Inequality, Costly Redistribution and Welfare in an Open Economy*

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Abstract

This paper studies the welfare implications of trade liberalization in a world in which trade increases income inequality, and in which redistribution needs to occur via a distortionary income tax-transfer system. We provide tools to characterize and quantify the *actual* amount of compensation that will take place following trade opening, as well as the *efficiency costs* of undertaking such redistribution. We propose two types of adjustments to standard measures of the welfare gains from trade: a 'welfarist' correction inspired by the Atkinson (1970) index of inequality, and a 'costly-redistribution' correction capturing the efficiency costs associated with the behavioral responses of agents to *trade-induced* shifts across marginal tax rates. We calibrate our model to the United States over the period 1979-2007 using data on the distribution of adjusted gross income in public samples of IRS tax returns, as well as CBO information on the tax liabilities and transfers received by agents at different percentiles of the U.S. income distribution. Our quantitative results suggest that these corrections are nonnegligible and erode about one-fifth of the gains from trade.

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1 Introduction

Two of the most salient phenomena in the world economy in recent years have been a rapid increase in the extent to which economies have become interconnected and a significant rise in income inequality in many countries. For instance, during the period 1979-2007, the U.S. trade share (defined as the average of exports and imports divided by GDP) increased from a value of 9.2% to 14.0%, while the Gini coefficient associated with the distribution of U.S. market income grew dramatically from a level of 0.48 all the way to 0.59. Furthermore, as is clear from Figure 1, trade integration and inequality grew very much in parallel even at fairly low frequencies. The extent to which these two phenomena are causally related has been the subject of intense academic debates, but it is by now a widely accepted view that trade integration has been a significant contributor to increased wage and income inequality in the U.S. and many other industrialized countries.[1] The picture emerging from developing countries also points to the importance of trade-induced inequality. Goldberg and Pavcnik (2007) summarize a body of literature studying the consequences of trade liberalization across a number of developing countries after 1970s, with the bulk of episodes triggering significant increases in inequality.

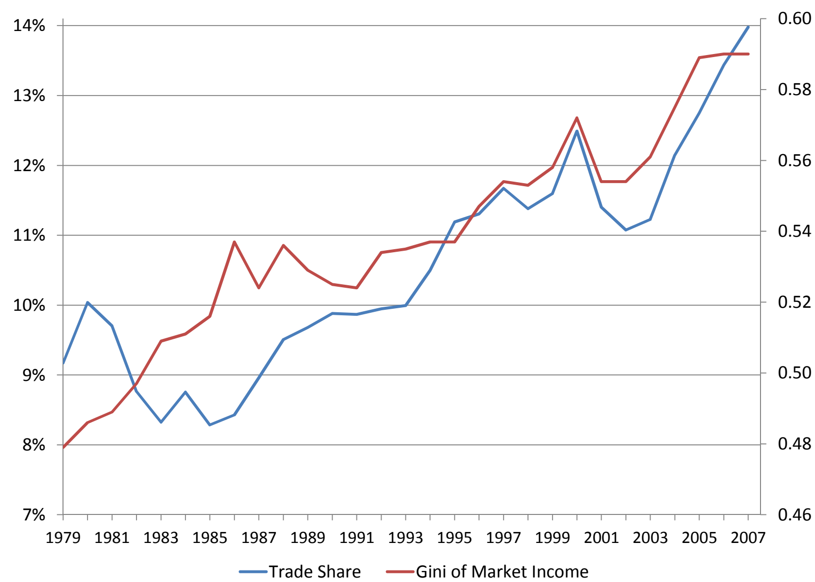

Figure 1: Trade Integration and Income Inequality: United States (1979-2007)

Despite these recent trends, the standard approach to demonstrating and quantifying the welfare gains from trade largely ignores the implications of trade-induced inequality. The paradigm used to evaluate the social welfare consequences of trade integration is the Kaldor-Hicks compensation principle (Kaldor 1939, Hicks 1939). This approach begins by computing the compensation variation or equivalent variation of a change in the environment at the individual level,

[1] Feenstra and Hanson (1999), for instance, estimate that outsourcing alone could account for as much as 40% of the increase in the U.S. skill premium in the 1980s. Other studies, summarized in Krugman (2008), arrive at more conservative estimates suggesting that trade accounted for about 15-20% of the increase in income inequality.

and then aggregates this money metric across agents. The celebrated "gains from trade" result demonstrates that, in competitive environments, when moving from autarky to any form of trade integration, the losers can always be compensated and there is some surplus to potentially turn this liberalization into a Pareto improvement. A key advantage of the Kaldor-Hicks criterion as a tool for policy evaluation is that it circumvents the need to base policy recommendations on interpersonal comparisons of utility, thus extricating economists' prescriptions from their own moral convictions (cf., Robbins (1932)).

As influential as the Kaldor-Hicks compensation principle has proven to be in Economics, there are two basic shortcomings with this approach. First, the fact that there is the *potential* to compensate those that are hurt from a particular policy does not imply that these losers will be compensated *in practice*. If one knew that the redistribution or compensation necessary for a policy to generate Pareto gains would not happen or would not be complete, shouldn't the evaluation of such a policy take this fact into account? Second, the simple aggregation of individual compensating or equivalent variations in the Kaldor-Hicks criterion implicitly assumes the existence of nondistortionary means to redistribute part of the gains from the policy to those that do not directly benefit from it. In reality, compensation often takes places through a tax and transfer system embodying nontrivial deadweight losses, so it seems reasonable to build this 'lucky-bucket' characteristic of redistribution into measures of the social welfare effects of a policy.

In this paper, we study the welfare implications of trade opening in a world in which international trade affects the shape (and not just the mean) of the income distribution, and in which redistribution policies are constrained by information frictions, and need to occur via a distortionary income tax-transfer system. In this environment, we provide tools to quantify the *actual* amount of compensation that will take place following trade opening, as well as the *efficiency costs* of undertaking such redistribution. More specifically, we propose two types of adjustments to standard measures of the welfare gains from trade. On the one hand, we develop a 'welfarist' correction which captures the negative impact that an increase in inequality in the distribution of disposable income has on the welfare an inequality-averse social planner. This first adjustment is tightly related to the Atkinson (1970) index of inequality, which has been rarely applied to trade contexts.[2] On the other hand, we derive a 'costly-redistribution' correction which captures the behavioral responses of agents to *trade-induced* shifts across marginal tax rates. This second adjustment is in turn related to the work of Benabou (2002) but generalized to apply to income distributions other than the lognormal one.

We begin our analysis in section 2 within a fairly general environment that illustrates the rationale for these two corrections when evaluating *any* policy (not just trade liberalization) that has the potential to affect the shape of the income distribution beyond its mean. In this environment, we derive explicit formulas for these adjustments in terms of specific moments of the income distribution, the level of progressivity of the tax-transfer system, the degree of

[2]Two very recent exceptions are the ongoing projects by Rodriguez-Clare, Galle, and Yi (2015) and Porto (2015).

inequality of aversion of the social planner, and the elasticity of taxable income to changes in marginal tax rates.

Our environment in section 2 is silent on the primitive determinants of the income-generation process or on the precise mechanism that leads to a positive elasticity of income to changes in marginal taxes. In section 3, we develop a microfounded simple general equilibrium framework that illustrates how the ability of individuals and their labor supply decisions translate in equilibrium earnings and welfare levels given the tax system in place. When solving for the closed-economy equilibrium of the model, we are able to decompose changes in welfare into changes in the welfarist correction, changes in the costly-redistribution correction and changes in the welfare of a hypothetical 'Kaldor-Hicks' economy with access to costless redistribution and in which a dollar in the hands of a rich individual is valued in the same manner as a dollar in the hands of a poor individual.

The economic environment we develop builds on Itskhoki (2008), and is inspired by the canonical optimal taxation framework of Mirrlees (1971) and the workhorse model of trade liberalization of Melitz (2003). Agents in our economy are worker-entrepreneurs each producing a distinct task associated with the production of a final good. Unobservable heterogeneity in productivity across agents generates income inequality, which an inequality-averse social planner may try to moderate via a progressive system of income taxation. The two key departures from the classic Mirlees framework is that we allow for imperfect substitutability in the task services provided by different workers and that we restrict attention to a specific form of nonlinear taxation that, consistently with U.S. data, implies a log-linear relationship between income levels before and after taxes and transfers (see also Heathcote, Storesletten, and Violante 2014). Imperfect substitutability is not essential for our closed-economy results but is the source of the welfare gains from trade later in the paper.[3]

Before moving to this open-economy environment, in section 4 we provide a brief calibration of the closed-economy model that decomposes the evolution of social welfare in the U.S. over the period 1979-2007 in terms of the welfarist and costly-redistribution corrections and the welfare of the hypothetical 'Kaldor-Hicks' economy. We calibrate our model using data on the distribution of adjusted gross income in public samples of IRS tax returns, as well as CBO information on the tax liabilities and transfers received by agents at different points of the U.S. income distribution. Our calibration unveils a very significant decline in the degree of tax progressivity over this period despite the concomitant increase in 'primitive' income inequality. This in turn implies that, even for modest degrees of inequality aversion, social welfare gains were significantly lower than the average real income gains recorded over this period. We also use our simple calibration to shed light on the growth in average real income that the U.S. would have attained if the progressivity of the U.S. tax system had been kept constant at its 1979 level, or if tax progressivity had increased to avoid the observed rise in income inequality. We find that real income growth in those counterfactual scenarios would have been markedly

[3]Imperfect substitutability between different types of labor in the Mirrlees model were studied by Feldstein (1973) and Stiglitz (1982) in a two-class economy.

lower than the 44.2% increase observed in the data. For instance, for the case of a degree of inequality aversion equal to 1 and an elasticity of taxable income equal to 0.5, we find that real income would have grown by 27.8% if tax progressivity had remained constant, and by 10.2% if progressivity had increased to keep income inequality unchanged over the period.

Armed with this suggestive evidence of the empirical relevance of our two key inequality corrections, in section 5 we move to an open-economy environment, which is a straightforward extension of the closed-economy framework in section 3. In particular, our assumed imperfect substitutability of the tasks performed by different workers worldwide results in welfare gains from trade integration associated with final output being produced with a wider range of differentiated tasks. These love-for-variety gains from trade are thus analogous to those in Krugman (1980) or Ethier (1982).[4] In order to generate nontrivial effects of trade on the income distribution, we follow Melitz (2003) and introduce fixed costs of exporting, which allow only the most productive agents to participate in international trade.[5] Consequently, trade disproportionately benefits the most productive agents in society, leading to greater income inequality in a trading equilibrium than under autarky. The progressivity of the tax system attenuates the rise in inequality following trade liberalization, but unless tax progressivity increases with trade, the distribution of disposable income will necessarily become more unequal with trade, thus leading to a higher welfarist correction than under autarky. Furthermore, selection into exporting generates an extensive margin of trade, which is sensitive to national redistribution policies and contributes to the overall efficiency costs of taxation. Thus, our 'costly-redistribution' correction is also generally exacerbated by a process of trade integration.

In section 6, we calibrate our open-economy model with the same IRS tax returns data employed in section 4, together with measures of trade costs and trade shares to calibrate the key trade frictions parameters of the model. Our preliminary quantitative results suggest that these corrections are nonnegligible and erode about one-fifth of the gains from trade under plausible parameter values, such as a degree of inequality aversion equal to 1 and an elasticity of taxable income of around 0.5. The welfarist correction to the welfare gains can however be significantly higher for larger values of inequality aversion, eliminating up to one-third of the gains from trade under certain parameter values. Similarly, the welfare loss from the costly redistribution correction can also rise to close to one-third of the welfare gains from trade for taxable income elasticities in the neighborhood of 1 or 1.5.

Our model of the effects of trade on the income distribution is highly stylized and abstracts from many features that have been emphasized in past and more recent research on trade and labor markets. For many years, the Heckscher-Ohlin (HO) model, and in particular its Stolper-Samuelson theorem, provided the key conceptual framework used to analyze the links between trade and wage inequality. Nevertheless, the empirical limitations of this framework have become

[4] Broda and Weinstein (2006) studied the empirical importance of this love-of-variety channel and estimated sizeable welfare gains from increased variety through international trade for the United States.

[5] Empirically, only a small fraction of firms export even in the most tradable sectors (Bernard and Jensen 1999) and fixed costs of trade appear to be quantitatively very important (Das, Roberts, and Tybout 2007).

apparent in recent years. As mentioned above, trade liberalizations have led to sharp increases in inequality not only in rich countries but also unskilled-labor abundant developing countries, a phenomenon at odds with the predictions of the HO model.[6] In addition, the contribution of the residual component of wage inequality within groups of workers with similar observable characteristics appears to be at least as important as the growing skill premium across groups, as emphasized by the HO model.[7] Finally, contrary to the main mechanism of adjustment in the HO model, the reallocation within sectors appears to be more important than across sectors for both adjustment to trade and inequality dynamics.[8]

For these reasons, recent work has explored alternative models featuring richer interactions between labor markets and trade liberalization. One branch of this literature has explored the role of search frictions and other type labor-market imperfections (see, for instance, Helpman, Itskhoki, and Redding (2010) or Amiti and Davis (2012), among many others), while a second branch has focused on the role of sorting of heterogeneous workers into firms or technologies (see, for instance, Yeaple (2005), Costinot and Vogel (2010) or Sampson (2014)), or the matching of heterogeneous workers into production teams (see Antràs, Garicano, and Rossi-Hansberg 2006). Our international trade model is much more parsimonious than those developed in this recent research, yet the mechanism through which it generates trade-induced inequality is similar in spirit to the one generating the same link in those models. A crucial advantage of our stylized model relative to these alternative ones is that it is much more amenable to calibration and quantification of the counterfactual inequality effects of a trade liberalization. An open question for future research is the extent to which the inequality corrections arising from our framework are similar in magnitude to those one would obtain in richer frameworks.

Within the international trade field, our paper is also related to previous work studying the redistribution of the gains from trade.[9] Following Dixit and Norman (1980, 1986), this strand of the literature has mainly focused on the possibility of compensating losers from trade through a variety of tax instruments. Dixit and Norman themselves focused on the sufficiency of commodity and factor taxation for ensuring Pareto gains from trade, while Spector (2001) and Naito (2006) showed how Mirrlees-type incentive constraints could undermine differential factor taxation, thereby opening the door for the possibility that trade could lead to welfare losses by hampering redistribution.[10] Relative to this body of work, our goal is to instead characterize and quantify the *actual* efficiency costs of redistribution given the observed features of the system

[6] A related observation is that the movements in relative prices of skilled to unskilled goods, which are at the core of the Stolper-Samuelson mechanism, tended to be small (e.g., see Lawrence and Slaughter 1993).

[7] For example, see Autor, Katz, and Kearney (2008) for the evidence for US and Attanasio, Goldberg, and Pavcnik (2004) for the evidence for a developing country (Colombia).

