate, the long-run adjustment costs would be equivalent to a mere 0.046 percent of the discounted value of the gains.

All these papers share a similar methodology. One concern with it is the procedure to transform output loss due to liberalization into employment losses. de Melo and Tarr (1990) improve this procedure with the help of a general equilibrium model. They study the labor adjustment costs associated with the removal of quantitative restrictions on U.S. imports of textiles, steel and automobiles. The approach is general equilibrium in the sense that the analysis incorporates the linkages between these industries and the rest of the economy. The estimates of the cost of adjustment are, as before, small. Few workers, around 0.25 percent of the labor force, would be forced to re-allocate to other sectors. Assuming earning losses for 6 years, de Melo and Tarr estimate adjustment costs equivalent to around 1.5 to 3.6 percent of the gains from liberalization. In a similar setting, but with a partial equilibrium framework, Morkre and Tarr (1980) estimate costs of adjustment of 6.25 percent, 1.47 percent, and 1.75 percent of the gains from liberalization in sugar, footwear, and textiles and apparel, respectively (for the U.S. economy).

4.2 Modern Approach

Most of the work reviewed in the previous section shares a weakness: the relatively crude structure of the transition from job displacement and unemployment into reallocation in the labor force. Assigning the going wage (sometimes conditional on demographics or individual characteristics) to those workers displaced by trade omits the value of unemployment. In other words, it neglects the fact that income or earnings during unemployment are not necessarily zero. There is generally a reservation value because workers can engage in informal work, help at home (home-production activities), perform odd-jobs and so on. Also, the reallocation may be itself costly (beyond forgone income) if workers need to retool themselves to accumulate sector-specific skills. More recent work on trade adjustment costs attempts to better model and quantify these factors and to provide foundations to these issues.

The papers in this literature are heavily structural and the foundations vary from paper to paper. Each of the papers reviewed here focus on different foundations. First, I look at a strand of literature on *labor* adjustment costs. The drivers of those costs are labor market frictions, sector-specific skills (human capital) and training costs, hiring and firing costs, and labor mobility costs. Second, I look at capital adjustment costs and capital market imperfections. All these paper rely of variants of dynamic stochastic general equilibrium models that are partly calibrated and partly estimated using firm and worker data. In this section, I review the main examples in this literature emphasizing both the size of the cost of adjustment and the role of the driver of those adjustment costs. Table 1 summarizes the main results.

4.2.1. Labor Mobility Costs

I begin my review of the literature with a series of papers on labor mobility costs, namely Cameron, Chaudhuri, and McLaren (2007), Chaudhuri and McLaren (2007), Artuc, Chaudhuri, and McLaren (2010), and Artuc, Chaudhuri, and McLaren (2008). I begin here because the definition of labor mobility costs is broad enough and encompasses many of the channels that I will explore in more detail below.

These papers present a method for estimating the costs of labor mobility based on a dynamic rational-expectations model of labor adjustment. The procedure also explains how to use the model to simulate the transition of the economy following a (trade) policy shock and to use those simulations to assess the dynamic distributional impacts of trade reforms. The model relies on the interplay between labor demand and labor supply in a rational expectations equilibrium. The demand side is simple because labor demand is just the value of the marginal product of labor for firms that do not face any costs of adjusting either labor or capital (see Bet, Brambilla, and Porto, 2011). Labor supply to different sectors is derived from workers' intertemporal optimization decision. In a given period, a worker produces in a sector and earns the equilibrium wage in that sector. At the end of each period, each worker has the opportunity to switch sectors, but at a cost. These costs have a common component to all workers and an idiosyncratic component that varies for each worker over time. The common costs and the parameters of the distribution of idiosyncratic costs can be estimated with panel data. To do this, the authors derive an Euler equation that represents the equilibrium condition for the workers. This equilibrium condition essentially links gross flows of workers across sectors (from sector i to sector j and also from sector j to sector i) with future intersectoral wage differentials. The Euler equation can easily be implemented as a linear regression.

The interpretation of the labor mobility costs in these papers is, in principle, broad. It is possible to argue that these costs include retraining and relocation costs as well as psychological or other non-pecuniary costs of moving (such as tedium in the current job). In addition, the parameters that characterize the labor mobility costs are identified with the correlation of job flows and wage differentials across sectors. This means that, in the data, labor market imperfections and other features of the economy (not modeled) that affect job flows, for instance, will affect the estimate of the labor mobility costs. In consequence, these costs are in some sense "reduced-form" labor mobility costs. I will explore some of their microfoundations in later sections.

A key feature of this theory is that the time-varying idiosyncratic costs allow for a gradual reallocation of workers to a trade shock. This creates a rich dynamic response to trade policy that provides a very detailed illustration of how an economy moves during the transition. In principle, while the authors use the simulation exercises to assess trade policy, I believe it is possible to set up exercises of green growth policy too. I elaborate on this idea in section 4.3 below.

The estimation often delivers extremely high average moving costs and very high variance of moving costs. Using U.S. data, for instance, Artuc, Chaudhuri and McLaren (2010) report moving costs that range from 4 to 13 times the annual wage income. Using data from Turkey, Artuc and McLaren (2010) also report moving costs equivalent to roughly 5-13 times the annual wage.[7] For Argentina, Bet, Brambilla and Porto (2011) report costs of around 9 times the annual wage. In all these instances, the moving costs show a very high variance indicating that, at each period, workers can be subject to very large positive or negative idiosyncratic shocks.

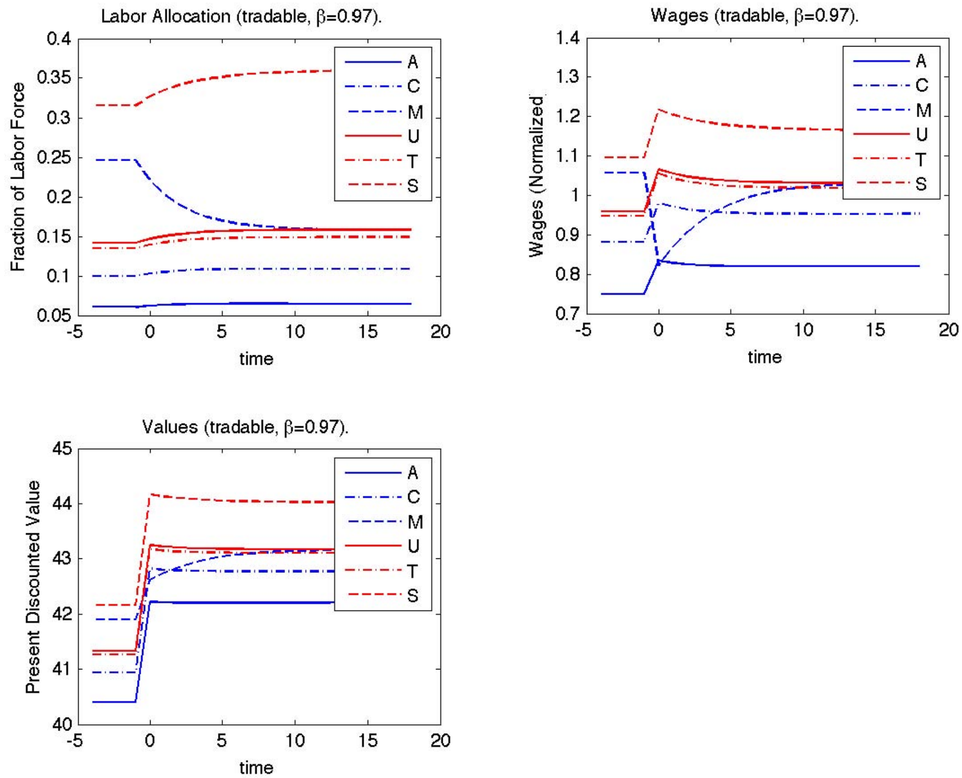
While the estimated costs appear too large, they typically produce a very realistic dynamic aggregate behavior in the economy. For the ease of exposition and to exemplify the results, I reproduce in Figure 3 the dynamics of labor allocations, real wages, and the present value for workers obtained in the simulations of Artuc, Chaudhuri and McLaren (2010). The adjustment of the labor market to a trade shock is sluggish: it takes several years to approach the new steady state. The import-competing sector

