The Welfare Effects of Trade with Labour Market Risk*

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September 16, 2021

Abstract

This paper evaluates the welfare effects of trade in a setting with risk averse workers and uncertainty in labour market outcomes. We examine the bias introduced in welfare analysis when individuals are assumed to be risk neutral when they are in fact risk averse. We provide conditions under which a small change in relative prices due to trade reduces welfare in a static endowment economy. Using a dynamic production model we quantify the set of price changes that result in a welfare loss following trade. We also examine the welfare implications of large price changes due to trade. For a realistic calibration, the gains from trade exist but are smaller than in a world with risk neutral individuals.

*The authors would like to thank Reshad Ahsan, Chris Edmond, Juan Carlos Gozzi, Pierre-Olivier Gourinchas, Andrei Levchenko, Thijs van Rens, Gabor Virag, Shang-Jin Wei and seminar participants at the Australian National University, the University of Auckland, the Univeristy of Warwick, the National Bank of Poland, the NBER Summer Institute and the Workshop of the Australasian Macroeconomics Society for helpful comments. All remaining errors are ours. Contact details: luren@unimelb.edu.au and mousavis@student.unimelb.edu.au

1 Introduction

The welfare effects of trade in a small open economy are well known.[1] The consensus is that international trade creates winners and losers but that on balance, trade is welfare improving. In particular, if lump-sum transfers are available then the losers can be adequately compensated so that everyone wins. These welfare results are generally shown in environments in which there is no uncertainty *or* in environments in which workers are risk neutral.[2] However, in reality, we often view individuals as being risk averse. Furthermore, we think of uncertainty as being pervasive in economic life. Individuals suffer from unexpected job loss or wage cuts and only have a limited ability to insure themselves against these adverse events.

Recent evidence suggests that changes in trade flows alter the level of risk that workers in an economy face. The prominent study by Autor, Dorn and Hanson (2013) shows that regions more exposed to trade with China suffer from worse labour market conditions including an increase in the unemployment rate. Through the lens of a standard job search model, this increase in unemployment would be associated with an increase in risk. Further direct evidence is provided by Krebs, Krishna and Maloney (2010) and Krishna and Senses (2014). They find that reductions in tariffs or increased exposure to trade leads to an increase in the variance of permanent shocks to the income of individuals more exposed to tariff reductions or changes in trade flows.

This paper examines the welfare effects of trade integration for a small closed economy in which workers are risk averse *and* they face uncertainty in an environment with incomplete financial markets. The introduction of these features changes the welfare analysis of trade integration. It is unsurprising that when we alter preferences by introducing risk averse agents that the welfare effects of trade change quantitatively. However, in this paper we demonstrate that there are systematic patterns associated with how welfare changes. To understand these patterns note that *any* closed economy with risk averse workers facing uncertain outcomes in the presence of incomplete markets suffers from two distinct market failures. First, the presence of risk aversion and market incompleteness implies that risk will not be distributed in a socially optimal manner across individuals. The lack of international trade is a second distortion. Hence, this is a world in which the Theory of the Second Best applies. A policy reform that reduces the severity of one distortion, such as

[1] See Dixit and Norman (1980) for a discussion of gains from trade in a traditional framework or Arkolakis, Costinot and Rodriguez-Clare (2012) in new trade models or Fajgelbaum and Khandelwal (2016) for a discussion of unequal gains from trade.

[2] Our standard economic theory also highlights why redistribution may be difficult to achieve. The political process may limit the use of lump-sum transfers or alternative methods of redistribution. Alternatively, and also plausibly, there are informational issues that may hinder redistribution. Governments may be unaware of which individuals are left worse off by trade. Furthermore, transfers to mitigate welfare losses associated with trade may weaken incentives.

removing trade barriers that restrict international trade, may increase the severity of the remaining distortion. In some cases, this may even lead to aggregate welfare losses if the distribution of risk across individuals within a society moves further away from the socially optimal allocation.