[8] For example, Faggio, Salvanes, and Van Reenen (2007) show that most of the increase in wage inequality in UK happened within industries, while Levinsohn (1999) shows the relative importance of within-industry reallocation in response to trade liberalization in Chile.

[9] Another strand of literature, started by Cameron (1978) and Rodrik (1998), studies the optimal size of the government sector in an open economy.

[10] Davidson and Matusz (2006) design the lowest cost compensation policies for the losers from trade in a two-sector economy with heterogenous agents and participation decisions, but fixed labor supply.

used to carry out such compensation in the real world.[11] In that sense, our focus on the income tax-transfer system as the vehicle for redistribution is motivated by the small scale and limited relevance of more direct means of compensation, such as trade adjustment assistance programs. For instance, in their influential recent study on the U.S. labor-market implications of the rise of Chinese import competition, Autor, Dorn, and Hanson (2013) find that the estimated dollar increase in per capita Social Security Disability Insurance (SSDI) payments following trade-induced job displacements is more than thirty times as large as the estimated dollar increase in Trade Adjustment Assistance (TAA) payments.

Finally, our welfarist and costly redistribution corrections are not only related to the seminal work of Kaldor (1939), Hicks (1939), Atkinson (1970), and Benabou (2002), but they also connect to a large body of related work. The welfarist approach to policy evaluation originates in the pioneering work of Bergson (1938) and Samuelson (1948), and has constituted an important paradigm in the optimal policy literature since the seminal work of Diamond and Mirrlees (1971), and the more recent literature that spun from the work of Saez (2001). Similarly, we are certainly not the first to incorporate the costs of redistribution into the analysis of the welfare effects of policies. The need to do so was actually anticipated by Hicks himself in the concluding passages of his 1939 paper, and was subsequently explored by Kaplow (2004) and, more recently, by Hendren (2014). Hendren (2014), in particular, estimates the *inequality deflator* associated with the transfer of $1 of income from individuals at different positions in the U.S. income distribution to the rest of the U.S. population. He finds that this deflator is higher for rich individuals than for poor individuals and uses it to quantify the effects of increased income inequality on U.S. economic growth. His approach to costly redistribution is certainly more sophisticated than the one adopted in this paper, as it involves an estimation of the joint distribution of marginal tax rates and the income distribution using the universe of U.S. income tax returns in 2012. The thought experiment that motivates his work is however distinct from ours. While we seek to understand the efficiency costs associated with the behavioral responses of agents triggered by trade-induced shifts across marginal tax rates, his focus is on understanding the efficiency consequences of *local changes* to the nonlinear income tax schedule aimed at compensating the losers from a particular policy. It might be fruitful to adopt his approach to the study of the effects of trade liberalization, but we leave this for future research.

2 Inequality and Welfare: A Primer

We begin the analysis in this section by considering various approaches to measuring the evolution of social welfare in the face of changing inequality and when complete and costless redistribution is infeasible. We first review the Kaldor-Hicks principle and the Atkinson's welfarist approach, and then present our novel costly redistribution approach. While doing so, we introduce our two main inequality correction terms for measuring welfare gains—the welfarist

[11] Rodrik (1992) is a noteworthy antecedent to our work in discussing the costs of redistribution following changes in trade policy.

correction and the costly-redistribution correction—and discuss their properties. In order to simplify the exposition, the framework developed in this section will leave some of the primitive determinants of income, welfare and costly redistribution unspecified. In section 3, we formalize these correction terms in a context of a simple but fully microfounded constant-elasticity model, and we illustrate how to use this framework to provide back-of-the-envelope calculations of welfare changes when both aggregate income but also inequality change over time.

2.1 Economic Environment

Consider a society composed of a measure one of individuals indexed by their ability level φ with associated real earnings r_φ. Agents' preferences are represented by an utility function U defined over consumption c_φ. Agents' consumption is in turn equal to their real *disposable* income r^d_φ, defined as:

$$r^d_\varphi = \left[1 - \tau(r_\varphi)\right] r_\varphi + T_\varphi, \tag{1}$$

where $\tau\left(r_\varphi\right)$ denotes a non-linear income tax and T_φ represents a lump-sum transfer. The distribution of φ in the population is given by the cumulative distribution function H_φ, while the associated income distribution for real before-tax earnings is denoted by F_r.

The society is evaluating the consequences of a policy (such as a trade liberalization) that would generate heterogeneous effects on agents' real incomes, thereby leading to a shift from the initial distribution of earnings F_r to a new distribution of real income F'_r. What are the welfare consequences of the move from F_r to F'_r? For simplicity, we assume that the government budget is balanced both before and after the shift, so that

$$\int r^d_\varphi \mathrm{d}H_\varphi = \int r \mathrm{d}F_r = R.$$

We discuss below three different approaches to the evaluation of the social welfare implications of the move from F_r to F'_r.

2.2 The Kaldor-Hicks Principle

The Kaldor-Hicks compensation principle constitutes the standard approach to evaluating the welfare effects of a policy. To identify a Kaldor-Hicks improvement, one starts by computing the compensating or equivalent variation for each individual associated with the particular policy under study opening, and these money metrics are then aggregated across all individuals. In our example above, this principle implies that *mean* real income growth is a sufficient statistic for comparing social welfare under F_r and F'_r, regardless of the effect of the policy on the higher moments of the income distribution.

Let us illustrate this for the case of the compensating variation, which we denote with v_φ for an individual of type φ and which satisfies:

$$u\left(r^{d\prime}_\varphi + v_\varphi\right) = u\left(r^d_\varphi\right). \tag{2}$$

It follows that the required aggregate compensation satisfies:

$$-\int v_{\varphi} \mathrm{d}H_{\varphi} = \int r_{\varphi}^{d\prime} \mathrm{d}H_{\varphi} - \int r_{\varphi}^{d} \mathrm{d}H_{\varphi} = \int r \mathrm{d}F_r' - \int r \mathrm{d}F_r. \tag{3}$$

Clearly, the right-hand-side of (3) corresponds to the change in aggregate real income, which we write as $R' - R$. If this quantity is positive, it means that the amount of money necessary to restore the losers' welfare to its pre-policy level is lower than the amount that winners are jointly willing to give up for the policy to be adopted. In order to quantify the gains from trade, it is standard to express the change in (3) as a percentage change relative to the initial level of aggregate real income R, which we can denote by

$$\mu^{KH} = \mu^{R} \equiv \frac{R' - R}{R}. \tag{4}$$

The gains μ^{KH} from the policy thus correspond to the mean real income growth μ^{R} it generates. More generally, the overall welfare impact of other exogenous shocks can be evaluated analogously by only considering their effect on average income (or GDP).

Although we have assumed that all agents have a common indirect utility function U, it is clear from equation (2) that the result in (3) will apply even when agents are heterogeneous not only in income but also in preferences. This is a key appealing feature of the Kaldor-Hicks criterion: it does not rely on interpersonal comparisons of utility.[12]

As noted in the Introduction, there are however two key limitations of the Kaldor-Hicks criterion. First, the fact that there is the *potential* for the winners to compensate the losers does not mean that this compensation *actually* takes place in practice. If little redistribution takes place and the ex-post distribution of income is much more unequal than the ex-ante one, it is less clear that mean income should be a sufficient statistic for measuring welfare changes. Second, the focus on compensating or equivalent variations is justified only in the presence of lump-sum taxes that are needed to ensure the frictionless redistribution of gains across the individuals. While a useful theoretical tool, lump-sum transfers are informationally intensive and rarely feasible in practice. Naturally, compensation may also be achievable via other forms of redistribution, but these alternative instruments are likely to impact economic efficiency and thus the magnitude of the welfare gains from a policy.

In light of these limitations, we next discuss two alternative (and complementarity) approaches to policy evaluation that explicitly correct for the induced effect of a policy on income inequality.

2.3 The Welfarist Approach

The welfarist (or social welfare) approach to policy evaluation instead begins by positing the existence of a social welfare function that maps the vector of agents' welfare levels into a single

[12] In other words, the welfare gains in (4) are independent of the particular cardinal utility functions that are chosen to represent the ordinal preferences of individuals.

real number. It is customary to express this function as an integral of concave transformations of agents' *actual* (and not potential) disposable incomes (and thus consumption levels):[13]

$$V = \int u(r^d_\varphi)\mathrm{d}H_\varphi, \tag{5}$$

where $u'(\cdot) > 0$ and $u''(\cdot) \leq 0$. There are at least two possible justifications for specifying $u(\cdot)$ as a concave function. First, given two distributions of *disposable* income with the same mean, one would expect society to prefer the one with the lowest dispersion or inequality (c.f. Atkinson 1970), with the concavity of $u(\cdot)$ reflecting inequality aversion on the part of the social planner. It is important to emphasize that, under the plausible assumption that agents' preferences feature diminishing marginal utility of income, inequality aversion is completely consistent with a utilitarian social planner that simply seeks to maximize the sum of agent's utilities. A second justification for the concavity of $u(\cdot)$ is that it might capture risk aversion on the part of ex-ante identical individuals in some sort of "original position" attempting to compute the individual welfare implications of changes in the environment behind a "veil of ignorance" (c.f., Vickrey 1945, Harsanyi 1953).

To fix ideas, we shall follow Atkinson (1970) and consider a constant-elasticity function:

$$u(r^d_\varphi) = \frac{\left(r^d_\varphi\right)^{1-\rho} - 1}{1-\rho}, \tag{6}$$

where $\rho \geq 0$ can be interpreted as reflecting a constant degree of inequality aversion on the part of the social planner or a constant degree of of risk aversion on the part of agents in the original position (or a combination of both). In order to express social welfare changes in terms of equivalent changes in aggregate consumption, it will further prove convenient to consider the simple monotonic transformation

$$W = \left[1 + (1-\rho)V\right]^{1/(1-\rho)} \tag{7}$$

of the social welfare function in (5). With this transformation, social welfare can be expressed as a multiplicatively separable function of aggregate real income R and a term Δ, which is inversely related to the level of inequality underlying the distribution of disposable income:

$$W = \Delta \cdot R, \tag{8}$$

where

$$\Delta = \Delta(F^d_r, \rho) = \frac{\left[\mathbb{E}\left(r^d_\varphi\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}}{\mathbb{E}r^d_\varphi}. \tag{9}$$

The term Δ, which we will refer to as a *welfarist inequality correction*, corresponds *exactly* to one

[13] More generally, the social welfare function is represented by a vector (density) of utility weights which the planner uses to aggregate individual welfare levels.

minus the Atkinson (1970) index, a widely used measure of inequality. By Jensen's inequality we have that $\Delta \leq 1$, with $\Delta = 1$ only if either there is no inequality aversion ($\rho = 0$) or if the distribution of disposable income F_r^d is fully egalitarian (has zero dispersion). Furthermore, Δ tends to be lower the higher is the level of inequality in the distribution of income F_r^d or the higher is inequality aversion ρ. To be more precise, while Δ is invariant to proportional shifts of the income distribution (i.e., when all income levels are scaled by the same constant), Δ is reduced by mean-preserving spreads of the distribution of disposable income (c.f., Atkinson 1970). And holding constant the distribution of disposable income, F_r^d, the higher is the degree of inequality (or risk) aversion ρ, the greater is the correction (smaller Δ).[14] As we will discuss below, for certain standard distributions, it is also possible to relate Δ to the Gini coefficient associated with F_r^d.

The expression for welfare (8) immediately implies that the percentage welfare gains from a policy are given by:

$$\mu^W = \frac{W' - W}{W} = (1 + \mu^R)\frac{\Delta'}{\Delta} - 1, \tag{10}$$

where μ^R is the growth rate of real income as defined in (4) and $\Delta' = \Delta(F_r^{d\prime}, \rho)$ corresponds to the correction term under the new income distribution. Thus in the absence of any effect of trade on inequality as captured by Δ, the change in welfare corresponds exactly to the percentage change in real income μ^R, as in the Kaldor-Hicks compensation principle approach in (4). Nevertheless, if trade increases inequality, then welfare increases by less than μ^R, that is $\mu^W < \mu^R = \mu^{KH}$, with a larger downward correction the larger ρ is and, of course, the larger the increase in inequality. The particularly size of the correction can be easily computed with data (real or counterfactual) about the distribution of disposable income before and after the policy.

As mentioned above, an advantage to using the function W in (7) instead of any other monotonic transformations of V in (5) is that μ^W also corresponds to the consumption-equivalent change in social welfare of moving from F_r^d to $F_r^{d\prime}$. More specifically, if one were to compute the percentage change in all agents' consumption or disposable income that would make society indifferent between F_r^d and $F_r^{d\prime}$ the answer one would get would be $\mu^C = (1 + \mu^R)\frac{\Delta'}{\Delta} - 1$ regardless of whether social welfare is measured in terms of the function V or of any monotonic transformation of V (including W).[15]

[14] This can again be established invoking Jensen's inequality:

$$\Delta(F, \rho') = \frac{\left[\mathbb{E}r^{1-\rho'}\right]^{\frac{1}{1-\rho'}}}{\mathbb{E}r} = \Delta(F; \rho) \cdot \left(\frac{[\mathbb{E}x^{\upsilon}]^{1/\upsilon}}{\mathbb{E}x}\right)^{\frac{1}{1-\rho}} < \Delta(F; \rho),$$

where $x \equiv r^{1-\rho}$ and $\upsilon \equiv (1 - \rho')/(1 - \rho) \in (0, 1)$ for $\rho' > \rho$.

[15] To see this, note that for any function nondecreasing function f,

$$f\left(\int \frac{\left(\left(1 + \mu^C\right) c_\varphi\right)^{1-\rho} - 1}{1 - \rho} \mathrm{d}H_\varphi\right) = f\left(\int \frac{\left(c'_\varphi\right)^{1-\rho} - 1}{1 - \rho} \mathrm{d}H_\varphi\right)$$

2.4 The Costly-Redistribution Approach

Despite its widespread use in the optimal policy literature, the welfarist approach remains controversial. This is in large part due to the sensitivity of its prescriptions to the value of certain parameters, such as the degree of inequality aversion (or, more generally, the social marginal weights assigned to agents with different income), that are difficult to measure and over which people have vastly different ethical views. For this reason, we shall now consider a third alternative approach that is more akin to the Kaldor-Hicks compensation principle, but that explicitly models the fact that redistribution is costly, and the costs of redistribution are increasing in the extent of economic inequality. The welfare correction in this case quantifies the forgone gains in real income due to the costly redistribution mechanism put in place by society to reduce income inequality.

For this purpose, we return to our previous example but suppose now that lump-sum transfers are not feasible (i.e., $T_\varphi \equiv 0$) and redistribution has to work through the income tax system. Above, we have introduced a general nonlinear income tax $\tau(r_\varphi)$, but we will now focus on the particular case, used among others by Feldstein (1973) and Benabou (2002), in which we have

$$r_\varphi^d = \big[1 - \tau(r_\varphi)\big] r_\varphi = k r_\varphi^{1-\phi}, \tag{11}$$

for some constant k which can be again set to ensure that the government budget is balanced. Average net-of-tax rates thus decrease in reported income at a constant rate ϕ, with this parameter governing the degree of progressivity of the tax system. When $\phi = 0$, all agents face the same tax rate k and there is no redistribution from the rich to the poor; in fact, with budget balance there is no redistribution whatsoever. When $\phi = 1$, (11) implies that all agents end up with the same after-tax income and thus redistribution is full and eliminates inequality.