[7] Note that Artuc, Chadhuri and McLaren (2010) use instruments in the estimation of the Euler equation to deal with several biases that may take place if OLS is used instead. However, because the Turkey panel is short and because the instruments are the lagged values of wages, Artuc and McLaren (2010) cannot use IV methods. Instead, they estimate OLS coefficients and fix them to account for the biases reported in Artuc, Chaudhuri and McLaren (2010).

that is hit with a tariff cut faces a large drop in wages and the wage never recovers. As workers move out of the import-competing sector, labor supply increases in recipient sectors and thus nominal wages tend to decline. With lower prices due to tariff cuts, real wages instead increase. Workers in the non-import-competing sector unequivocally gain from the trade reform. Workers in the import-competing sector can also benefit from the liberalization because the high volatility of their idiosyncratic shocks combined with rising real wages in other sectors implies higher option values, and this effect can dominate the direct loss from the lower wages in their own sector. This happens in the U.S. simulations (Artuc, Chaudhuri and McLaren, 2010) and in the Argentine simulations (Bet, Brambilla, and Porto, 2011) but not in the Turkish simulations (Artuc and McLaren, 2010).

Given the information provided in these papers, I cannot recover the estimates of the TACs using the formulas from section 2. However, an idea of the magnitude of the costs can be glimpsed with the examination of the evolution of the present discounted values (bottom panel of Figure 3). As discussed, the values for all workers increase due to trade liberalization. However, there is an important difference is the dynamics of values for workers initially in the protected sectors vis-à-vis workers in all the other sectors. Lifetime utilities for workers in the non-manufacturing sectors increase at the announcement of the trade policy and then gradually and slightly decline towards the steady state. Instead, the lifetime utility of initially protected workers increases to a lesser extent at the time of the announcement and then continues to increase towards the steady state. The reason, as explained above is the option value. Note that this implies positive TACs attached to workers in the initially protected sector, but negative TACs for all other workers. This is because of the overshooting of wages in non-protected sectors. From the plots in Figure 3, it appears that the trade adjustment costs borne by manufacturing workers dominate the short-run exceptional gains (which are given by the size of the overshoot in values) in all other sectors. But this is not necessarily true, which raises the possibility of negative adjustment costs.

Figure 3
Adjustment to Trade Liberalization
Employment, Wages, and Values



Source: Artuc, Chaudhuri and McLaren (2010.
Notes: Sectors are: Agriculture and Mining (A); Construction (C); Manufacturing (M); Transport and Utilities (U); Trade (T); Services (S).

This model of labor mobility cost can be extended to estimate costs for heterogeneous workers. In principle, given sufficient data the Euler equation can be estimated for sub-groups of the population such as skilled-unskilled, young-old, combinations of young-old with skilled-unskilled, by age, by region, and so on. This heterogeneity in the mobility costs is important to capture the different realities of different workers when facing the liberalization of trade. While the typically available data do not allow for such a rich estimation of mobility costs (see section 8), the emergence of social security records will make this line of research increasingly promising. For the U.S., the available estimates in Artuc, Chaudhuri and McLaren (2010) show higher costs for old than for young workers, and also higher costs for skilled than for unskilled workers. The finding that the mobility costs are higher for older workers is also in Artuc (2009).

4.2.2. Labor Market Frictions and Training

Carl Davidson and Steve Matusz are pioneers in this topic (Davidson and Steven J. Matusz, 2000; 2002; 2004a; 2004b; 2004c; 2006a; and 2006b). They have written extensively and their work is summarized in Davidson and Matusz (2010) in which I base this review. Their papers develop a model with frictions in labor adjustment. In the simplest setting, there are two sectors in the economy, one of which is initially protected by tariffs. Labor adjusts freely in the protected sector, but to enter the unprotected sector workers need to acquire skills (via training) and must search for jobs. When trade is liberalized, the protected sector shrinks and the unprotected sector grows, but does so only slowly because of the need for job training and because of the search process (that can create unemployment).

In contrast to the findings from the early approach, Davidson and Matusz illustrate that adjustment costs to greater trade can be quite large. Using numerical simulation exercises they conclude that adjustment costs can range from 33 to 80 percent of the gross benefits from trade reforms. These adjustment costs increase with the level of training costs (measured in terms of average wages) and decrease with the size of the protected sector (because the unprotected sector, which is the one that requires training, is thus smaller). A key finding is that ignoring the resource costs of training reduced the adjustment costs considerably, which would range from 5 to 25 percent of the gross gains from trade. This helps explain the discrepancy with the previous findings. Finally, Davidson and Matusz show that, as expected, the process of adjustment takes time: output dips immediately after the trade reform and it takes between one and two and a half years to return to pre-liberalization output levels.

In the last couple of years, modeling trade with labor market frictions and rigidities has becomes a mainstream concern in the literature. Helpman and Itskhoki (2010), for instance, develop a trade model with search and matching frictions in the labor market and wage bargaining. While the paper does not directly address the cost of labor adjustment, the authors shows that trading countries gain from trade, even in the presence of market frictions, and also unequivocally gain from simultaneous reductions in labor market frictions. However, the analysis uncovers the possibility of welfare losses at home from reductions in market frictions in the labor market of major trade partners.[8] This brings up new dimensions in the definition of trade adjustment costs. Can green growth policies in the rest of the world affect trading partners in a globalized world?

4.2.3. Firing and Hiring Costs

Firing and hiring costs on the firm side are one of the major factors that determine the inflexibility of labor markets in developing economies. Firing will be suboptimal in the presence of firing costs and this entails efficiency losses. In addition, firing costs reduces hiring because it is costly to dismiss workers in the event of bad future productivity shocks. Facing a trade reform, firms may not expand as much as they would like because of hiring costs, and perhaps may not enter the market at all. At the same time, firms in contracting sectors may find it optimally not to downsize. These issues are studied in detail by Kambourov (2009) who develops a structural dynamic general equilibrium model of trade with firing and hiring costs, coupled with human capital sectoral specificity and human capital accumulation by learning (that is, workers accumulated experience by working in a sector but human capital is lost entirely upon switching sectors). The model is calibrated to the Chilean and Mexican economies. In both cases, Kambourov finds that the concurrent liberalization of the labor market with the trade reforms speeds up the intersector labor reallocation and allows for the realization of a larger fraction of the gains from

[8] This will happen if the market frictions are lower in the differentiated-goods sector. The reason is that lower frictions in this sector endow the country with a competitive advantage in this sector. This is akin to a productivity gain in the Melitz model. That is, the differentiated-goods sector in the foreign country attracts more firms while the home country attracts fewer firms. The entry and exit of firms overwhelms the terms of trade movement, leading to welfare gains in the country with improved labor market frictions and welfare losses in its trade partner.

trade. Or, conversely, he finds that if a country does not liberalize its labor market at the outset of its trade reform, then the intersectoral reallocation of workers will be significantly slower, and a substantial fraction of the gains in real output and labor productivity in the years following the trade reform will be lost.