The specification in equation (11) may seem quite ad hoc and unlikely to provide a valid approximation to the complicated tax and transfer systems employed in modern economies. Nevertheless, its implied log-linear relationship between market income and income after taxes and transfers fits U.S. data remarkably well, as we will illustrate in more detail in section 4 (see also Heathcote, Storesletten, and Violante 2014 and Guner, Kaygusuz, and Ventura 2014).

A larger degree of progressivity tends to compress the after-tax income distribution, but it implies that rich people face disproportionately larger marginal tax rates. More specifically, the marginal tax rate implied by (11) is given by $\tau^m(r_\varphi) = 1 - k\,(1-\phi)\, r_\varphi^{-\phi}$ and thus rises with both the degree of tax progressivity ϕ as well as the level of income r_φ. To the extent that higher marginal tax rates generate behavioral responses of agents that lead them to generate less income than they would under a lower marginal tax rate, the increased redistribution brought about by a higher degree of progressivity will generate costs. To capture this costly aspect of redistribution in a simple though fairly standard way, we posit the existence of a a positive,

only if $1 + \mu^C = \Big[\mathbb{E}\big(c'_\varphi\big)^{1-\rho}\Big]^{\frac{1}{1-\rho}} / \Big[\mathbb{E}\big(c_\varphi\big)^{1-\rho}\Big]^{\frac{1}{1-\rho}} = \Delta' R' / (\Delta R) = (1+\mu^R)\Delta'/\Delta$.

constant elasticity of taxable (realized) income to the net-of-tax rate:

$$\varepsilon \equiv \frac{\partial \log r_{\varphi}}{\partial \log(1-\tau^{m}(r_{\varphi}))} \geq 0, \tag{12}$$

where $\tau^m(r_\varphi)$ is the marginal tax rate faced by agents with income r_φ.

The combination of a progressive tax system of the type in (11) and a positive elasticity of taxable income ε makes redistribution from rich people to poor people costly, thereby motivating an alternative correction to the standard measures of the welfare effects of a policy. More specifically, one can manipulate equations (11) and (12) and impose budget balance, to obtain (in parallel with (8)):

$$R = \Theta \cdot \tilde{R}, \tag{13}$$

where $\tilde{R}$ is the *potential* income in the absence of progressive redistribution ($\phi = 0$) or behavioral responses to taxation ($\varepsilon = 0$), and

$$\Theta = \Theta(F_r, \phi, \varepsilon) = (1-\phi)^{\varepsilon} \frac{\left(\mathbb{E}r_{\varphi}\right)^{1+\varepsilon}}{\left(\mathbb{E}r_{\varphi}^{1-\phi}\right)^{\varepsilon} \cdot \left(\mathbb{E}r_{\varphi}^{1+\varepsilon\phi}\right)} \tag{14}$$

is a term we refer to as our *costly-redistribution inequality correction.*

Although perhaps not immediate from inspection of (14), Hölder's inequality implies that the second term is no larger than 1, which in turn implies $\Theta \leq 1$. Furthermore, $\Theta = 1$ if and only if the tax-transfer system features zero progressivity ($\phi = 0$) or if the elasticity of taxable income is zero ($\varepsilon = 0$). Thus, when $\phi > 0$ and $\varepsilon > 0$, real income is lower than it would be in the absence of distortionary redistribution.[16] More importantly for our purposes, the term Θ is highest whenever the income distribution is perfectly egalitarian and it tends to be lower the more unequal is the distribution of income.[17] For instance, when considering two distributions of income F_r and F'_r, it is easy to show that $\Theta(F'_r, \phi, \varepsilon) < \Theta(F_r, \phi, \varepsilon)$ when F'_r is a mean preserving multiplicative spread of F_r.[18] Conversely, Θ is invariant to proportional shifts of the income distribution (i.e., when all income levels increase proportionately). In analogy to the Atkinson index, one can interpret Θ as a welfare-relevant measure of inequality, and for certain standard distributions, we will show below that Θ can be related to the Gini coefficient associated with F_r.

We are now ready to revisit our initial question of how should society evaluate the welfare implications of the move from F_r to F'_r. Even when one adheres to a welfare criterion, such as the Kaldor-Hicks principle, that judges policies based on their implications for real income

[16] In fact, Θ is strictly decreasing in ε and ϕ for all primitive distributions of potential output $\tilde{R}$ we have experimented with, but we have not been able to prove the result for any general distribution of $\tilde{R}$.

[17] Note that Θ is less than one even when all agents share the same income and thus there is no redistribution in equilibrium. The reason for this is that when considering an off-the-equilibrium path deviation that would increase an agent's income, this agent understands that it will be taxed as a result of that deviation.

[18] The distribution F'_r is a mean preserving multiplicative spread of F_r whenever there exists a random variable θ independent of the original income r such that $r' = (1+\theta)\, r$ with $\mathbb{E}(\theta) = 0$.

growth, with costly redistribution society will take into account the effects of the policy on higher moments of the income distribution. The reason for this is that, in the absence of lump-sum transfers, those higher moments shape the determination of mean disposable income. More precisely, building on (13) we can express the average real income gains of the policy as

$$\mu^R = \frac{R' - R}{R} = (1 + \tilde{\mu}^R)\frac{\Theta'}{\Theta} - 1, \tag{15}$$

where $\tilde{\mu}^R \equiv \frac{\tilde{R}' - \tilde{R}}{\tilde{R}}$ measures the real income gains in disposable income in the absence of costly redistribution. Whenever the policy has no measurable impact on Θ, the change in welfare corresponds exactly to real income growth of an hypthetical *Kaldor-Hicks economy* that could use lump-sum transfers for redistribution purposes. Such an equivalence would hold when the policy increases the incomes of all agents proportionately (and ϕ and ε do not change). If however the policy increases inequality and thereby lowers Θ, the implied change in aggregate income will be strictly lower than in the case in which inequality had remained unaffected. To summarize, the costly redistribution correction measures the forgone gains in real income due to the interaction between the increased inequality and the progressivity of the tax schedule.

2.5 Two Parametric Examples

We next consider two common parametric examples to further illustrate the properties of the correction terms. Specifically, we consider the cases in which the distribution of market income is either lognormal or Pareto. Even though neither of these two distributions matches observed incomes perfectly, these are the two most popular distributions in the literature offering a reasonably good fit of the data.[19] In both cases, we postulate a distribution for (before-tax) market incomes r, and calculate the (after-tax) disposable income according to (11) for a given value of ϕ, that is $r^d = kr^{1-\phi}$.[20]

Lognormal distribution When market incomes are distributed lognormally with a mean parameter μ and a variance parameter σ^2, the after-tax disposable income is also distributed log-normally with variance parameter $(1-\phi)^2\sigma^2$. In this case, it is straightforward to show that the welfarist and costly-redistribution corrections are equal to:

$$\Delta = \Delta\left(\sigma; \rho, \phi\right) = \exp\left\{-\rho(1-\phi)^2\frac{\sigma^2}{2}\right\}, \tag{16}$$

$$\Theta = \Theta(\sigma; \varepsilon, \phi) = (1-\phi)^{\varepsilon}\exp\left\{-\varepsilon(1+\varepsilon)\phi^2\frac{\sigma^2}{2}\right\}. \tag{17}$$

[19] It is often argued that the Pareto distribution provides a good fit of the top percentiles of the income distribution, while the bottom 80–90% of incomes are better approximated by a lognormal distribution. It is straightforward to develop analogous formulas for mixtures of lognormal and Pareto distributions, such as the case of the double Pareto-lognormal distribution, which offers a better fit of the data.

[20] The value of intercept k is inconsequential for any of the calculations.

Thus, in both cases, the size of the corrections is increasing in the single parameter σ^2 governing the inequality of income. Furthermore, the effect of inequality on the welfarist correction is magnified by a higher inequality aversion ρ and moderated by the extent of tax progressivity ϕ. In contrast, the effect of inequality on the costly redistribution correction is magnified by a higher degree of progressivity ϕ, and also by a higher taxable income elasticity ε. Note also that because the Gini coefficient associated with a lognormal distribution is simply given by $G = 2\Phi\left(\sigma/\sqrt{2}\right) - 1$, it is straightforward to re-express (16) and (17) as functions of the Gini coefficient rather than σ^2.

Pareto distribution When market incomes are distributed Pareto with shape parameter α, the after-tax disposable income is distributed Pareto with shape parameter $\alpha/(1-\phi)$, with a lower value of α corresponding to greater inequality.[21] In this case, we obtain:

$$\Delta = \Delta(\alpha;\rho,\phi) = \frac{\alpha-(1-\phi)}{\alpha}\left[\frac{\alpha}{\alpha-(1-\rho)(1-\phi)}\right]^{\frac{1}{1-\rho}}, \tag{18}$$

$$\Theta = \Theta(\alpha;\varepsilon,\phi) = (1-\phi)^{\varepsilon}\left[1-\frac{1-\phi}{\alpha}\right]^{\varepsilon}\left[1-\frac{1+\varepsilon\phi}{\alpha}\right]. \tag{19}$$

Straightforward differentiation demonstrates that both Δ and Θ are increasing in the shape parameter α, and thus higher inequality levels (smaller α) are associated with larger inequality corrections (smaller Δ and Θ). Because the Gini coefficient of a Pareto distribution is simply given by $G = 1/(2\alpha-1)$, it is again trivial to re-express (17) and (19) as functions of the Gini coefficient rather than α. Furthermore, it can also be easily verified that Δ is again decreasing in inequality aversion ρ and increasing in the degree of tax progressivity ϕ, while Θ is instead decreasing in ϕ and also decreases in the taxable income elasticity ε.

These two parametric examples illustrate that, on account of both the welfarist and costly-redistribution corrections, social welfare is negatively impacted by higher (or increasing) levels of inequality of the income distribution. Nonetheless, the two measures behave differently with regards to a key tool available to governments to correct such inequality, namely progressive taxation. While the welfarist correction favors greater redistribution, the costly-redistribution correction is magnified the greater is the degree of tax progressivity. This raises the issue of what might be the optimal degree of tax progressivity resulting from a government program which takes into account both the degree of inequality aversion of society and the behavioral responses of agents to taxation. To further study this relationship, and to better understand how these two corrections shape social welfare, we need a fully specified model, in which the income distribution is endogenized and in which the response of agents to taxation is properly modelled and taken into account in computing social welfare. We turn to this task in the next section.

[21] Specifically, the cdf of the pre-tax market income in this case is $F_r = 1 - (r_{\min}/r)^{\alpha}$.

3 Inequality and Welfare in a Constant-Elasticity Model

We next develop a simple general equilibrium framework, which specifies how the ability of individuals and their labor supply decisions translate in equilibrium earnings and welfare levels given the tax system in place. In light of our choices of functional forms, we refer to our model as the constant-elasticity model.

The model features four constant elasticity parameters, which we introduce below: (i) a constant Frisch elasticity of labor supply $(1/(\gamma-1))$; (ii) a constant elasticity of substitution between the labor services (or tasks) performed by different agents in society $(1/(1-\beta))$; (iii) a constant degree of tax progressivity (ϕ); and (iv) a constant social inequality aversion (ρ). This constant-elasticity structure results in a tractable general equilibrium characterization, which is particularly useful to illustrate the welfare corrections terms that are applicable more generally. We should emphasize, however, that our model will place little structure on the underlying primitive distribution of ability, and can thus flexibly accommodate *any* equilibrium distribution of income one may choose to calibrate the model to. Let us next introduce the key ingredients of the model more formally.

3.1 Preferences, Technology and Individual Behavior

Consider for now a closed economy inhabited by a continuum of agents with linear GHH preferences (c.f., Greenwood, Hercowitz, and Huffman 1988) over the consumption of an aggregate good c and labor ℓ:

$$u(c,\ell) = c - \frac{1}{\gamma}\ell^{\gamma}. \tag{20}$$

The parameter $\gamma \geq 1$ controls the Frisch elasticity of labor supply, which is given by $1/(\gamma-1)$ and is decreasing in γ. In the presence of elastically supplied labor, theoretically-grounded measures of welfare need to correct income for the disutility costs of producing it, an issue we ignored in section 2. This utility specification results in no income effects on labor supply and is often adopted in the optimal taxation literature.

Each individual produces output $y = \varphi\ell$ of his own variety of a task (or intermediate good) where, as in section 2, φ is individual ability and is distributed according to H_φ. The tasks performed by different agents are imperfect substitutes and are combined in the production of the aggregate consumption (final) good according to

$$Q = \left(\int y_\varphi^\beta \mathrm{d}H_\varphi\right)^{1/\beta},$$

where $\beta \in (0,1]$ is a parameter that controls the elasticity of substitution $1/(1-\beta)$ across tasks. In the limiting case of $\beta = 1$, the individual tasks become perfect substitutes, and the model turns into a special case of a neoclassical Mirrlees (1971) economy. Imperfect substitutability becomes essential when we introduce an explicit model of international trade in section 5, but for the qualitative implications of this section whether $\beta = 1$ or $\beta < 1$ is not important.

Under the above assumptions, the market (real) earnings of an individuals supplying y units of his task to the market are given by:[22]

$$r = Q^{1-\beta} y^{\beta}. \tag{21}$$

Notice that when $\beta < 1$, the demand for each individual task is increasing in aggregate income

$$Q = R = \int r_{\varphi} \mathrm{d}H_{\varphi},$$

yet the agents face decreasing demand schedules and as a result their revenues are concave in their own output. When $\beta = 1$, the individual revenues are simply $r = y$, and thus are only a function of their ability and labor supply decisions.

Individual consumption equals after-tax income, $c = r^d = [1 - \tau(r)]r$. As in section 2, we assume that the tax-transfer system is well approximated by equation (11), where the parameter ϕ governs tax progressivity and the parameter k controls the average tax rate across agents. The government uses collected taxes for redistribution and to finance exogenous government spending G, and runs a balanced budget. In other words, the total income of the economy equals the sum of total private consumption (aggregate disposable income) and government spending, so $Q = \int r_{\varphi}^{d} \mathrm{d}H_{\varphi} + G$. We further assume that government spending is a fraction g of GDP, i.e. $G = gQ$, and it does not directly affect the individual utilities in (20). Under these circumstances, we can rewrite the government budget balance as:

$$k \int r_{\varphi}^{1-\phi} \mathrm{d}H_{\varphi} = (1-g)Q, \tag{22}$$

which defines a relationship between k and g given the tax schedule progressivity ϕ. In other words, given the exogenous share of government spending g, there exists a unique average tax parameter k which balances the government budget for any given level of tax progressivity ϕ.

Individuals maximize utility (20) by choosing their labor supply and consuming the resulting disposable income, a program that combining (11) and (21) we can write as:

$$u_{\varphi} = \max_{\ell} \left\{ k \left[Q^{1-\beta} (\varphi \ell)^{\beta} \right]^{1-\phi} - \frac{1}{\gamma} \ell^{\gamma} \right\}.$$

[22] The demand for an individual task variety is given by $q = Q(p/P)^{-\frac{1}{1-\beta}}$, were p is the price of the variety and $P = \left(\int p_{\varphi}^{-\frac{\beta}{1-\beta}} \mathrm{d}H_{\varphi} \right)^{(1-\beta)/\beta}$ is the price of the final good. We normalize $P = 1$ so that all nominal quantities in the economy are in terms of the final good, and thus are in real terms as well. Under these circumstances, task revenues are $r = pq = Q^{1-\beta} y^{\beta}$, where we have substituted the market clearing condition $q = y$.

The solution for equilibrium revenues and utilities is given by:

$$r_\varphi = \Big[\beta(1-\phi)k\Big]^{\frac{\varepsilon}{1+\varepsilon\phi}} \Big[Q^{1-\beta}\varphi^\beta\Big]^{\frac{1+\varepsilon}{1+\varepsilon\phi}}, \tag{23}$$

$$u_\varphi = \frac{1+\varepsilon\phi}{1+\varepsilon} k r_\varphi^{1-\phi}, \tag{24}$$

where we have made use of the following auxiliary constant:

$$\varepsilon \equiv \frac{\beta}{\gamma-\beta},$$

which also equals the overall elasticity of taxable income to changes in marginal tax rates, as previously defined in (12).[23] When tasks are perfectly substitutable ($\beta = 1$), this elasticity ε coincides with the Frisch elasticity of labor supply $1/(\gamma-1)$. With imperfect substitutability in tasks ($\beta < 1$), this elasticity is reduced by the downward pressure of increased output on prices.

Equations (23)–(24) show how individual ability translates in equilibrium into market revenue and individual utility, which is proportional in this model to the after-tax income, as the utility cost of labor effort is proportional to disposable income under the optimal allocation. Equilibrium revenues are a power transformation of underlying individual abilities, with the power increasing in the elasticity parameters ε and β, and decreasing in the progressivity of taxation ϕ. The tax progressivity not only reduces the dispersion of after-tax incomes and utilities, but also compresses the distribution of pre-tax market revenues as it has a disincentive effect on labor supply, which is particularly acute for high-ability individuals.

3.2 Aggregate Income and Social Welfare

The characterization of equilibrium revenues and utilities relies on two endogenous aggregate variables, k and Q. The closed-form solutions for these variables are provided in Appendix A.1, where we show that aggregate income (GDP) of the economy can be expressed as

$$Q = \Theta^\kappa \tilde{Q}, \tag{25}$$

where $\Theta < 1$ is the same costly-redistribution correction term introduced above in equation (14), and where

$$\tilde{Q} = [\beta(1-g)]^{\kappa\varepsilon} \left(\int \varphi^{\beta(1+\varepsilon)} \mathrm{d}H_\varphi \right)^\kappa$$

is is the counterfactual (potential) aggregate real GDP with a flat tax schedule characterized by $\phi = 0$ and $k = 1-g$ to finance government spending. In these expressions, the auxiliary parameter κ

$$\kappa \equiv \frac{1}{1-(1-\beta)(1+\varepsilon)} \geq 1$$

[23] To see this, remember that the marginal tax rate associated with (11) is given by $\tau^m(r_\varphi) = 1 - k(1-\phi) r_\varphi^{-\phi}$. Plugging this marginal tax rate into (23) and simplifying delivers $r_\varphi = (\beta(1-\tau^m(r_\varphi)))^\varepsilon \left(Q^{1-\beta}\varphi^\beta\right)^{1+\varepsilon}$.

captures an amplification effect associated with the aggregate demand externality (or love-for-variety effect) stemming from the imperfect substitutability of tasks.[24]

Several comments are in order. First, note that aggregate real income in equation (25) depends on the costly redistribution correction term Θ and on potential real income, which is a simple function of the primitive fundamentals of the model, namely the ratio g of government spending to GDP, the distribution of ability H_φ, the task-substitutability parameter β, and the Frisch elasticity of labor supply γ (which together with β determine the elasticity of taxable income ε). Second, in the absence of progressive taxation, remember that $\phi = 0$ and $\Theta = 1$, in which case realized and potential GDP coincide. Third, note that (25) is the counterpart to equation (13) in section 2, with the only difference being that now the output loss $Q/\tilde{Q}$ is amplified by the aggregate demand externality operating in the model whenever $\beta < 1$ (and thus $\kappa > 1$).

So far, we have focused on a discussion of the determination of aggregate real income in the model. Equation (24) provides the utility level associated with the disposable income and labor supply decisions of an individual with ability φ. In order to aggregate these utility levels into a measure of social welfare, we adopt the welfarist approach and express social welfare as

$$W = \left(\int u_\varphi^{1-\rho} \mathrm{d}H_\varphi \right)^{\frac{1}{1-\rho}}, \tag{26}$$

which is the exact counterpart to our earlier equation (7). Note that the risk aversion parameter $\rho \geq 0$ is inconsequential for the choices of individuals in this static model, and only matters for cross-individual welfare comparisons. Therefore, ρ can be viewed as either the property of individual utilities of the agents or the social inequality aversion parameter. When $\rho = 0$, social welfare corresponds to the simple integral of utility levels across individuals, which remember are linear in real disposable income.

This completes the description of the model environment, and we can now characterize equilibrium welfare W given the solution for equilibrium utilities in (24). We do this in two steps. First, we characterize:

Proposition 1 *The welfare in the economy with zero tax progressivity ($\phi = 0$) and no inequality aversion ($\rho = 0$) is given by:*

$$\tilde{W} = \frac{1-g}{1+\varepsilon} \times \tilde{Q}. \tag{27}$$

Note that welfare in this case is closely related to real GDP, since the cost of producing GDP is proportional to output, and is reflected in the discount in front of $\tilde{Q}$ in (27). The numerator $1 - g$ reflects the share of the output of the economy that goes towards the provision

[24] Note that when $\beta = 1$, $\kappa = 1$, but κ is otherwise increasing in ε and decreasing in β. As is clear from the definition of κ, we need to impose the stability condition $(1-\beta)(1+\varepsilon) < 1$, which is satisfied if ε is not too large or β is not too small.

of the public good, which is financed via a proportional tax schedule $k = 1 - g$ when $\phi = 0$.[25] The denominator $1 + \varepsilon$ reflects the disutility costs of producing the output $\tilde{Q}$. The immediate corollary of Proposition 1 is that in the absence of inequality aversion or tax progressivity, changes in welfare can be measured using the growth rate of GDP

$$\frac{\tilde{W}' - \tilde{W}}{\tilde{W}} = \tilde{\mu}^R = \frac{\tilde{Q}' - \tilde{Q}}{\tilde{Q}},$$

provided that the elasticity ε and the share of public spending g stay constant over time.

This result illustrates that a criterion analogous to the Kaldor-Hicks prescription in (4) may still apply in more general settings, even when lump-sum taxes are unavailable and average taxes are positive, provided that society does not care about inequality and does not use a progressive tax system to address it.

Nevertheless, outside this limiting case with $\phi = \rho = 0$, real income growth is no longer an appropriate measure of welfare gains, and instead we have:

Proposition 2 *Outside the case $\phi = \rho = 0$, social welfare can be written as:*

$$W = \Delta \times (1 + \varepsilon\phi)\Theta^{\kappa} \times \tilde{W}, \tag{28}$$

where Δ and Θ are the welfarist and the costly-redistribution corrections defined in (9) and (14), respectively.

Note that the two inequality correction terms that were introduced earlier in section 2 appear explicitly in the welfare expression in (28). The two corrections clearly complement each other. Indeed, realized welfare W equals potential welfare $\tilde{W}$ discounted in turn by the two correction terms, which are both less than 1 (see our discussion in section 2).

The effect of inequality aversion on social welfare is captured by the exact same term Δ derived in section 2, and is closely related to the Atkinson inequality measure. The effect of costly redistribution is instead slightly modified relative to our previous derivations in section 2. First, and as already discussed above, the presence of aggregate demand externalities magnify the loss of output associated with distortionary taxation, and $\Theta < 1$ is now raised to a power $\kappa > 1$. Second, note that (28) incorporates a new term $(1 + \varepsilon\phi)$ which captures the fact that lower output comes along with a lower disutility of labor effort, which other things equal, raises welfare. Despite the presence of this term, the overall effect of distortionary taxation captured by the term $(1 + \varepsilon\phi)\Theta^{\kappa}$ inherits the same properties of the term Θ described in section 2. In particular, this term can be split into the product of $(1 + \varepsilon\phi)(1 - \phi)^{\kappa\varepsilon}$ and $\left(\mathbb{E}r_{\varphi}\right)^{\kappa(1+\varepsilon)} / \left[\left(\mathbb{E}r_{\varphi}^{1-\phi}\right)^{\varepsilon} \cdot \left(\mathbb{E}r_{\varphi}^{1+\varepsilon\phi}\right)\right]$, with both of these terms being strictly less than 1 when $\phi > 0$. The first term captures the utility loss from taxation in the absence of inequality (and continues to be decreasing in ε and

[25] Remember that potential output is given by $\tilde{Q} = [\beta(1-g)]^{\kappa\varepsilon} \left(\int \varphi^{\beta(1+\varepsilon)} \mathrm{d}H_{\varphi}\right)^{\kappa}$, and hence is itself decreasing in $k = 1 - g$ due to the disincentive effect of the average tax rate g even in the absence of progressivity of taxation.

ϕ), while the second term captures the additional loss due to the interaction of inequality with a progressive income tax schedule.

Equation (28) also emphasizes the tradeoff faced by a benevolent government (maximizing social welfare W) in deciding on the optimal progressivity of the tax schedule ϕ. Recall from our earlier analysis that the welfarist correction Δ is increasing in ϕ, while the costly-redistribution correction (and also the full correction term $(1 + \varepsilon\phi)\Theta^{\kappa}$) is decreasing in ϕ. Therefore, the government needs to balance these two conflicting forces. Intuitively, a greater degree of tax progressivity allows to attain greater income equality (favored by the Δ term), but comes at the expense of a greater income and utility loss (diminishing both Θ and $(1+\varepsilon\phi)\Theta^{\kappa}$). In the context of our two parametric examples in section 2, one can further show that the optimal choice of ϕ is increasing in the inequality aversion and in the dispersion of incomes (due to dispersed abilities in the population of agents) and is decreasing in the elasticity of taxable income captured by parameter ε. Although this is not a central theme of this paper, we will briefly return to the discussion of the optimal choice of ϕ in the context of our trade model in section 5.

To summarize, we have shown that social welfare can be expressed as the product of (i) potential welfare in a hypothetical (Kaldor-Hicks) world with non-distortionary taxation, (ii) our welfarist correction, and (iii) a (modified) costly-redistribution correction. The presence of these two correction terms introduces a tradeoff for the policy maker when deciding on the optimal degree of tax progressivity. Independently of the amount of redistribution that society chooses to implement, these two corrections reduce welfare disproportionately more in environments with higher economic inequality. In the model developed so far such increases in inequality can only originate from increases in the dispersion of ability across agents (perhaps due to skill-biased technological change) or from increases in the primitive parameters β and γ. In section 5, we will show however that trade integration can generate qualitatively similar effects. Before doing so, and to build some intuition for our quantitative analysis, in the next subsection we provide a preliminary look at U.S. data through the prism of our closed-economy model.

4 A Preliminary Look at the Data

Although the main focus of this paper is to apply the tools developed above to the study of the welfare gains from trade integration, in this section we briefly illustrate how the corrections developed above can be readily applied to existing data to interpret recent trends in inequality and their implications, and also to perform simple counterfactuals.

More specifically, in this section we decompose social welfare in the U.S. over the period 1979-2007 according to equation (28), thus backing out the size and evolution of the welfarist and inequality correction terms. We then use this expression to compute the income and welfare levels that would have attained in counterfactual scenarios in which U.S. income inequality had not increased as much as it did over this period.

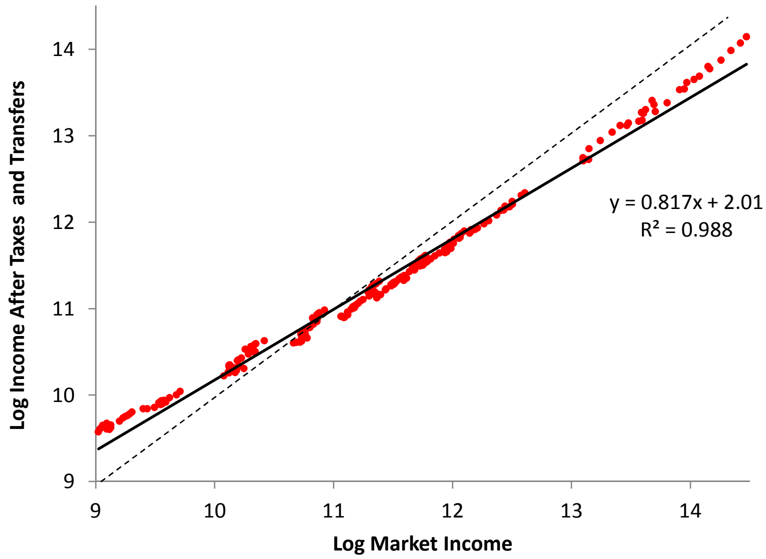

Figure 2: Progressivity

4.1 Calibration

In order to put the above model to work, it is necessary to calibrate its key parameters. Remember that the primitive parameters of the model are the Frish elasticity parameter γ, the task substitutability parameter β, the degree of tax progressivity ϕ, the share of government spending in GDP g, the distribution of ability in society H_{φ}, and the inequality aversion parameter ρ. Some of these objects, such as the distribution of agents' ability, are notoriously difficult to calibrate. Fortunately, we shall see that, for our purposes, it will suffice to calibrate (i) the degree of tax progressivity of income ϕ, (ii) the distribution of market income r_{φ}, (iii) the elasticity of taxable income $\varepsilon = \beta/(\gamma - \beta)$, and (iv) the degree of substitutability between the tasks provided by different workers, as captured by β. Let us discuss each of these in turn.

Consider first our modeling of the tax-transfer system in equation (11). This specification may seem quite ad hoc, but the log-linear relationship between market income and income after taxes and transfers implied by equation (11) fits the data remarkably well. This is illustrated in Figure 2 using CBO data for eight percentiles of the income distribution for the period 1979-2010.[26] The best log-linear fit of the data achieves a remarkable R-squared 0.988.