For my purposes, Kambourov's paper serves four objectives. First, it provides additional estimates of the costs of adjustment, namely those related to firing and hiring costs coupled with human capital specificity. Second, it compares the Chilean and Mexican experiences, which differ fundamentally in the degree of labor market reform implemented with the trade reform. Third, it compares firing and hiring costs with human capital specificity and human capital accumulation, which will allow us to learn the relative importance of these factors in the costs of adjustments. Finally, the findings in the paper will allow us to qualify and improve the interpretation and quantification of trade adjustment costs. Next, I elaborate on each of these objectives.

Kambourov (2009) does not provide estimates of the costs of adjustment, at least in the sense of the definition advanced before. That is, while the author provides estimates of the gains from trade in the steady state, and for selected years during the transition, he does not compute the formulas of section 2. It is possible, however, to approximate those formulas with some back of the envelope calculations (built from Tables 8-11 in Kambourov, 2009). For the case of Chile, in steady state, total welfare in the free trade equilibrium (but with labor market frictions) is 8.8 percent higher than in the distorted initial steady state. During the transition, and due to firing and hiring costs and due to the specificity of human capital, welfare is 5.7 percent higher in the (first and) second year, 6.5 percent higher in the third year, 7.1 percent higher in the fifth year, and 7.5 percent higher in the seventh year. Extrapolating these effects and implementing the formulas to calculate TAC from section 2, I estimate the costs of adjustment to be approximately equivalent to 7.5 percent of the present discounted value of the gains from trade.

There are also gains from reforming the labor markets. To calculate them, Kombourov simulates an economy without tariffs and without firing and hiring costs (but with human capital specificity and learning). In this scenario, welfare in steady state increases by 9.5 percent (as opposed to 8.8 percent in the case of trade reforms only). Note that this implies a different steady state from the free trade but distorted equilibrium (recall Figure 2 in section 2). Note also that trade reforms appear in principle to have a much larger effect than labor market reforms. This is because in the presence of high firing costs, labor reallocates less as a result of which resources are misallocated and output, productivity, and welfare decline. This, however, is offset by two factors. First, by staying in their sector a larger fraction of the labor force becomes experienced (through human capital accumulation). Second, in the presence of firing costs reallocation is smaller which leads to a higher level of employment. As a result, in steady state the overall effect of firing costs on output, productivity, and welfare is not substantial.

During the transition, welfare is 6.4 percent, 7.6 percent, 8.1 percent, and 8.6 percent higher than in the initial steady state after 2, 3, 5 and 7 years, respectively. As I show in Table 2, these gains are 5.7 percent, 6.5 percent, 7.1 percent and 7.5 percent, respectively, if only trade is liberalized. This illustrates the foregone benefits from not liberalizing the labor market concurrently with the liberalization of trade. More concretely, the economy that does not liberalize labor markets is foregoing 11 percent of the potential increase in welfare by the second year, 15 percent by the third year, 13 percent by the fifth year and 13 percent by the seventh year.[9]

I want to emphasize the fact that labor market reforms affect the steady state of the economy and that this fact has implications for the interpretation and qualification of the costs of adjustment. Note that this model has two types of labor market imperfections. One is the costs of firing and hiring and the other is the specificity of human capital and its accumulation via production/learning. In the experiments, the author works with a trade reform and with a labor market reform, but the specificity of human capital remains in place. This creates a dynamic adjustment, even when the economy is fully liberalized. That is to say, the elimination of both trade and labor imperfections does not make the economy jump from the distorted steady state to the non-distorted steady state. Instead, the economy starts a dynamic path as workers accumulate human capital and switch sectors. Taking into account this transition, Kambourov reports welfare gains from the trade reform only of 7.3 percent (as opposed to 8.8 percent) and welfare gains from the joint reform of trade and labor markets of 8.1 (as opposed to 9.5 percent). Human capital specificity is thus playing an important role.[10]

It is also plausible to argue that the full elimination of firing/trade costs is unfeasible, not only politically but also perhaps technologically. This should be kept in mind when assessing the costs of adjustments, because the counterfactual welfare levels used in the calculations of the trade adjustment costs may depend on complementary factors that may be costly to achieve (such as full labor market flexibility).

Kambourov also studies the case of Mexico, a country with a less flexible labor market than Chile. The trade reform was, in turn, gradual and thus the author simulates an economy in which tariffs are initially halved and later eliminated completely after three years. The results are qualitatively very similar to the Chilean experience. Eliminating trade distortions increases welfare by 5.8 percent while eliminating trade and labor market distortions, by 6.1 percent. As before trade reforms seem to have larger impacts on the steady state than labor market reforms. Further, there are foregone benefits from not liberalizing the labor market jointly with the international trade market.

4.2.4. Labor Mobility Costs and Worker Sector-Specific Experience

Dix-Carneiro (2010) estimates a dynamic structural model of the labor market with labor mobility costs and worker sector-specific experience using Brazilian data. Labor demand is given by the value of the marginal productivity of labor in perfectly competitive sectors without frictions. The labor supply side features overlapping generations of heterogeneous workers who, as in Artuc, Chaudhuri and McLaren (2010) can switch sectors at a cost. Dix-Carneiro offers a very rich model with several nice additions to the labor mobility cost model of Artuc et al. Workers are heterogeneous in various dimensions, they can

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[9] If the increase in welfare, after 2 years, with both labor and trade reforms is 6.4 percent and the increase in welfare, after 2 years, with only trade reform is only 5.7 percent, then the labor reform brings about additional gains of 0.7 percent, after 2 years, or 11 percent of 6.4.

[10] Note that fully addressing the role of human capital requires modifying the model to eliminate human capital specificity. This, in turn, requires recalculating the steady states and the transition. Kambourov (2009) does this in section 6.3 of the paper: ``The results from this experiment suggest that both firing costs and human capital play a role in the benchmark analysis. Firing costs do play an important role since in both models they slow down the intersectoral reallocation of workers and reduce the benefits from a trade reform. Human capital, however, does play a role as well − in the absence of human capital, the foregone benefits from not liberalizing the labor market are less than half of what they are in the benchmark case.''

endogenously accumulate sector-specific experience, and they self-selection into sectors based on observable and unobservable components of wages as well as on costly switching of sectors. The model also includes a residual sector (representing informality, or home-production, for example).

As Artuc, Chaudhuri and McLaren (2010), Dix-Carneiro estimates large workers' costs of switching too. The median of costs of mobility, in terms of annual wages, ranges from 0.68 (into Agriculture/Mining) to 3.25 (into High-Tech Manufacturing). Costs of mobility into Low-Tech Manufacturing and Non-Tradeables are equal to 1.5 and 2.15 times conditional annual average wages respectively. In terms of the present value of staying in the current sector, the median costs of mobility toward Agriculture/Mining equal 3 percent and the median costs of mobility toward High-Tech Manufacturing is equal to 13 percent. The author also shows that these costs vary across individuals being higher for females, older workers and less educated workers.

An important finding is that sector-specific experience is imperfectly transferable across sectors, leading to additional barriers to mobility. However, switching costs are high and play a more important role in the adjustment process. This finding is in contrast to Cosar (2010), who develops a model with search and labor market frictions together with sector-specific experience that is not transferable across sectors at all. In the calibrated model to Brazilian data, Cosar finds that the adjustment of the labor market is very slow and that the main driving factor is sector-specific experience. The result in Dix-Carneiro, that experience is partially transferable, suggests a bigger relative role for labor market frictions instead.