The implied average degree of progressivity ϕ over the period is equal to 0.183, although when estimating progressivity year by year, it is clear that it is significantly lower in recent years than at the beginning of the period (see Figure 3). The log-linear relationship between

[26] In particular, Figure 2 depicts market income and income after taxes and transfers for the first four quintiles of the income distribution, as well as the 81st to 90th percentiles, the 91st to 95th percentiles, the 96th to 99th percentiles, and the top 1 percent, for the period 1970-2007. Market income consists of labor income, business income, capital gains (profits realized from the sale of assets), capital income (excluding capital gains), income received in retirement for past services, and other sources of income. Government transfers include cash payments and in-kind benefits from social insurance and other government assistance programs. Federal tax liabilities include individual income taxes, social insurance or payroll taxes, excise taxes, and corporate income taxes.

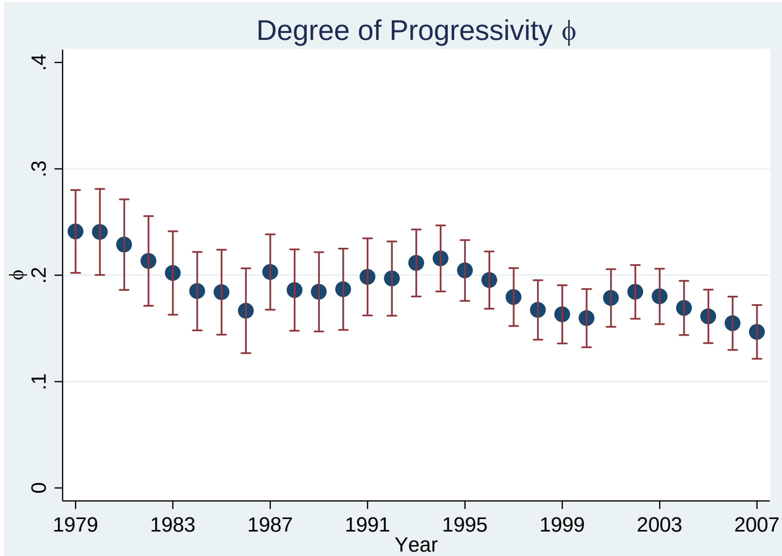

Figure 3: Progressivity Over Time

market income and after-government income is a very good approximation in *all years*, with the R-squared of the regressions never falling below 0.98. We will thus use these yearly estimates of ϕ to calibrate the time path of progressivity over the period 1979-2007.[27]

We next turn to our calibration of the distribution of market income. Because our quantitative results are pretty sensitive to fine features of the income distribution (such as the shape of its right tail) we need to resort to richer information on the U.S. income distribution than that provided by the CBO data we used to calibrate ϕ. For this reason, we employ the public use samples of U.S. Federal Individual Income Tax returns available from the NBER. These amounts to approximately 3.5 million anonymized tax returns (about 150,000 per year) over the period 1979-2007. Contrary to survey-based sources of income distribution data, the NBER IRS data is more likely to provide an accurate picture of the income of particularly rich taxpayers. To ensure the representativeness of the sample, we further apply the sampling weights provided by the NBER. We map before-tax income r_φ in the model to adjusted gross income (AGI) in line 37 of IRS Form 1040 and restrict the sample to returns with a strictly positive AGI. Together with our yearly estimates of ϕ, it is then possible to estimate disposable income r^d_φ up to a constant (k) which is irrelevant for the computation of our two inequality corrections.[28]

In the left panel of Figure 4, we plot the cumulative distribution of income for the year 2007, and for comparison we also plot the best lognormal fit of the distribution. As can be seen,

[27]Heathcote, Storesletten, and Violante (2014) find an equally remarkable fit of this log-linear relationship with data from the Panel Study of Income Dynamics (PSID) for survey years 2000, 2002, 2004, and 2006, with an implied value $\phi = 0.151$, which is very much consistent with the estimates we obtain from CBO during the 2000-06 period.

[28]We could have in principle obtained disposable income by using the NBER TAXSIM program which calculates federal and state income tax liabilities from market income data. Nevertheless, this would have missed government transfers which are essential for understanding why disposable income is higher than market income for low-income individuals.

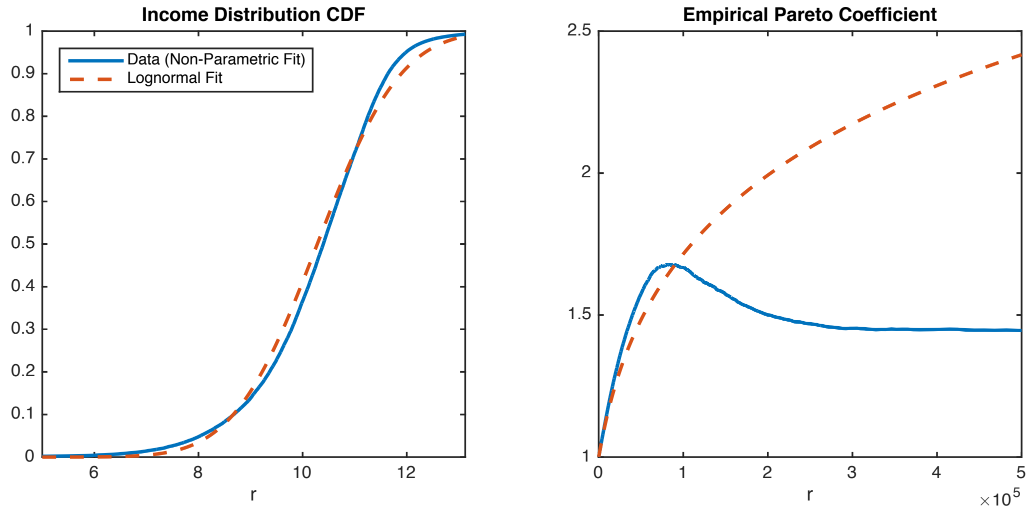

Figure 4: U.S. distribution of reported income (2007)

the empirical distribution of income is pretty well approximated by a lognormal distribution. Nevertheless, the right panel of Figure 4 demonstrates that the lognormal fit is really poor for relatively high incomes, and in that range, a Pareto distribution appears to fit the data much better. More specifically, following Saez (2001), this right panel plots the ratio $\mathbb{E}\left(r_{\varphi} \mid r_{\varphi} > r\right)/r$ for different values of income r. Consistently with the properties of a Pareto distribution, for large enough income levels this ratio is relatively flat (at a value close to 1.5), whereas a lognormal distribution would predict this term to rise with income. As we shall see in our trade application, this right-tail deviations from a lognormal distribution have significant implications for the quantitative results discussed below.

Having discussed the calibration of the progressivity parameter ϕ and the income distribution for each year in 1979-2007, we are left with the parameters ε, β and ρ. The size of the elasticity of taxable income ε has been the subject of heated debates in the academic literature. The influential work of Chetty (2012) has demonstrated, however, that when interpreting the wide range of estimated elasticities through the lens of a model in which agents face optimization frictions, an elasticity of elasticity of taxable income to changes in marginal tax rates of around 0.5 can rationalize the conflicting findings of previous studies. With that in mind, we shall set $\varepsilon = 0.5$ in our benchmark calibration.[29]

Moving on to the substitutability parameter β, in our benchmark calibration we will set

[29] It should be noted that five of the fifteen studies Chetty (2012) builds on to provide bounds on the intensive margin labor supply elasticity are based on the response of hours worked (rather than taxable income) to changes in marginal tax rates. In our model, these two elasticities are not identical due to the imperfect substitutability in tasks. We have however replicated Chetty's (2012) calculations restricting the analysis to the ten papers estimating taxable income elasticities. The resulting *intensive* margin elasticity is equal to 0.33, which is identical to the one obtained by Chetty (2012) when using all fifteen papers. Chetty (2012) also finds that the compensated and uncompensated elasticities taxable income are very similar, which helps to motivate our assumption of GHH preferences in (20). It is important to mention however that the evidence suggests that these elasticities appear to be higher for rich individuals than for poor ones, a feature that is absent in our model.

$\beta = 0.8$. The resulting elasticity of substitution $1/(1-\beta) = 5$ is slightly larger than that the one typically estimated with product-level trade (see Broda and Weinstein 2006) or with firm-level mark-up data (see Bernard, Eaton, Jensen, and Kortum 2003 or Antràs, Fort, and Tintelnot 2014), but it seems reasonable to us to postulate that workers' tasks are more substitutable than the products that embody those tasks. When we quantitatively evaluate the effects of trade opening we will consider the sensitivity of our results to different values of β.

Finally, we discuss the calibration of the coefficient of inequality (or risk) aversion ρ. The often-used logarithmic utility case, which corresponds to $\rho = 1$, will provide a focal point for our quantitative analysis, but we readily admit that little is known about this parameter (especially when interpreted in terms of inequality aversion), and thus we will report results for various values of ρ ranging from $\rho = 0$ (no inequality aversion) all the way to $\rho = 2$.[30]

4.2 Evolution of the Inequality Correction Terms

Figure 5 depicts the evolution of the welfarist correction Δ and costly redistribution correction $(1 + \varepsilon\phi)\Theta^{\kappa}$ over the period 1979-2007 for the case $\rho = 1$. The smallest dot corresponds to the 1979 value of these terms, while the the largest dot corresponds to their 2007 value (the size of the dots grows over time). This graph embodies different pieces of information. Notice first that the welfarist discount factor Δ has been falling steadily over time, starting at a value of 0.757 in 1979 but ending at 0.587 in 2007. This decline necessarily reflects an increase in inequality in the distribution of disposable income. The graph however also shows that the causes of this increased dispersion in disposable income are twofold. On the one hand, the degree of tax progressivity has declined over time, something which was made clear in Figure 3, but which is also reflected by a noticeable upwards shift in the costly redistribution correction, which increased from 0.897 in 1979 to 0.926 in 2007. If that was the only change in the environment, however, we would have expected the dots to line up along a negatively sloped locus. Instead, it is clear that the dots have also shifted *inwards* during this period, which necessarily implies an increase in the primitive determinants of inequality (i.e., in the distribution of ability in our model).

Table 1 further illustrates the consequences of these shifts for the evolution of U.S. social welfare over the period 1979-2007. The table uses equation (28) to decomposes changes in social welfare according to

$$\frac{W'}{W} = \frac{\Delta'}{\Delta} \times \frac{(1+\varepsilon\phi)'}{(1+\varepsilon\phi)} \times \underbrace{\frac{\Theta'^{\kappa}}{\Theta^{\kappa}} \times \frac{\tilde{W}'}{\tilde{W}}}_{Q'/Q},$$

where as indicated, changes in real income correspond to the changes in the product of Θ^{κ} and $\tilde{W}$ (for a constant ε and g over time).[31] The top panel of the Table performs the decomposition

[30] Layard, Mayraz, and Nickell (2008) relate ρ to the degree to which marginal utility of income falls with income, and use survey data to argue that a value of $\rho = 1.26$ best explains the data. We have explored which value of ρ would rationalize the observed degree of tax progressivity as being optimal in light of the social welfare function (26), and we have found the implied ρ to be much lower (around 0.6), which can be interpreted as reflecting a lower degree of inequality aversion or a higher influence of rich individuals in the setting of tax policies.

[31] The share of government consumption in total GDP has indeed been relatively flat over the period 1979-2009,

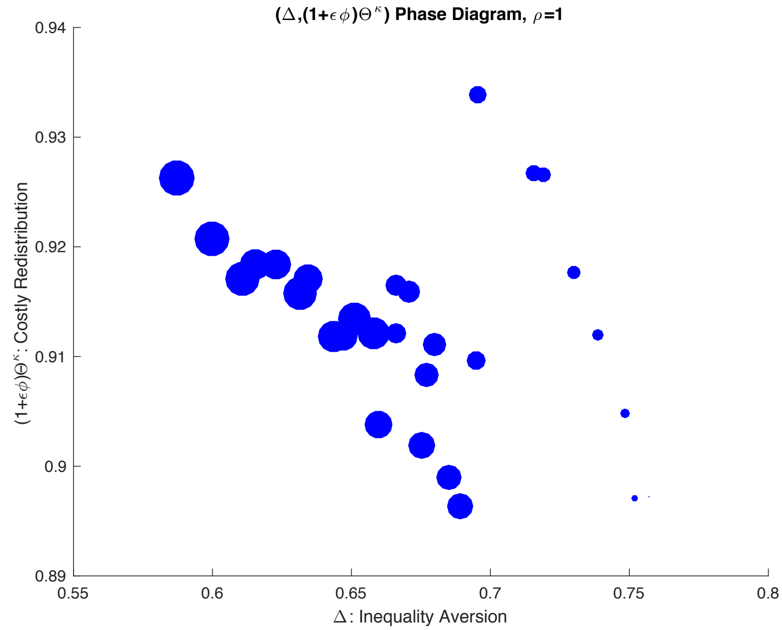

Figure 5: Evolution of the Welfarist and Costly-Redistribution Corrections

for various values of ρ. This serves to isolate the role of the welfarist correction in shaping the evolution of social welfare given the observed growth in real income. According to our data, mean real income grew 44.2% over 1979-2007, which translates into an annualized growth rate of 1.32% per year. If the welfarist correction had not changed over time, the associated increase in U.S. social welfare over this period would have been slightly lower (39% or 1.18% per year) due to the increase in labor supply triggered by the decline in progressivity. Given that Δ fell over time, however, the growth in social welfare was necessarily lower, and more so the higher is the degree of inequality aversion ρ. The first column of Table 1 provides the discount factor by which the gross income growth rate 1.39 needs to be deflated in order to obtain the inequality-adjusted growth in social welfare for different values of ρ. The adjustment is potentially sizeable. For instance, for the logarithmic case ($\rho = 1$), the implied annual growth rate in social welfare is down to 0.31% (i.e., $(1.091)^{1/28} - 1$). Adopting a constant inequality aversion of 2, would actually result in a sizable *decline* of social welfare of 3.54% per year.

Turning to the costly redistribution correction, notice that $(1 + \varepsilon\phi)\Theta^\kappa$ has been rising over time despite the observed increase in inequality. The reason for this has been the marked decline in tax progressivity observed over these years. On account of this costly redistribution channel, social welfare has thus been growing by *more* than it would have in an economy without costly redistribution. This effect is however quite modest: in a hypothetical *Kaldor-Hicks* economy with access to costless redistribution, average income would have grown by 1.09% per year on average, rather than the observed 1.32% annual growth.

equalling 15.4% in 1979 and 15.3% in 2007.

Table 1: Welfare, Inequality, and Costly Redistribution

	Change between 1979-2007				
$\rho =$	Δ	$1+\varepsilon\phi$	Θ^{κ}	$\tilde{W}$	W
0	1.000	0.964	1.062	1.356	1.388
0.25	0.927	0.964	1.062	1.356	1.287
0.5	0.874	0.964	1.062	1.356	1.213
1	0.786	0.964	1.062	1.356	1.091
1.5	0.658	0.964	1.062	1.356	0.913
2	0.263	0.964	1.062	1.356	0.365

4.3 Counterfactuals

Some readers might be struggling to wrap their head around the interpretation of the costly redistribution correction since it involves a comparison of actual data with a hypothetical economy having access to costless redistribution. The usefulness of the adjustment will perhaps become more apparent when considering a couple of counterfactual exercises. As mentioned above, part of the reason why the welfarist term Δ decreased so markedly over time is the fact that U.S. redistribution became much less progressive over that period. One might then wonder: by how much would real disposable income and social welfare have increased if the degree of tax progressivity had been held constant at its 1979 level? And by how much would they have changed if tax progressivity had *increased* to ensure that the Atkinson measure of inequality (or our welfarist correction Δ) had not changed over 1979-2007?

Figure 6 provide answers to these questions for the benchmark case of $\rho = 1$. The figure indicates that real disposable income would have grown at an average annual rate of 0.90% (instead of the observed 1.32%) if tax progressivity had been held constant at its 1979 level, while it would have grown at an even lower annual rate of 0.44% if tax progressivity had increased to keep the Atkinson index constant. Despite the negative effect of these counterfactual policies on real income growth, the figure also shows that for $\rho = 1$, these policies would have increased social welfare by a nontrivial amount (from 0.31% to 0.52% and 0.57%, respectively).[32]

5 Trade, Inequality and Costly Redistribution

In this section we consider a simple extension of our constant-elasticity model in section 3 to study the implications of costly redistribution and inequality aversion for the measurement of the welfare gains from international trade. The economic environment of this simple trade model is a generalization of that in Itskhoki (2008), and is designed to depart minimally from

[32] When considering lower levels of inequality aversion, one obtains similarly large downward adjustments to income growth in these two counterfactuals, but the implications for social welfare can of course be quite different. For sufficiently low levels of ρ, social welfare is naturally reduced by the reduction in income growth triggered by the increase in tax progressivity associated with these policy counterfactuals.

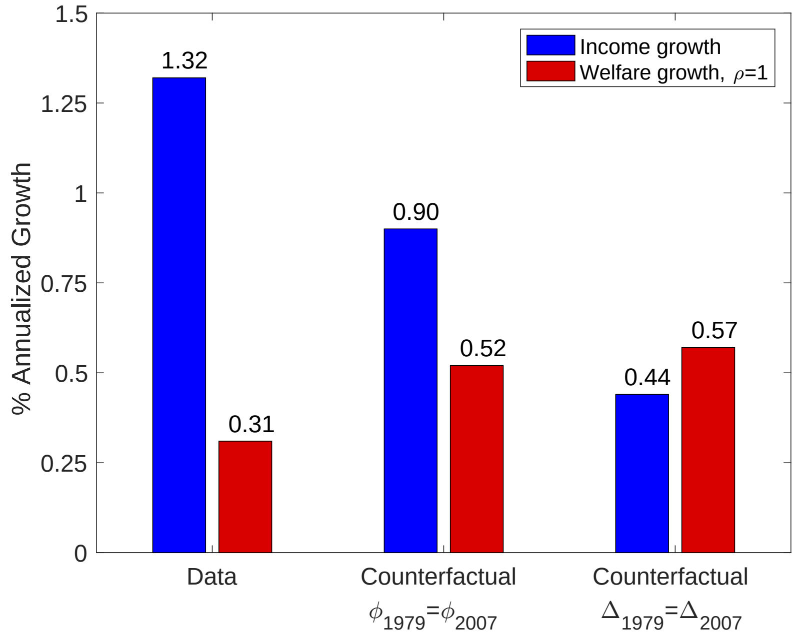

Figure 6: Counterfactuals: Holding ϕ constant and holding Δ constant

the canonical frameworks of Mirrlees (1971) and Melitz (2003). Our model is highly stylized but generates trade-induced inequality via an intuitive mechanism that features prominently in the recent international trade literature. More specifically, our model captures the notion that agents can market their labor services in foreign markets only by incurring certain costs that are (at least in part) fixed in nature. Due to these costs, exporting is worthwhile *only* for the most productive agents in society. As a result, an even though all agents benefit as consumers from access to a larger measure of imperfectly substitutable tasks, trade integration raises real income disproportionately more for the highest-ability agents in society, thereby increasing income inequality.

Relative to alternative models of trade-induced inequality featuring labor market imperfections or sorting of heterogenous agents, the simplicity of our framework makes it particularly amenable to calibration and quantification, as we shall illustrate in section 6.

5.1 A Simple Model of Trade-Induced Inequality

We now consider a world economy consisting of $N + 1$ symmetric regions analogous to the closed economy described in section 3. The fact that all regions are symmetric is not essential for the quantitative results, but greatly simplifies the exposition of the model.[33] As in our closed-economy model, individuals worldwide share the same preferences in (20) defined over the consumption of an aggregate final good and leisure, while they produce units of their

[33]Furthermore, we do not view this symmetry assumption as a major loss of generality since these regions need not be interpreted as countries, but rather as trading blocs chosen to be symmetric with regards to the model's primitives.

differentiated task according to a linear technology in their labor effort. We assume that the aggregate final goods produced in different regions are perfect substitutes, and hence, given our symmetry assumption, they are not traded across regions. Conversely, all task (or intermediate inputs) produced worldwide are imperfectly substitutable and thus trade integration allows the final good to be produced more efficiently by combining a greater diversity of tasks provided by agents worldwide.

Agents can market their task in the local market at no cost, while in order to send the output of their task to other markets they need to incur trade costs which are both fixed and variable in nature. Specifically, in order to access $M \leq N$ foreign markets, any individual needs to pay M separate fixed costs $f(1)$, $f(2)$,..., $f(M)$ where we characterize the fixed cost associated with the n-th market with the constant-elasticity function:

$$f(n) = f_x n^{\alpha}, \qquad \alpha \geq 0, \; n > 1. \tag{29}$$

Notice that f_x governs the average level of these fixed costs, while the parameter α shapes the curvature of the fixed cost function with respect to the number of foreign markets serviced. Even with $\alpha = 0$, the model produces selection into exporting, as some agents would opt out of selling their tasks abroad. With $\alpha > 0$, however, the model leads to a richer extensive margin of trade by which relatively more able individuals market their tasks in a larger number of markets (i.e., n_φ will be nondecreasing in φ).[34] On top of these fixed costs, when exporting to particular market, an agent needs to ship $\tau > 1$ units of task services for one unit to reach that foreign market. As a result, the import revenues obtained by an individual with ability φ from any foreign market j are given by $Q^{1-\beta}(q_\varphi/\tau)^\beta$, where q_φ is the number of units of task services provided by φ in that market.

An agent with ability φ thus invests in access to n_φ foreign markets, and optimally allocates the total output of its task y_φ across the markets, which yields a total revenue of:[35]

$$r_\varphi = \Upsilon_{n_\varphi}^{1-\beta} Q^{1-\beta} y_\varphi^\beta, \tag{30}$$

where

$$\Upsilon_{n_\varphi} = 1 + n_\varphi \tau^{-\frac{\beta}{1-\beta}}. \tag{31}$$

We assume that individuals are indifferent with regards to which particular markets to serve, and choose to access a random subset of n_φ markets out of the total N foreign markets, thus maintaining symmetry across markets.

Market revenue is taxed according to a schedule $T(r)$ given by (11). Note that the tax is

[34] We have also experimented with a variant of the model featuring heterogeneity of fixed costs of exporting across individuals, in a manner analogous to Eaton, Kortum, and Kramarz (2011) or Helpman, Itskhoki, Muendler, and Redding (2012).

[35] Formally, $r_n(y) = \max_{\{q_0, q_1, \ldots, q_n\}} \left\{ Q^{1-\beta} \left[q_0^\beta + \sum_{j=1}^n (q_j/\tau)^\beta \right] \;\middle|\; \text{s.t. } \sum_{j=0}^n q_j = y \right\}$, with the solution given by $q_0 = y/\Upsilon_n$ and $q_j = \tau^{-\beta/(1-\beta)} y/\Upsilon_n$ for $j = 1, \ldots, n$. Lastly, the agent with ability φ optimally choose $n = n_\varphi$ and $y = y_\varphi$, as we describe below, and we denote with $r_\varphi = r_{n_\varphi}(y_\varphi)$.

conditional only on market revenue, but not on the number of non-local markets served, n_φ. In other words, we assume that not only the ability of individuals is not observable, but neither are their investment decisions when accessing non-local markets. As in our constant-elasticity model in section 3, we continue to adopt the log-linear tax schedule introduced in section 2 and empirically motivated in section 4, so disposable income for an agent with ability φ is given by:

$$r_\varphi - T\big(r_\varphi\big) = k r_\varphi^{1-\phi},$$

where k is chosen to ensure balanced government budget, $\int_0^1 T\big(r_\varphi\big)\mathrm{d}H_\varphi = gQ$. Agents consume their disposable income net of the fixed cost of entry and of the tax payments,

$$c_\varphi = k r_\varphi^{1-\phi} - f_x n_\varphi^\alpha, \tag{32}$$

and choose their labor supply ℓ_φ and export entry decisions n_φ to maximize utility (20) given the production technology $y_\varphi = \varphi \ell_\varphi$, the revenue function (30) and the budget constraint (32).

The tasks sold in each market are combined by competitive firms into final output and sold on the local market. In equilibrium, trade across regions is balanced and the government spends all its net tax revenue on the final good, and thus the total expenditure on the local final good equals the total revenues of individuals in the region, $Q = \int r_\varphi \mathrm{d}H_\varphi$, which using (30) can be rewritten as:

$$Q = \left(\int_0^1 \Upsilon_{n_\varphi}^{1-\beta} y_\varphi^\beta \mathrm{d}H_\varphi \right)^{1/\beta}. \tag{33}$$

This completes the description of open-economy, general equilibrium environment of the model. We will use the model to study the effect of a reduction in trade costs τ on social welfare, taking into account the effects of trade liberalization on aggregate income but also on inequality. As in our previous closed-economy model, we will measure social welfare according to the constant-inequality aversion function in equation (26).

5.2 Open-Economy Equilibrium

Solving the individual labor supply and market access problem results in the following before-tax revenue and utility schedules

$$r_\varphi = \big(\Upsilon_{n_\varphi}\big)^{\frac{(1+\varepsilon)(1-\beta)}{1+\varepsilon\phi}} r_{0\varphi}, \tag{34}$$

$$u_\varphi = \big(\Upsilon_{n_\varphi}\big)^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} u_{0\varphi} - f_x \sum_{n=1}^{n_\varphi} n^\alpha \tag{35}$$

where

$$r_{0\varphi} = \big(\beta(1-\phi)k\big)^{\frac{\varepsilon}{1+\varepsilon\phi}} \Big[Q^{1-\beta}\varphi^\beta\Big]^{\frac{1+\varepsilon}{1+\varepsilon\phi}} \quad \text{and} \tag{36}$$

$$u_{0\varphi} = \frac{1+\varepsilon\phi}{1+\varepsilon} k \left(r_{0\varphi}\right)^{1-\phi}, \tag{37}$$

correspond to before-tax revenue and utility of an agent with ability φ that only sells locally, and where $\Upsilon_{n_\varphi} = 1 + n_\varphi \tau^{-\frac{\beta}{1-\beta}}$ with $n_\varphi \in \mathbb{Z}^+$ being determined by

$$\left[\Upsilon_{n_\varphi}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} - \Upsilon_{n_\varphi - 1}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} \right] u_{0\varphi} \geq f_x n_\varphi^\alpha, \tag{38}$$

$$\left[\Upsilon_{n_\varphi + 1}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} - \Upsilon_{n_\varphi}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} \right] u_{0\varphi} < f_x (n_\varphi + 1)^\alpha. \tag{39}$$

Because $(1+\varepsilon)(1-\beta) < 1$ and $\alpha \geq 0$, the existence of a unique $n_\varphi \in \mathbb{Z}^+$ is guaranteed.

These equilibrium expressions are cumbersome, but they can be used to establish that, starting from autarky, trade integration induces an increase inequality in our framework. To see this, define an *increase in inequality* in a given variable x as a situation in which the ratio $x_{\varphi^H}/x_{\varphi^L}$ for two individuals with abilities $\varphi^H > \varphi^L$ is either left unchanged or increased, with this ratio being increased for at least a pair of individuals. With this definition in hand, we can then show (see the Appendix) that:

Proposition 3 *A move from autarky to a trade equilibrium in which some individuals export in some but not all markets necessarily increases inequality in pre-tax and after-tax real income and in utility levels.*

The intuition for the result is simple. In the presence of fixed costs of exporting, some relatively low-ability individuals will not be able to profitably market their task in foreign markets, while these same agents will now face increased competition from foreign high-ability individuals selling their task in their local market.

This result is illustrated in Figure 7 which plots the Gini coefficient and coefficient of variation of real market and disposable income for different levels of trade costs. As is clear, these measures of inequality are minimized for the largest values of variable trade costs τ, which indeed place the economy close to autarky. The figure also shows that the effect of trade integration on inequality need not be monotonic. In fact, it is straightforward to show that if fixed costs of exporting are sufficiently low, a reduction in iceberg trade costs that leads all individuals to market their tasks in all regions will necessarily reduce inequality. This is because the level of inequality associated with an economy in which all individuals sell in all markets is identical to the level of inequality under autarky. Despite the fact that trade cost reductions could *theoretically* reduce income inequality, as the Figure indicates our calibration exercise (to be discussed in detail in the next section) indicates that it would take a significant decline in trade costs to enter the region in which trade is associated with reduced rather than increased income inequality.

So far we have focused on the implications of the model for the effect of trade on inequality and we have been able to state Proposition 3 without solving for the endogenous aggregate variables k and Q. In order to study the welfare gains from trade integration it is, however necessary to solve for these objects. Aggregate income Q can be solved as a function of k as the

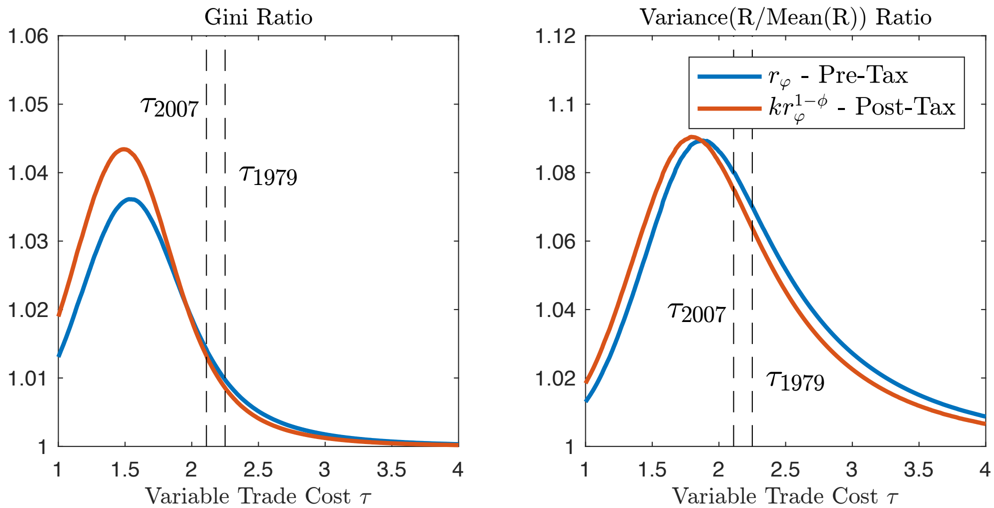

Figure 7: Trade Integration and Income Inequality

fixed point of

$$Q = \int r_\varphi (Q, k) \, \mathrm{d}H_\varphi,$$

where $r_\varphi (Q)$ is obtained by combining equations (34)-(39). The value of Q and k can then obtained by noting that $k = \int r_\varphi (Q, k) \, \mathrm{d}H_\varphi / \int (r_\varphi (Q, k))^{1-\phi} \, \mathrm{d}H_\varphi$.