Once some parameters are estimated and others calibrated, Dix-Carneiro performs simulations to examine the effects of a decrease in the price of the import-competing sector (High-Tech Manufacturing). He finds that the response of the labor market to trade liberalization is large, but that the transition may take several years. In the model, workers in the import-competing sector suffer large welfare losses, especially if they are unskilled and young. Both skilled and unskilled wages in other sectors increase and workers in those sectors enjoy welfare gains. Dix-Carneiro provides estimates of the costs of adjustment using the formulas in Davidson and Matusz (2010). Under perfect capital mobility, the costs of adjustment are equivalent to 16 percent of the gains in aggregate welfare.

4.2.5. Capital Adjustment Costs

The treatment of capital adjustment costs is succinct in the literature. Artuc, Chaudhuri and McLaren, (2010) assume fixed sector capital and briefly observe that allowing for perfect capital mobility does not affect their results. Dix-Carneiro (2010) incorporates imperfect capital mobility by running a simulation in which sectoral capital can only be adjusted by at most 5 percent per year. He shows that under imperfect capital mobility, adjustment costs are equivalent to 32 percent of the aggregate welfare gains from trade (as opposed to 16 percent under perfect capital mobility). Interestingly, as noted above, the adjustment costs in the case of fixed capital is negative (equivalent to -4.5 percent of the gains from liberalization) because of the initial overshooting in values.

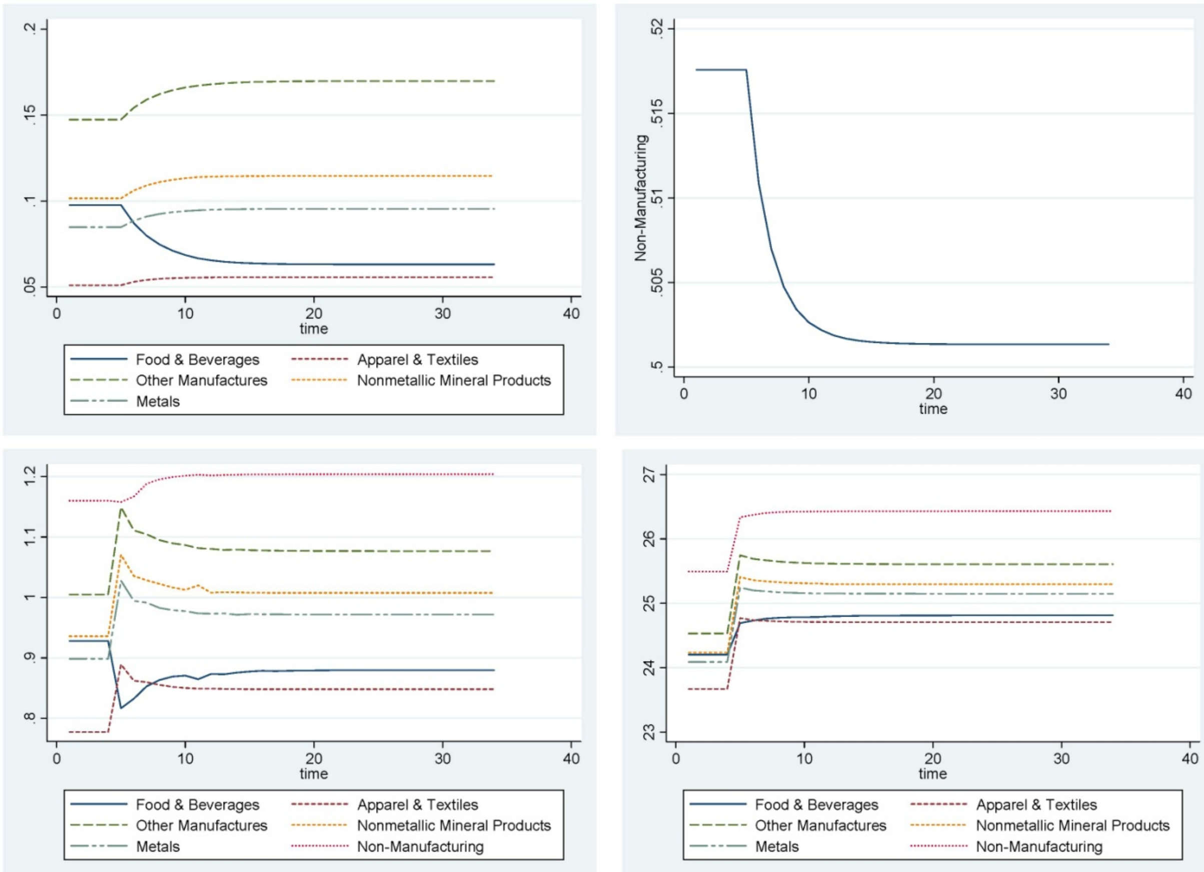
Bet, Brambilla and Porto (2011) argue that in order to expand to meet new market opportunities created for example by trade liberalization, existing firms must adjust the capital stock by investing in product lines, machines and equipment, and entrants must incur significant startup costs. This process is costly and imperfect, and, in fact, industry adjustment and entry may be fully hindered. This, in turn, has implications for labor demand and wages and thus for the gains from trade. To study these issues, the authors formulate a dynamic structural model of trade with worker's intersectoral search and firm's capital accumulation decisions. The model combines the labor supply model with worker mobility costs of Artuc, Chaudhuri and McLaren (2010) with the labor demand model with capital adjustment costs of Cooper and Haltiwanger (2006) and Bloom (2009). The labor supply side is characterized by a rational expectations optimization problem of workers facing mobility costs and a time-varying idiosyncratic shock. The labor demand side is characterized by the rational expectations intertemporal profit maximization problem of firms facing costs for adjusting their capital stock.

Bet, Brambilla and Porto (2011) fit the model to plant-level panel data and household survey data from Argentina. They estimate large costs of adjusting both capital and labor. For capital, the fixed cost of adjustment is around 14.5 percent of the firm's capital stock, and the quadratic cost parameter is 0.11. The partial irreversibility cost parameter is 0.91, suggesting that the selling price of installed capital is 9 percent lower than the buying price of capital. As discussed in section 5.1, the labor mobility costs are equivalent to around 9 times the annual value of wages.

The authors also study transitional dynamics following a tariff cut in the Food and Beverages sector. Figure 4 reports the evolution of employment in the manufacturing sectors (top left panel), employment in the non-manufacturing sector (top right panel), real wages (bottom left) and workers' present values (bottom right). Overall, Bet, Brambilla and Porto (2011) observe a sizeable effect of trade liberalization on labor markets and a sluggish adjustment of employment. For instance, labor reallocation towards the new steady state is complete after more than 15 years. In particular, labor allocation in the food and beverages sector decreases from a steady-state value of approximately 10 percent to a new steady-state of around 6 percent. Labor reallocates to all other sectors, with the largest increases in Non-manufactures and Other Manufactures.

In the bottom panels, as expected, real wages in the food and beverages sector decrease as a result of trade liberalization. Real wages in the shocked sector overshoot its long-run value with a sharp initial drop and a lower new steady-state level. In particular, after the sudden shock of the drop in food and beverages prices, workers begin to move out of the sector bringing wages up. The other sectors exhibit gains in real wage levels because of the drop in consumer prices. Additionally, some of these sectors also exhibit overshooting (but in the opposite direction and because of similar reasons). In spite of the fact that real wages fall in the food and beverages sector, the present discounted value increases in this sector, exactly as in Artuc, Chaudhuri, and McLaren (2010).

Figure 4
Adjustments to Tariff Reduction in Food & Beverages
Argentina



Source: Bet, Brambilla, and Porto (2011).

4.2.6. A Brief Review of Technical Issues[11]

Most of the recent papers I have discussed in this section rely on the estimation and calibration of dynamic stochastic general equilibrium (DSGE) models. These are structural models that attempt to provide a very detailed and careful representation of the structure of the aspect of the economy under consideration (that is, firing and hiring costs, or labor mobility costs, or capital adjustment costs). As always, the results of these models may depend a lot on the structure and it is difficult to assess a priori the damage that structural assumptions can produce in the end. For this reason, it is always important to assess those assumptions. That said, it should be kept in mind that questions related to trade adjustment costs are very difficult to study empirically due to the existence of confounding factors and thus structural models provide answers that would otherwise be unavailable. This explains why the literature is dominated by DSGE models. Furthermore, it is important to back empirical work in rigorous models.

[11] This section is technical and it is included for completeness. It can be skipped without loss of continuity.

Dynamic Stochastic General Equilibrium models are typically hard to estimate because the structure of the model is complicated and non-linear and thus the likelihood function does not have a closed-form. For this reason, simulations methods are typically needed. There are of course exceptions. Artuc, Chaudhuri and McLaren (2010) is one. With assumptions on the distribution of the idiosyncratic shocks, the authors derive an equilibrium condition, an Euler equation, that can be estimated with linear econometrics (OLS, IV or GMM). But these exceptions are rare. In most instances, and even in Artuc et al. model without distributional assumptions, the solution to the model does not have a closed-form.

Next, I briefly discuss how these models can be estimated (See Cameron and Trivedi, 2005). To do this, I introduce some notation. Let a (SDGE) model generate predictions for an outcome *y*, given some data **x** and some parameters θ. The density of *y* given **x** and θ is

$$f(y|\mathbf{x},\theta) = \int h\,(y|\mathbf{x},\theta,\mathbf{u})g(\mathbf{u})d\mathbf{u}$$

where **u** denotes a random variable, not necessarily and error term, that needs to be integrated out. The functions *g(·)* and *h(·)* are known. If the integral has an analytical solution, then **u** can be integrated out analytically and the likelihood function has a closed-form solution. MLE methods can be used easily in this case. If the integral cannot be solved analytically, then there is no closed-form solution for the likelihood function. In this case, simulated-based methods are used. The basic idea is to replace the integral by a numerical approximation $\hat{f}(y|\mathbf{x},\theta)$ and then maximize the simulated likelihood. There are essentially three estimating methods: maximum simulated likelihood, simulated method of moments, and indirect inference.

Maximum Simulated Likelihood

Assume the density is

$$f(y_i|x_i,\theta) = \int h\,(y_i|x_i,\theta,u_i)g(u_i)du_i$$

A direct simulator for $f(y_i|x_i,\theta)$ is

$$\hat{f}(y_i|x_i,\mathbf{u}_{iS},\theta) = \frac{1}{S}\sum_{s=1}^{S} h\,(y_i|x_i,\theta,u_i^s)$$

where $\mathbf{u}_{iS}$ is a vector of *S* draws $u_i^s, s = 1,\ldots,S$ that are independent draws from $g(u_i)$. Note that this is just a simple average of $h(.)$ over the S draws. The MSL estimator maximizes

$$\ln \hat{L}_N(\theta) = \sum_{i=1}^{T} \ln \hat{f}(y_i|x_i,u_{iS},\theta)$$

(Note that MLE instead max $\ln L_N(\theta) = \sum_{i=1}^{T} \ln f(y_i|x_i,\theta)$.)

Moment-Based Simulation Estimation

The simulation approach to estimation when the objective function has no closed-form solution can be extended to other estimators than MLE. For the case of moment-based estimators, write the objective function as

$$Q_N(\theta) = \frac{1}{N}\sum_{i=1}^{N} q\ (y_i, x_i, \theta)$$

(in MLE, $q(y_i, x_i, \theta) = \ln f(y_i|x_i, \theta)$).

Assume no closed-form solution exists for q but that an estimate $\hat{q}$ is available. The simulated m-estimator maximizes

$$\hat{Q}_N(\theta) = \frac{1}{N}\sum_{i=1}^{N} \hat{q}\ (y_i, x_i, \mathbf{u}_{iS}, \theta)$$

where, usually,

$$\hat{q}(.) = \frac{1}{S}\sum_{i=1}^{S} \hat{q}\left(y_i, x_i, u_i^S, \theta\right)$$

The simulated m-estimator is consistent if the ``original'' m-estimator is consistent. With many simulations, the estimator is consistent and asymptotically normal.

Method of Simulated Moments (SMM)

Suppose theory leads to a moment condition

$$E[m(y_i, x_i, \theta_0)|x_i] = 0$$

If $m(.)$ has a closed form solution, we can use a method of moments estimator, like GMM (as in Artuc, Chaudhuri and McLaren, 2010). But if $m(y, x, \theta)$ has no closed-form solution, obtaining a MM estimator is not feasible. As before, assume, for example, that we can write

$$m(y_i, x_i, \theta) = \int h\ (y_i, x_i, u_i, \theta) g(u_i) du_i$$

Let w_i denote instruments, such that

$$E[w_i m(y_i, x_i, \theta_0)|x_i] = 0$$

The MSM (or SMM) estimator minimizes:

$$\hat{Q}_N(\theta) = \left[\frac{1}{N}\sum_{i=1}^{N} w_i \hat{m}\ (y_i, x_i, u_{iS}, \theta)\right]' \left[\frac{1}{N}\sum_{i=1}^{N} w_i \hat{m}\ (y_i, x_i, u_{iS}, \theta)\right]$$

where $\hat{m}$ is the unbiased simulator for m such that

$$E[m(y_i, x_i, u_{iS}, \theta)] = m(y_i, x_i, \theta)$$

An important point is that MSM or SMM is consistent even if $S = 1$. However, there is an efficiency loss for finite S.

Indirect Inference

Assume we have a model that generates a probability density function for $y, f(y, \theta)$ and where the parameter vector θ is difficult to estimate. Assume there is an auxiliary model, with pdf $f^a(y, \beta)$, that is easier to estimate. For example, the auxiliary model may be an approximation to the exact likelihood, or it may be an exact likelihood of an approximate model (a linearization of the first order conditions?). Let $\hat{\beta}$ denote the quasi ML (QML) estimate (the QML is the max of a log likelihood function that is misspecified). Assume there is a binding function $\beta = h(\theta)$. The analytical form of $h(.)$ may not be known so that $h^{-1}(\beta)$ may not always be computable.

The Indirect Inference estimator is

- get $\hat{\beta}$ from the QML
- use $f(y, \theta)$ to simulate y^s using $\hat{\beta}$
- use the auxiliary model under $f^a(y, \beta)$ to estimate $\hat{\beta}^s$
- solve $\hat{\theta} = arg\ min_\theta (\hat{\beta}^s - \hat{\beta})' \Omega (\hat{\beta}^s - \hat{\beta})$

Note that the seed to generate y^s is kept unchanged so that variations in the pseudo-observations across simulations are due to variation in $\hat{\beta}^s$

5. Modeling Green Growth Adjustment Costs: Analogies and Differences with Trade Policy

In this section, I discuss similarities and differences between the measurement of trade adjustment costs, TAC, and the measurement of green growth adjustment costs, which we can label GGAC. My discussion will be based on the premise that, among the various approaches presented above, efforts to measure green growth adjustment costs should be based on some version of a stochastic dynamic general equilibrium model. The methods used in the early approach can only provide quick back of the envelope calculations of GGAC. While these calculations may be useful as first approximations, they should nevertheless be taken with caution. Instead, research based on SDGE models can generate, I believe, credible estimates of those adjustment costs. The ultimate goal of this discussion is to provide insights, hopefully useful, to implement a careful analysis, theoretical and empirical, of green growth adjustment costs.