Manipulating these equations, we show in the Appendix that:

Proposition 4 *A reduction in the costs of exporting (variable τ or fixed F) leads to an increase in real income Q. Furthermore, the utility of all agents increases with trade.*

In sum, despite the fact that trade typically decreases the relative revenues obtained by low-ability individuals, the reduction in the price index faced by these individuals when acting as consumers is always large enough to leave them at least as well off as before the reduction in trade costs.

5.3 Social Welfare and the Gains from Trade

Once we have solved for the aggregates of the model, we can plug them back into (35) and (37) and invoke (26) to compute social welfare in the open-economy equilibrium. As in section 3, we can denote by $\tilde{W}_T$ as social welfare in the economy with zero tax progressivity ($\phi = 0$) and no inequality aversion ($\rho = 0$), and use this definition to decompose social welfare as

$$W = \frac{\left[\mathbb{E}\left(u_\varphi\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}}{\mathbb{E}u_\varphi} \times \frac{\mathbb{E}u_\varphi}{\tilde{W}} \times \tilde{W} = \Delta_T \times \Theta_T \times \tilde{W}_T. \quad (40)$$

Welfare is thus the product of the potential welfare level $\tilde{W}_T$ attainable in the absence of tax progressivity or inequality aversion, and two terms, Δ_T and Θ_T, that are analogous to the welfarist and costly-redistribution corrections developed in sections 2 and 3.

Given the equilibrium values of u_φ in (35), the welfarist correction term Δ_T can easily be computed for a particular value of ρ. Furthermore, the fact that, by Proposition 3, trade integration increases inequality in utility levels implies that:

Proposition 5 *Relative to its value under autarky, Δ_T is strictly lower in a trade equilibrium in which some individuals export in some but not all markets. Furthermore, the welfare gains from trade are strictly decreasing in the degree of inequality aversion ρ.*

In our numerical simulations of the model, we have found that the first statement also seems to apply for the case of the costly redistribution correction Θ_T. The proof of that result is however much more cumbersome for reasons very much related to the those we will next discuss in reference to the effects of tax progressivity in the open-economy equilibrium.

5.4 The Effects of Tax Progressivity

In section 3, we discussed how in the closed-economy model, one could characterize the equilibrium degree of progressivity ϕ as balancing efficiency and equity concerns. Because in the decomposition in (40), the term $\tilde{W}_T$ is independent of tax progressivity, it continues to be the case that a benevolent social planner would simply set ϕ to maximize $\Delta_T \times \Theta_T$. The effect of ϕ on each of these terms is however more complex than in the closed economy, because tax policy not only reduces the incentives to supply labor given a trade status, but also shapes the extensive margin decisions of agents as to whether service particular foreign markets. This feature of the model bears some resemblance to analysis of optimal income taxation with both intensive and extensive margins of labor supply responses, as in Saez (2002).

As a result of these forces, the optimal redistribution policy response to trade liberalization is in general ambiguous. On the one hand, selection into exporting activity leads to an increase in the dispersion of relative revenues across the groups of exporters and non-exporters. This causes greater income inequality and calls for more redistribution. On the other hand, selection into exporting activity also results in an active extensive margin of trade, which is sensitive to the stance of the redistribution policy.[36] Therefore, the efficiency losses from redistribution also increase in an open economy as they now combine both intensive and extensive margins. On net, the optimal policy response to increasing trade can be both to raise or to reduce marginal taxes and the progressivity of the tax schedule.

Despite these theoretical ambiguity, in our quantitative analysis with reasonable parameter values (see section 6), we have found that our model predicts that the degree of tax progressivity should decline with trade liberalization, although the effect is quantitatively very small.

[36] Higher marginal taxes do not necessarily affect the extensive margin directly, however, they have an indirect effect through the response of the optimal scale of production. Fixed costs activities require a certain scale in order to be justified. Since higher marginal taxes reduce the optimal scale for all firms they also negatively affect the extensive margin.

6 Calibration and Counterfactuals: U.S. (1979-2007)

We next turn to a quantitative exploration of our model centered on the U.S. experience over the period 1979-2007. Our ultimate goal is to quantify the role of trade-induced inequality in shaping the welfare consequences of the observed rise in trade integration over the period 1979-2007. We proceed in two steps. On a first pass, we calibrate our model to match certain moments of 2007 United States data. We then increase trade frictions to bring the openness of the U.S. economy back to its 1979 level (and also back to autarky in an auxiliary exercise). This allows us to compute the effect of changes in trade openness on aggregate income and on inequality, thereby allowing us to gauge quantitative importance of the two corrections developed in this paper. More specifically, we seek to answer the following questions: how large are the gains from trade for different degrees of inequality aversion? How large would the gains from trade be if costless redistribution was available?

6.1 Calibration

The calibration is analogous in many ways to the one we performed in section 4 for the closed economy version of the model. In particular, we continue to set $\beta = 0.8$ and ε=0.5, while we again back out the tax progressivity parameter ϕ by regressing the logarithm of CBO post-tax and transfer income on the logarithm of market income for 2007 as shown in Figure 8. As is clear from the figure, the fit of this simple log-linear regression is remarkable and delivers a value of $\phi = 0.147$.

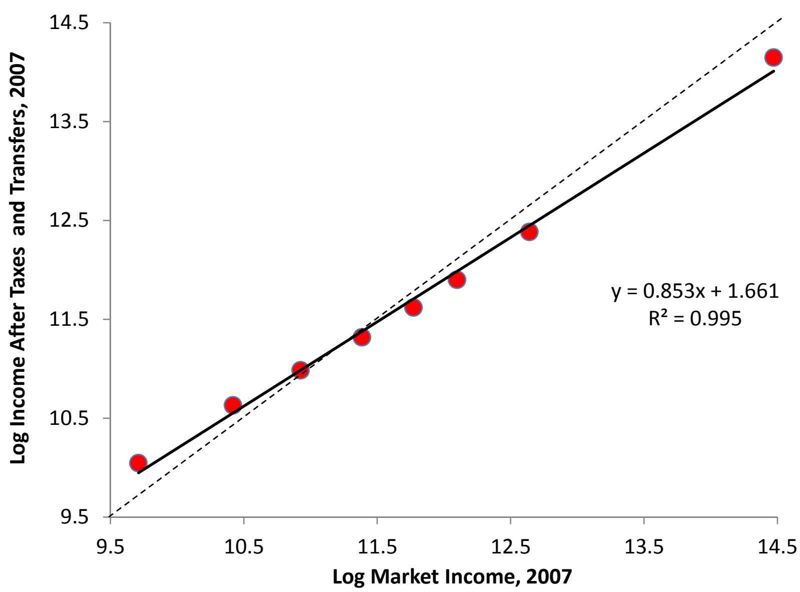

Figure 8: Calibrating Progressivity in 2007

The only new sets of parameters to calibrate in the open economy are (i) the iceberg costs τ which determine variable trade costs, and f_x and α determining the structure of fixed costs of exporting; and (iii) the number of symmetric foreign regions N. Because the U.S. accounts for roughly 10-15% of world GDP, we set $N = 5$ in our benchmark calibration, though we will also present some sensitivity results for different values of N in section 6.3.

The calibration of the other trade parameters is more involved. Realizing that the income distribution produced by the model is crucially affected by the exporting decisions of agents, we jointly calibrate the ability distribution H_φ and the trade parameters (τ, f_x, α) to exactly match the 2007 distribution of market income (from the NBER-IRS data) as well as three moments of the U.S. trade sector. These three "trade moments "are (i) the U.S. trade share in 2007, defined as the ratio of the average between U.S. exports and imports and gross output in the U.S. (7.8%); (ii) the share of exporters' sales in the total sales of U.S. firms (60%), and (iii) the share of U.S. exports accounted by for exporters that sell to more than five foreign markets (89%). We provide more details on the data used to compute these moments in the Appendix, where we also include a discussion of the technical aspects of the calibration. The resulting parameter estimates are $\tau = 2.11$, $f_x = 750$, and $\alpha = 0.53$. Our estimated iceberg trade costs may appear to be somewhat high, but note that we are calibrating the model to the whole U.S. economy, rather than to its manufacturing sector, as is standard in quantitative models of trade.[37]

When performing our counterfactuals, we hold all parameters fixed, including the distribution of ability, and we set $\tau_{1979} = 2.25$ to match the 1979 trade share of 5.2%, while we also set $\tau_{autarky} = +\infty$ in a more extreme counterfactual studying a shift to autarky.

6.2 Counterfactuals

Table 2 reports the implications of a move to 1979 and autarky levels of iceberg trade frictions for aggregate consumption, for aggregate welfare without inequality aversion (i.e., $\rho = 0$), and for the Gini coefficient. As is clear from the Table, the real consumption gains from trade are higher, the higher is the taxable income elasticity ε. Notice, however, that the higher is this parameter, the larger is also the amount of inequality induced by trade opening.

Table 2: Welfare Gains from Trade and Induced Inequality

	% Consumption Gains		% Welfare Gains ($\rho = 0$)		% Increase in Gini	
	τ_{1979}	$\tau = \infty$	τ_{1979}	$\tau = \infty$	τ_{1979}	$\tau = \infty$
$\varepsilon = 0.25$	0.8	2.5	0.8	2.4	0.4	1.1
$\varepsilon = 0.5$	1.2	3.5	1.1	3.3	0.5	1.3
$\varepsilon = 1$	2.0	6.3	1.8	5.9	0.6	1.7

Figure 9 plots the welfarist adjustment to the gains from trade for different values of ρ and ε. More precisely, the Figure plots the factor by which the net gains from trade in the absence of inequality aversion need to be multiplied to obtain the net gains from trade corresponding

[37]When calibrating our model to the U.S. manufacturing sector we indeed back out a smaller value of τ, in line with those in Anderson and van Wincoop (2004) and Melitz and Redding (2015).

to different values of ρ. Although the autarky counterfactual is associated with much larger consumption gains than the 1979 counterfactual (see Table 2), Figure 9 indicates that the welfarist adjustment turns out to be almost identical in both counterfactuals, regardless of the value of ε. For the case of logarithmic utility ($\rho = 1$) and a benchmark taxable income elasticity of $\varepsilon = 0.5$, welfare gains are 22% lower for both the 1979 and autarky counterfactuals. For $\varepsilon = 0.25$ and $\varepsilon = 1$, the analogous factors are 25%$and15%$, respectively.

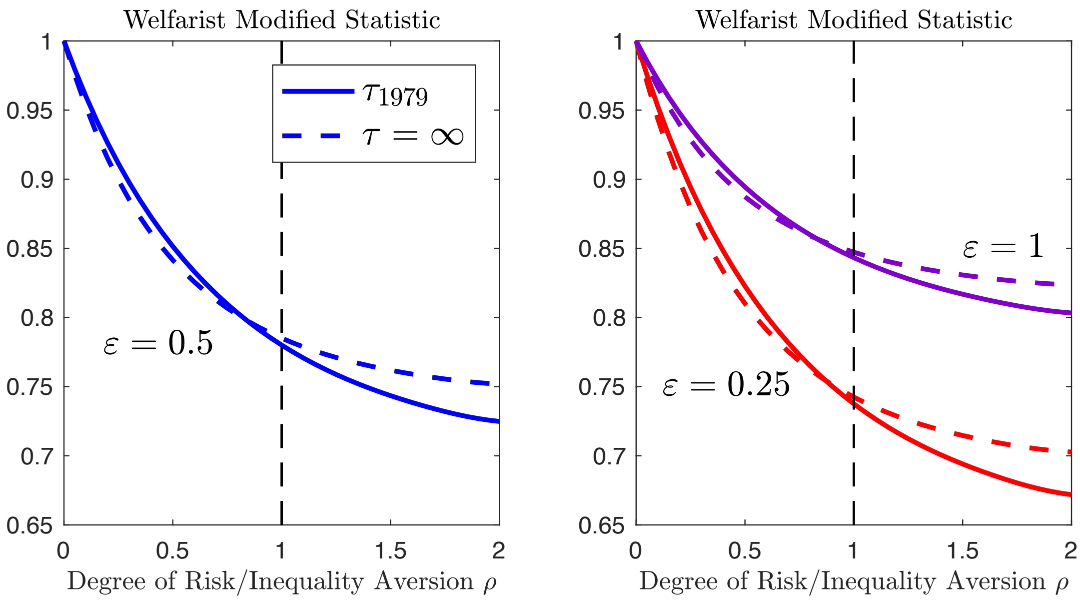

Figure 9: Welfarist Adjustment to the Welfare Gains from Trade

Figure 10 plots the costly redistribution adjustment to the welfare gains from trade for various values of ε. This adjustment is naturally higher, the higher is the elasticity of taxable income ε . When $\varepsilon = 0.5$, the welfare gains from trade are adjusted downards by 16% in our autarky counterfactual and by 10% in the 1979 counterfactual.