The recent literature on trade adjustment costs takes, in general, a simple view of trade policy. As I have shown, most of the papers adopt a simple setting where trade liberalization takes the form of lower protection in an import-competing sector. In consequence, trade liberalization materializes as a change in relative prices against the import-competing sector and in favor of export industries. In other words, the trade literature focuses, to a large extent, on impacts of taxes on outputs. This is clearly a simplification, but, I believe, a useful one in order to narrow down the discussion of green growth policies and the suitability of trade models to green growth policies.

The broad definition of the green growth process makes it much more difficult to pin down the policies actually used. Different countries adopt different policies and focus on different angles of green growth issues. To make things even more complicated, the different emphasis is unlikely to be exogenous, or random, but rather to respond to political and idiosyncratic features of each country. This complicates the analogies between TAC models and GGAC models that can be drawn.

In principle, any green growth policy that acts as a tax or subsidy on *outputs* can be easily incorporated into the SDGE models. In fact, policies that affect output prices directly could be explored without the need to amend those models. The idea is straightforward: just as trade adjustment models can incorporate changes in domestic and international output prices through tariff reductions (or increases), the same modeling can capture the impacts of increased domestic output taxation to include a charge on (local) pollution.

Arguably, however, green growth policies are best described as affecting input choices rather than outputs. For instance, governments may tax certain types of energy or may subsidize others (such as solar energy, for instance). In addition, many GG policies focus on inducing firms to switch inputs or substitute one type of input for another (to reach a "cleaner" input mix). While the scope to use TAC models becomes narrower in this setting, they are still useful.

If a GG policy can be conceptualized as an input tax, current TAC models can be adapted to assess GGAC. This approach is applicable to policies to reduce energy intensity and to reduce GHGs from fossil energy use. The problem then is being able to capture empirically the substitution of lower-carbon energy for higher-carbon energy. In addition, the input tax approach treats the production function as given, when in fact one could think of some energy efficiency measures as changing the production function.

A somewhat bigger challenge comes when the policy can be conceived of as akin to a tax on an environmentally undesirable co-product: burning coal produces electricity but also produces particulate matter. Conceptually we could include this in an expanded version of the TAC modeling; but it may be possible instead to take a simpler approach by representing the response to a pollution tax which leads to substitution of cleaner technology for dirtier technology through (i) a fixed investment cost per plant (that could be included as a cost amortized over time also), and (ii) a higher operating cost (e.g. for the energy to run the pollutant removal technology).

The hardest case is when policy is technologically prescriptive. If one could figure out how to model the new steady state with the new technology, then one could get a sense of what happens to the cost of output post-conversion, changes in labor requirements in different sectors, and then try to assess transition costs. At the moment, it is not clear to me that this type of analysis can be done is a convincing way.

A concern with green growth initiatives is the social versus private nature of the benefits and costs. In trade theory, gains and losses are private (to a very large extent at least). Unprotected firms lose profits and thus hire less workers and pay them lower wages, and as a result workers' welfare decreases. Export oriented firms benefit from enhanced trade opportunities and pay higher wages to their employees. As I have discussed, efficiency gains are often large enough to allow winners to fully compensate the losers and to still remain winners. In the models of this section, this result appeared once and again in the form of higher aggregate welfare, higher values for workers in different sectors, and so on.

When talking about green growth, at least part of the gain, if not most of it, is social. Better policies towards the environment, for instance, improve our quality of life but do so in a way that makes it difficult for individuals (workers, firms) to internalize those gains. There is an externality that is not accounted for in the individuals' decisions concerning employment, technology adoption, and so on. Conceptually, it is not hard to understand what the issues are. What is less clear is how to incorporate these features into the TAC models in order to use them for this purpose. As a crude and simple example, suppose we decide to model green growth policies as a cost shock so that the cost of the firm is now higher (perhaps in selected sectors of the economy) because firms need to improve their capital equipment, retool it to make it environmentally more efficient, etc. As I just argued, it wouldn't be too hard to incorporate these features into some of the TAC models and to simulate how the economy will respond to this specific example of a hypothetical green growth policy. But if we model this as a negative cost shock, the implications will be lower profitability, lower wages, lower employment, and, overall, lower welfare. But it would be incorrect to conclude that green growth policies lead to lower welfare, because there are social benefits that are being unaccounted for. We could amend the utility function of the individual to include a term related to the "environment" and link the size of the cost shock to this piece of the utility function. This idea is indeed implementable. The conceptual issues are clear, but working out all the full details empirically is not straightforward.

The last point I want to raise is data constraints in developing countries. To the extent that the green growth initiative focuses on developing countries, it is important to discuss whether any of the TAC models can be estimated (or at least calibrated) using data from developing countries. The modern approach exploits microdata as much as possible. Fortunately, micro-data have become increasingly available across the developing world and it is now easy to find firm surveys or household surveys for many countries. However, there are limitations. Studies such as Dix-Carneiro's rely on individual records of workers who are tracked along their working life. This type of administrative data is not, unfortunately, so widespread. Instead, the method in Artuc, Chaudhuri and McLaren (2010) requires panel data to compute flows of workers between sectors and interindustry wage differentials. While this type of data is generally more readily available, sufficiently large panels to estimate the model with a decent degree of precision are probably harder to come by than one would a priori think. In fact, in Artuc, Lederman and Porto (2011), while working on creating a mapping of labor mobility costs in the developing world, we have encountered enormous difficulties in finding the needed panel data. To overcome this limitation, we develop a modified version of the labor mobility cost model that could be estimated with repeated cross-section (instead of panels). One of the goals of the project is to facilitate applied research in developing countries on the topic of adjustment costs to trade and, if possible, to green growth.

For some questions such as for example the role of capital adjustment costs or firm's costs of adjusting employment, firm-level data is also needed. The rich data used by Bloom (2009) or Cooper and Haltiwanger (2006) is seldom available in developing countries. Many middle-income countries do have rich panels of firms (Argentina, Chile, Mexico, are examples). The investment climate data, which covers most countries of interest, is perhaps not suitable for this type of analysis.

6. Other Relevant Adjustments

There is a large literature on responses to trade reforms/shocks. Clearly, firms adjust labor and capital and also output and prices. Harrigan and Barrows (2009) provide a detailed account of the responses of world trade to the elimination of the U.S. Multi-Fiber Trade Arrangement (MFA). Research has also shown how firms adjust the skill intensity of production (Brambilla, Lederman, and Porto, 2011), adopt new technologies (Bustos, 2011a), upgrade quality (Verhoogen, 2008), invest in R&D (Bustos, 2011b), establish relationships with new customers (Freund and Pierola, 2010). This literature may be relevant for green growth policies if, for instance, firms endogenously choose to produce “greener” products. To make the analogy, let me work out an example. In Verhoogen (2008) and Brambilla, Lederman, and Porto (2011), for instance, higher income countries demand higher quality goods, while the production of higher quality goods is intensive in skilled labor. In turn, firms selling higher quality goods earn higher profits because they can sell at a higher price. In these models, firms that switch from exporting to middle-income to exporting to high-income countries will hire more skilled workers and pay them higher wages. In terms of green growth models, we can imagine a setting where higher-income countries demand “greener” products because consumers are more environmentally conscious. If so, the analogy is straightforward because firms that switch to greener products can adjust the combination of inputs they employ depending on various factor intensity assumptions. But this is probably as far as I would like to go without a much more detailed evidence of technology of green production and of preferences towards green products.[12]

There are two additional strands of trade literature, the literature on trade standards and the literature on fair labor, that can be very useful. Standards and fair labor requirements are imposed by importing countries on exporters, generally from developing countries. Standards refer to quality requirements that exporters need to meet and that may thus require the adoption of new technologies, the incorporation of new machines, or the hiring of specialized workers. Likewise, fair trade initiatives in importing countries support sellers utilizing fair labor conditions (i.e., no child labor, fair wages). These markets offer a premium to firms that abide by fairer labor conditions. In consequence, an exporter that wants to exploit these markets may need to adopt new production practices. To explore whether the standards and fair labor literatures may provide useful elements to our discussion on adjustments to green growth policies, I will review two key papers, one on standards (Swinnen and Maertens, 2010) and another on fair labor (Harrison and Scorse, 2010).

Swinnen and Maertens (2010) explore the role of product standards as determinants of exports of food and agricultural products. This paper is itself a review of the literature and consequently I can use it to summarize most of the available knowledge in this area. I find this study relevant because the authors examine whether standards can prevent the realization of the gains from trade liberalization, thus acting as a kind of driver of adjustment costs.

Standards can act as barriers or catalysts to trade and as barriers or catalysts to development. From the trade perspective, there is only limited evidence that standards act as barriers. Instead, they may facilitate trade between countries with diverging norms. Perhaps a similar analogy can be found with green standards.

On the question of standards as catalysts to development, standards can facilitate the exclusion of poor farmers from the supply chain and can facilitate the exploitation of smallholders, who would lose bargaining power (vis-à-vis large food exporters and multinational food companies). The evidence on the exclusion of smallholders because of high compliance costs and increasing levels of vertical coordination is mixed: there are cases of complete vertical integration with hardly any smallholder involvement (tomatoes in Senegal or fruits and vegetables in Zambia), and there are cases in which export production remains dominated by smallholders (vegetables in Madagascar and Ghana). In contrast, the evidence against exploitation of smallholder producers is more compelling because high-

[12] For instance, is there evidence that rich customers demand and value greener products produced in developing countries?

standards contract production often brings about productivity gains, increased household income, reduced income volatility, increased employment (downstream), and reduced poverty.

The analogies between trade standards and environmental standards are not entirely clear. Trade standards are often rooted in a demand for quality and therefore have an intrinsic monetary value. In other cases like health, standards, while valued, are imposed by governments. In this sense, if there is a demand for environmental quality or if the environment is valued but the externalities are not internalized, as I argued above, it is plausible to trace parallels between environmental and trade standards and it would be possible to argue that green policies of this type may bring benefits for developing countries. There is, to my best knowledge, little direct evidence on this and it would be useful to generate evidence supporting this conclusion.

Let me now turn to fair labor and the paper by Harrison and Scorse (2010), who study the role of anti-sweatshop activism on firm behavior in Indonesia. In the 1990s, activists targeted multinational firms such as Nike, Adidas and Reebok in the textiles, footwear and apparel sectors and requested improved working conditions, higher wages and various other human rights issues. As a result of activist pressure, the multinational firms were induced to sign codes of conduct pledging to raise wages and improve working conditions in factories producing their products.

The empirical strategy in Harrison and Scorse is entirely different from the structural modeling of section 4. The authors use a difference-in-differences strategy, by first comparing wage growth in textile, footwear, and apparel plants relative to wage growth in the rest of manufacturing before and after the advent of the anti-sweatshop campaigns, and, second, by exploiting differences in geographic location of Nike, Adidas and Reebok contractors across Indonesia.

Both approaches indicate that targeted plants increased real wages in response to activist pressure. Activism brought about wage increases ranging from 10 to 30 percent. Most of these wage increases were due to higher compliance with minimum wages on the part of targeted plants. There were costs associated with these responses. In particular, there were large, negative effects of the minimum wage increases on aggregate manufacturing employment with an estimated elasticity of around 0.12 (so that a 10 percent increase in the real minimum wage reduces production worker employment by 1.2 percent). However, there was no evidence of additional negative employment effects of the sharper wage increase at targeted TFA plants. That is, although TFA plants increased wages in large part by increasing compliance with minimum wages, greater compliance was not associated with significant employment losses relative to non-TFA plants. This is because firms adjusted particularly profits. In consequence, the anti-sweatshop movement resulted in “forced” profit sharing, where higher wages for TFA workers were financed largely through lower returns to capital.

The paper by Harrison and Scorse (2010) is particularly interesting for our purpose because it shows that policies resulting from the demand for fairer labor conditions in developing countries can be successful and bring small costs in terms of employment. That is, the minimum wage legislation, and the higher compliance of multinationals , which was induced by anti-sweatshop activists resulted in higher wages and almost no employment losses. (Profits declined but activists would argue they were originally too high due to unfair labor conditions.) I would perhaps expect similar outcomes from green activism, but there are differences to be considered. In particular, the analogy requires profit-sharing (and perhaps wage-sharing) with the “environment,” so that firms give up profits (and workers perhaps give up wages) in exchange for benefits of a cleaner environment. This may be so, but the mechanisms need to be clearly documented.

7. Policies: Compensation, Assistance, and TAC Intervention

In this section, I discuss policies related to trade adjustment costs. I distinguish between two different types of policies: compensation and assistance schemes and policies to ease the constraints imposed by the factors that hinder full factor adjustment.

I begin by reviewing the literature on compensation and assistance related to trade adjustment costs. I first briefly discuss the essence of the gains from trade with winners and losers, and I then explore some of the policies examined in the theoretical laboratories of the models presented in section 4. I conclude with a discussion of actual trade assistance programs in the U.S. and in the E.U.

The literature, both theoretical and empirical, shows substantial gains from trade liberalization. As I pointed out, however, there are winners and losers and there also are costs of adjustment that can be borne disproportionately by different segments of the population. It could be that, say, unskilled workers benefit from free trade, but they may suffer all the costs of adjustment during the transition.

The gains from trade arise because of the efficiency gains created by free interchange. While there are scenarios where free trade can bring about aggregate losses, the theory strongly suggests that gains are more likely than losses. Establishing gains from trade in a Pareto sense is harder. There are theorems and results that show that an appropriate set of subsidies and taxes unrelated to trade dominates the distorted trade equilibrium. That is, it is socially beneficial to liberalize trade and use the gains of the winners from trade to compensate the losses of the losers. This redistribution (done with lump-sum transfers or with taxes and subsidies) leaves everyone as well-off as before and at least someone better-off. One way to think about this result is with the second-best theorem: there are better instrument than trade policy to take care of distributive concerns. Clearly, the implementation of the scheme of transfers suggested by the theory may not be feasible, perhaps technologically (because of the information content of the redistribution scheme) or politically. In consequence, while the gains from trade are (almost) guaranteed in theory, there are practical concerns to be taken into account.

An analogy can be made with losers due to adjustment costs. Even if adjustment costs are large in some cases, the literature shows aggregate welfare gains from trade liberalization. This suggests that a transfer scheme could in principle be implemented during the transition so that winners can compensate losers and still enjoy net gains from trade.