6.3 Robustness

[TO BE WRITTEN]

7 Conclusions

In this paper, we have explored the welfare consequences of trade integration in an environment in which trade-induced inequality is partly mitigated by a progressive income tax-transfer system. Despite the progressive nature of taxation, trade integration leads to an increase in inequality in the distribution of disposable income. We have argued that, under these circumstances, the application of the Kaldor-Hicks criterion to quantitatively evaluate the welfare gains from trade is not devoid of value judgments. More specifically, unless one is willing to assume that a dollar in the hands of a poor individual has the same social value as a dollar in the

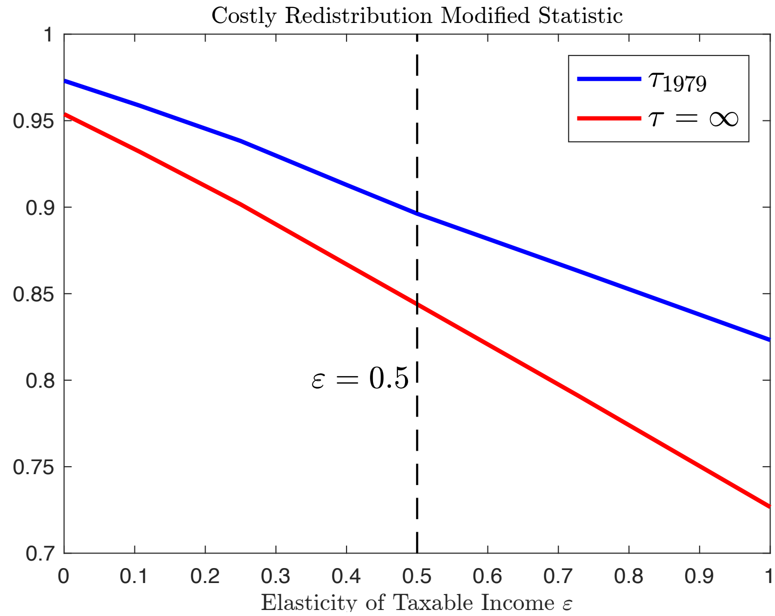

Figure 10: Costly Redistribution Adjustment to the Welfare Gains from Trade

hands of a rich individual, trade liberalization episodes that increase the real disposable income of some individuals but reduce that of others cannot be evaluated by simply adding those real incomes. Furthermore, in situations in which trade integration benefits some agents in society disproportionately, the progressivity of the tax system implies that these fortunate individuals will necessarily transition into higher marginal tax brackets, so they will naturally adjust their labor supply (or effort in production) in a way that diminishes the realized gains from trade relative to a situation in which redistribution was performed in a nondistortionary manner. In this paper, we have formalized these insights and we have developed welfarist and costly redistribution corrections to standard measures of the gains from trade integration. Under plausible parameter values, these corrections are nonneglible and eliminate about one-fifth of the (static) gains from trade.

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A Appendix (Incomplete)

A.1 Derivations for Section 3

Start with equation (23):

$$r_\varphi = \Big[\beta(1-\phi)k\Big]^{\frac{\varepsilon}{1+\varepsilon\phi}} \Big[Q^{1-\beta}\varphi^\beta\Big]^{\frac{1+\varepsilon}{1+\varepsilon\phi}}$$

and introduce a corresponding concept of a zero-tax variable (i.e., in the case under $\phi = 0$), which we denote with a tilde:

$$\tilde{r}_\varphi = \Big[\beta\tilde{k}\Big]^{\varepsilon} \Big[\tilde{Q}^{1-\beta}\varphi^\beta\Big]^{1+\varepsilon}.$$

We first solve for the GE variables under zero taxes, $(\tilde{k}, \tilde{Q})$. We have from (22) that

$$\tilde{k} = (1-g).$$

Next we have:

$$\tilde{Q} = \int \big[\beta\tilde{k}\big]^{\varepsilon} \Big[\tilde{Q}^{1-\beta}\varphi^\beta\Big]^{1+\varepsilon} \mathrm{d}H_\varphi.$$

Solving for $\tilde{Q}$ we get:

$$\tilde{Q} = \big[\beta(1-g)\big]^{\kappa\varepsilon} \left(\int \varphi^{\beta(1+\varepsilon)}\mathrm{d}H_\varphi\right)^{\kappa},$$

where

$$\kappa \equiv \frac{1}{1-(1-\beta)(1+\varepsilon)}.$$

Therefore we can write the solution for $\tilde{r}_\varphi$ without endogenous variables as:

$$\tilde{r}_\varphi = \big[\beta(1-g)\big]^{\kappa\varepsilon} \left(\int \varphi^{\beta(1+\varepsilon)}\mathrm{d}H_\varphi\right)^{\kappa} \frac{\varphi^{\beta(1+\varepsilon)}}{\int \varphi^{\beta(1+\varepsilon)}\mathrm{d}H_\varphi} = \tilde{Q}\frac{\varphi^{\beta(1+\varepsilon)}}{\int \varphi^{\beta(1+\varepsilon)}\mathrm{d}H_\varphi}.$$

Note that an increase in g decreases revenues for all agents with an elasticity $\kappa\varepsilon \geq \varepsilon$ due to the amplification from the CES structure (when $\beta < 1$).

We use the above derivations as interim steps to characterizing the allocation for $\phi > 0$. Note that we can write:

$$r_\varphi = (1-\phi)^{\frac{\varepsilon}{1+\varepsilon\phi}} \left(\frac{k}{1-g}\right)^{\frac{\varepsilon}{1+\varepsilon\phi}} \left(\frac{Q}{\tilde{Q}}\right)^{\frac{(1-\beta)(1+\varepsilon)}{1+\varepsilon\phi}} \tilde{r}_\varphi^{\frac{1}{1+\varepsilon\phi}},$$

$$\frac{k}{1-g} = \frac{\int r_\varphi \mathrm{d}H_\varphi}{\int r_\varphi^{1-\phi}\mathrm{d}H_\varphi} = (1-\phi)^{\frac{\varepsilon\phi}{1+\varepsilon\phi}} \left(\frac{k}{1-g}\right)^{\frac{\varepsilon\phi}{1+\varepsilon\phi}} \left(\frac{Q}{\tilde{Q}}\right)^{\frac{(1-\beta)(1+\varepsilon)\phi}{1+\varepsilon\phi}} \frac{\int \tilde{r}_\varphi^{\frac{1}{1+\varepsilon\phi}}\mathrm{d}H_\varphi}{\int \tilde{r}_\varphi^{\frac{1-\phi}{1+\varepsilon\phi}}\mathrm{d}H_\varphi},$$

$$Q = (1-\phi)^{\frac{\varepsilon}{1+\varepsilon\phi}} \left(\frac{k}{1-g}\right)^{\frac{\varepsilon}{1+\varepsilon\phi}} \left(\frac{Q}{\tilde{Q}}\right)^{\frac{(1-\beta)(1+\varepsilon)}{1+\varepsilon\phi}} \int \tilde{r}_\varphi^{\frac{1}{1+\varepsilon\phi}}\mathrm{d}H_\varphi.$$

Solving out $k/(1-g)$, we obtain:

$$\frac{k}{1-g} = (1-\phi)^{\varepsilon\phi} \left(\frac{Q}{\tilde{Q}}\right)^{(1-\beta)(1+\varepsilon)\phi} \left(\frac{\int \tilde{r}_{\varphi}^{\frac{1}{1+\varepsilon\phi}} \mathrm{d}H_{\varphi}}{\int \tilde{r}_{\varphi}^{\frac{1-\phi}{1+\varepsilon\phi}} \mathrm{d}H_{\varphi}}\right)^{1+\varepsilon\phi}$$

and substituting this into the expression for Q:

$$\frac{Q}{\tilde{Q}} = (1-\phi)^{\kappa\varepsilon} \left[\frac{\left(\int \tilde{r}_{\varphi}^{\frac{1}{1+\varepsilon\phi}} \mathrm{d}H_{\varphi}\right)^{1+\varepsilon}}{\left(\int \tilde{r}_{\varphi}^{\frac{1-\phi}{1+\varepsilon\phi}} \mathrm{d}H_{\varphi}\right)^{\varepsilon} \left(\int \tilde{r}_{\varphi} \mathrm{d}H_{\varphi}\right)}\right]^{\kappa}$$

and therefore:

$$k = (1-g)(1-\phi)^{\kappa\varepsilon\phi} \left[\frac{\left(\int \tilde{r}_{\varphi}^{\frac{1}{1+\varepsilon\phi}} \mathrm{d}H_{\varphi}\right)^{1+\varepsilon}}{\left(\int \tilde{r}_{\varphi}^{\frac{1-\phi}{1+\varepsilon\phi}} \mathrm{d}H_{\varphi}\right)^{\varepsilon} \left(\int \tilde{r}_{\varphi} \mathrm{d}H_{\varphi}\right)}\right]^{(\kappa-1)\phi} \left(\frac{\int \tilde{r}_{\varphi}^{\frac{1}{1+\varepsilon\phi}} \mathrm{d}H_{\varphi}}{\int \tilde{r}_{\varphi}^{\frac{1-\phi}{1+\varepsilon\phi}} \mathrm{d}H_{\varphi}}\right)^{1+\varepsilon\phi}.$$

A.2 Proof of Proposition 3

Take two individuals with ability with abilities $\varphi^H > \varphi^L$. From equations (34) and (36), we have that pre-tax incomes satisfy

$$\frac{r_{\varphi^H}}{r_{\varphi^L}} = \left(\frac{\Upsilon_{n_{\varphi^H}}}{\Upsilon_{n_{\varphi^L}}}\right)^{\frac{(1+\varepsilon)(1-\beta)}{1+\varepsilon\phi}} \left(\frac{\varphi^H}{\varphi^L}\right)^{\frac{(1+\varepsilon)\beta}{1+\varepsilon\phi}}. \tag{41}$$

The second term is identical as in the closed-economy model, while the first term is new, and because n_{φ} is nondecreasing in φ, this term is necessarily (weakly) higher than 1, and it will be larger than one as long as some individuals export in some but not all markets. The proof for after-tax incomes is then trivial since $r_{\varphi} - T(r_{\varphi}) = kr_{\varphi}^{1-\phi}$.

To show the result for the case of utility levels, we begin by using (38) to define an ability level $\tilde{\varphi}_n$ such

$$\left[\Upsilon_n^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} - \Upsilon_{n-1}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}}\right] u_{0\tilde{\varphi}_n} = Fn^{\alpha}.$$

In words, $\tilde{\varphi}_n$ is the minimum ability level such that choosing to export in n foreign markets is optimal. Note then that equation (35) can be expressed as

$$u_{\varphi} = \Psi(\varphi)\, u_{0\varphi}$$

where (using (37))

$$\Psi(\varphi) = \left(\Upsilon_{n_{\varphi}}\right)^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} - \sum_{n=1}^{n_{\varphi}} \left[\Upsilon_n^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} - \Upsilon_{n-1}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}}\right] \left(\frac{\tilde{\varphi}_n}{\varphi}\right)^{\frac{(1+\varepsilon)\beta(1-\phi)}{1+\varepsilon\phi}}. \tag{42}$$

We next show that $\Psi(\varphi) \geq 1$ and $\Psi'(\varphi) \geq 0$ which guarantees the validity of the statement in Proposition 3 with regards to utility levels. Note that $\Psi(\varphi) = 1$ for the lowest ability levels for which $n_\varphi = 0$, so it suffices to show that $\Psi'(\varphi) \geq 0$. This is obvious in the interval of abilities for which a common n_φ is optimal. In other words, for any $\varphi^H > \varphi^L$ for which $n_{\varphi^H} = n_{\varphi^L}$. Whenever $n_{\varphi^H} = n_{\varphi^L} + 1$, notice that

$$\Psi\left(\varphi^H\right) - \Psi\left(\varphi^L\right) = \left[\Upsilon_{n_\varphi}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} - \Upsilon_{n_\varphi-1}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}}\right]\left[1 - \left(\frac{\tilde{\varphi}_{n_\varphi}}{\varphi^H}\right)^{\frac{(1+\varepsilon)\beta(1-\phi)}{1+\varepsilon\phi}}\right]$$
$$+ \sum_{n=1}^{n_\varphi-1}\left[\Upsilon_n^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}} - \Upsilon_{n-1}^{\frac{(1+\varepsilon)(1-\beta)(1-\phi)}{1+\varepsilon\phi}}\right]\left[\left(\frac{\tilde{\varphi}_n}{\varphi^L}\right)^{\frac{(1+\varepsilon)\beta(1-\phi)}{1+\varepsilon\phi}} - \left(\frac{\tilde{\varphi}_n}{\varphi^H}\right)^{\frac{(1+\varepsilon)\beta(1-\phi)}{1+\varepsilon\phi}}\right] > 0.$$

It is then straightforward to show that the same is true for $n_{\varphi^H} = n_{\varphi^L} + m$ for any $m > 1$. This implies that $\Psi(\varphi)$ is nondecreasing and strictly higher than one as long as some individuals export in some but not all markets.

A.3 Parameter and Non-Parametric Ability φ Distribution Calibration

We observe the actual income distribution R_i. For simplicity let $x_i = \log(\varphi_i)$. For a given set of parameters we can back-out the $x_i's$ that deliver this distribution in equilibrium as follows.

1. Solve for the aggregate variables

$$Q = \text{mean}(R_i)$$
$$k = \frac{\text{mean}(R_i)}{\text{mean}\left(R_i^{1-\phi}\right)}$$

2. Define the following function

   $n_x(x) = n$ such that $\bar{x}_n \leq x < \bar{x}_{n+1}$ with
$$\bar{x}_n = \frac{\gamma - \beta(1-\phi)}{\gamma\beta(1-\phi)}\left[\log f_n - \log\left[\Upsilon_n^{\frac{\gamma(1-\phi)(1-\beta)}{\gamma-\beta(1-\phi)}} - \Upsilon_{n-1}^{\frac{\gamma(1-\phi)(1-\beta)}{\gamma-\beta(1-\phi)}}\right] - \frac{\gamma(1-\phi)(1-\beta)}{\gamma-\beta(1-\phi)}\log Q - \log\zeta\right]$$

   and $\zeta = \left(1 - \frac{\beta(1-\phi)}{\gamma}\right)k(\beta(1-\phi)k)^{\frac{\beta(1-\phi)}{\gamma-\beta(1-\phi)}}$. The number of countries to which households export is increasing in x so $n_x(x)$ is a weakly increasing step function that is discontinuous from the left at every $\bar{x}_n$.

3. A household with x_i will have revenue

$$r(x_i) = (\beta\phi k)^{\frac{\beta}{\gamma-\beta(1-\phi)}}\left(\Upsilon_{n_x(x_i)}^{1-\beta} Q^{1-\beta} e^{\beta x_i}\right)^{\frac{\gamma}{\gamma-\beta(1-\phi)}}$$

   Given our data all we have to do is find for each data point R_i its corresponding x_i such that $R_i = r(x_i)$ conditional on Q and k. These ;ast two are then found as a fixed point to this algorithm.

To calibrate the model using non-parametric draws we choose $\{F, \tau, \alpha\}$ with $f_n = Fn^\alpha$ such that the equilibrium matches the following three moments $M1, M2, M3$:

$$M1 = \frac{\sum_i \left(\frac{\Upsilon_{n_x(x_i)-1}}{\Upsilon_{n_x(x_i)}}\right) r(x_i)}{\sum_i r(x_i)}$$

$$M2 = \frac{\sum_{i:n_x(x_i)>0} r(x_i)}{\sum_i r(x_i)}$$

$$M3 = \frac{\sum_{i:n_x(x_i)>1} \left(\frac{\Upsilon_{n_x(x_i)-1}}{\Upsilon_{n_x(x_i)}}\right) r(x_i)}{\sum_{i:n_x(x_i)>0} \left(\frac{\Upsilon_{n_x(x_i)-1}}{\Upsilon_{n_x(x_i)}}\right) r(x_i)}$$