Some of the papers I have reviewed above provide insights into the type of compensation scheme that would be better suited to deal with trade adjustment costs. In Davidson and Matusz (2010), for instance, there are winners and losers from trade liberalization (despite the fact that labor is the only input) because workers are heterogeneous in ability. Workers in the export oriented sector prior to liberalization gain from trade, workers who remain in the import-competing sector subsequent to liberalization lose from trade, and workers who switch bear the adjustment costs.[13] Policies to compensate the losers (which are second-best in the absence of lump-sum transfers) are discussed in Davidson and Matusz (2006b). If the target group of the policies are the bearers of the adjustment costs, the least distorting policies should be tied to the ex post wage (e.g., wage subsidies). If the target group is the losers in the import-competing sector, then the least distorting policies are independent of the wage (e.g., employment subsidies). The authors use numeric techniques to get some sense of the costs

[13] In the model, the lower-ability workers in this segment are harmed by liberalization, while the higher ability workers benefit. This is consistent with the empirical evidence on the experience of displaced workers.

of compensation (measured as the size of the resulting distortion relative to the gain from trade). They find that using the correct policy creates very little deadweight loss, ranging from well under 1 percent of the gains from trade to approximately 30 percent of the gains from trade, depending upon parameter assumptions and the particular scenario studied. However, using the wrong policy causes these costs to balloon, in some cases more than doubling for the same set of parameter values and the same scenario.

In many instance, a large fraction of the costs of adjustment to trade are the result of an inherent distortion or market failure in the economy.[14] These distortions can affect labor markets (for instance if there are taxes and regulations that affect the cost of hiring and firing workers) or capital markets (if for instance there are credit constraints). In consequence, a direct way to tackle the trade adjustment costs is to implement policies to mitigate or eradicate the main distortions in the economy. Instead of listing broad policy measures (e.g., eliminate labor market frictions, improve credit markets, provide training to displaced workers), I'd rather discuss hard-core evidence from the models of section 4. The main exponents are Cosar (2010) and Dix-Carneiro (2010).

Cosar (2010) presents a model where the costs of adjustment are generated by frictional unemployment via labor search and matching. As in Dix-Carneiro (2010), this is an overlapping generation model and human capital is accumulated on the job. The model has three key features: i) worker mobility and adjustment costs age-dependent; ii) labor markets are subject to search frictions where young and old workers search for jobs and are randomly matched with firms. Depending on their match-specific productivity draws, they continue (or separate) and share rents via Nash-bargaining; iii) workers accumulate human capital through learning-by-doing on the job and skills are not transferable across sectors. Old workers in the import-competing sector are thus more likely to bear the costs of adjustment.

Cosar (2010) calibrates this model using Brazilian data and then works out different labor market policies to deal with trade adjustment costs. He finds that sector-specific human capital is a bigger impediment to mobility than labor market frictions (search and matching). In terms of policies, he compares an unemployment insurance program (similar to one actually implemented in Brazil in 1988) and a targeted employment subsidy paid to the initial old employed in the previously protected industry conditional on working in the export-oriented industry. The results show that the unemployment insurance (actual policy) experiment leads to an output loss during the transition by hampering what the economy needs most: reallocation and skill formation in the expanding sector. On the other hand, the employment subsidy (counterfactual policy) experiment suggests that it is possible to not only redistribute income toward workers harmed by the liberalization, but also to increase net output during the transition. The subsidy mitigates the market failure due to the learning externality: the underinvestment in skill formation is especially problematic during the transition which is a time for human capital build-up in the export-oriented industry. A policy that rewards work and mobility for workers adversely affected by trade not only compensates them, but it also speeds up the transition and helps the economy reap the gains from trade earlier on.

Dix-Carneiro (2010) also explicitly models labor market policies. Unlike Cosar (2010), the author finds that the costs of mobility are more important than sector-specific experience in explaining the slow adjustment of the labor market. This is because Dix-Carneiro allows experience to be imperfectly transferable (while Cosar assumes non-transferable experience) and estimates the degree of

[14] Note that the costs of re-tooling workers or of adapting capital as well as the efficiency losses from, for example, human capital specificity may also be significant. Recall, for example, the result in Davidson and Matusz (2010) reviewed in section 4.

transferability to be low but positive. In terms of policies, Dix-Carneiro (2010) finds that retraining workers initially employed in the adversely affected sector reduces welfare losses incurred by these workers and that a moving subsidy that covers switching costs is more promising in compensating workers initially employed in the affected sector, although at the expense of higher welfare adjustment costs.

I conclude this discussion with a review of policies actually implemented in practice. Most developing countries do not have trade-specific adjustment assistance programs, and thus I look at the trade assistance program in the United States (Richardson, 2010) and the agricultural support program of the E.U. (Swinnen, 2010).

Richardson (2010) analyzes the Trade Adjustment Assistance (TAA) program of the U.S. After a brief historical account of the American TAA, its mandate and coverage, the author assesses the role of a revised TAA program that could successfully deal with the modern process of global integration. Richardson argues that there are two main features of the current ``integrated integration'' process: large gains for the best-fitted agents (most productive firms, more able or motivated workers) and an increasingly unbalanced distribution of those gains against the less fit. In this context, Richardson claims that a successful TAA, one that would actually help improve and economy's overall performance and welfare, should increase its scale, its scope (and be transformed into a sort of structural adjustment assistance), and its constituency to harbor both ``natural'' American institutions (labor unions, community colleges) and new American institutions (like not-for-profit social services or insurance companies).

Swinnen (2010) describes the history of the E.U. Common Agricultural Policy (CAP). The main objective of agricultural policies in the E.U. was to support agriculture in order to protect farm incomes and employment from more general market liberalization. Initially, this was done by setting high import tariffs and export subsidies, and by fixing prices. Following the Uruguay Round, multilateral disciplines were negotiated for agricultural support policies in the WTO, and tariffs, export and production subsidies were partially replaced by ``compensation'' (direct) payments to farmers in the 1990s and, later, by so-called decoupled payments to farmers (not linked to output) in reforms in 2003 and 2008. These reforms can be regarded in some sense as adjustment policies---the aim being to compensate farmers for the changes while still achieving the objective of the CAP of ensuring a ``fair standard of living'' for farmers and ``stabilizing markets.'' Swinnen argues that while farm incomes are directly affected by the CAP, the observed catch-up to incomes in other sectors has been the result of non-CAP payments (for example, the integration of rural areas in factor markets and in the rest of the economy). Furthermore, there is no evidence of any impact on long-run employment levels in EU agriculture. Second, he argues that the evidence on stabilization is more nuanced. The old CAP system of price interventions reduced price variability but did not necessarily provide a good safety net. The current direct payment system has less or no impact on price variability, but does reduce income variability and reduces risk in farming households by providing a guaranteed source of income. Looking forward, Swinnen argues that the periodic reforms of the CAP have been successful in reducing market distortions but he doubts the Single Farm Payment system will address key challenges of the future, such as climate change and ensuring food quality.

8. Conclusions

Clearly, it is worth having estimates of the costs of adjustments to GG policies, both from a policy perspective and from an academic perspective. Some of the early approaches used to compute trade adjustment costs (TAC) could in principle be used to compute crude measures of green growth adjustment costs (GGAC). However, implementing a sophisticated dynamic general equilibrium model is also feasible. The discussion in Section 5 suggests ways to do this. Much more work is needed to fine tune the details, conceptually but more importantly empirically. But this effort is feasible and is also likely to generate evidence of significant value to assess Green Growth policies comprehensively.

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