In Section 2, to provide the main intuition of our results, we analyse a simple endowment economy. Individuals have preferences over two goods and receive a stochastic endowment. If endowment risk is absent, then moving from autarky to free trade will always be welfare improving. That is in a free trade equilibrium, workers can be compensated so that some workers are better off and no workers are worse off when compared to autarky. The same is true if endowment risk exists but workers are risk neutral or if markets are complete. However if endowment risk exists *and* if risk averse workers lack access to complete markets, then moving from autarky to trade may reduce welfare. That is, even if lump-sum transfers are available it may not be possible to compensate individuals without a positive inflow of resources into the economy. In fact, we show that the ability to compensate individuals following a small price change from autarky is linked to how financial markets would value output produced by workers in different sectors of the economy. Furthermore, we show that evaluating welfare assuming workers are risk neutral when they are in fact risk averse will, in general, bias our measure of the welfare impact of trade. More importantly, we link the direction of this bias to how stochastic output in different sectors of the economy would be valued by financial markets.

A natural question is how important is the absence of complete financial markets when evaluating trade outcomes in the presence of social and/or self-insurance. To this end, in Section 3, we construct a general equilibrium Ricardo-Viner specific factor model in which labour is attached to a particular sector. There are three key markets. First, there is a frictional labour market which provides a source of idiosyncratic risk. Workers find and lose jobs at a stochastic rate and this introduces risk into their economic lives. Second, there is an incomplete financial market. Workers are able to lend and borrow at a fixed interest rate but they are unable to perfectly insure themselves against their idiosyncratic income risk. However, social insurance is provided by the government in the form of unemployment insurance. Finally, there is a competitive product market in which the relative price of goods is determined.

We calibrate the model to evaluate the quantitative significance of our result. We segment workers into different sectors on the basis of their educational attainment. The model parameters are set to match a series of targets based upon the long run features of the US macroeconomy and upon observed differences in labour market outcomes by education. We then examine the impact upon welfare of a change in relative prices due to opening to trade. If there is an increase in relative prices of 3.5 per cent that favours the skilled sector, there are no gains from trade. If relative price changes from trade are larger or favour the less skilled sector we find that gains from trade exist. What happens if a researcher assumes that workers are risk neutral when they are in fact risk averse? In our calibration, if trade favours less educated workers they will tend to *underestimate* the gains from trade while if trade favours more educated workers they will tend to *overestimate* the gains from trade.

In our work, we follow a large literature that uses the Kaldor-Hicks criteria to evaluate welfare changes. This criteria examines the net value of transfers required to compensate individuals when the economy moves from autarky to a trade equilibrium. To extend the Kaldor-Hicks criteria to a setting with uncertainty we make the following modifications: in our static model, we allow transfers to be conditional upon the sector of employment but not on the realisation of uncertainty. For our dynamic model, we also allow transfers to be dependent upon sector and upon employment status at the time of trade integration but not upon future realisations of uncertain outcomes.[3] This restriction on compensatory transfers being independent of the realisation of uncertainty is important. If the government could condition transfers on future states of the world, it could replicate a complete markets outcome in which case trade integration would always be welfare improving. Antras, Gortari and Itskhoki (2017) study the link between inequality, trade and welfare assuming that redistribution is costly and by evaluating welfare with a social welfare function that penalises inequality. Our paper differs by retaining the standard Kaldor-Hicks criteria and by introducing uncertainty into the environment. We show that incorporating risk aversion alters our welfare analysis in a systematic manner. The changes are substantial enough that for some price changes due to trade, there is no potential for redistribution to compensate losers even if redistribution is costless.

Our work is related to Newbery and Stiglitz (1984) who highlight that free trade may reduce welfare in the absence of complete markets. In their work, trade integration raises aggregate volatility. If individuals are risk averse and markets incomplete this increase in volatility may reduce welfare. Our paper has a similar message but it differs in important respects. In our model, there is no aggregate uncertainty. Instead *all* risk is idiosyncratic and associated with labour market outcomes due to search frictions. Second, our result does not rely upon the rather special assumptions that are used in Newbery and Stiglitz (1984). We believe that the deviations from a baseline trade model that we consider - frictional labour markets and incomplete financial markets with risk averse agents - are modifications that many would find palatable.

[3] In our dynamic production economy we allow unemployment benefits which are transfers across individuals that depend upon employment status which changes over time. These unemployment benefits are not able to replicate a complete market setting.

Also related is the work of Dixit (1989) and Ranjan (2016). Dixit (1989) discusses welfare improving trade policy in an economy with one risky and one safe sector. He does not, however, outline conditions under which a move to free trade will reduce welfare or study quantitative outcomes. Ranjan (2016) examines how reduced import prices may worsen the allocation of productive resources in a directed search setting with risk averse workers. He builds upon Acemoglu and Shimer (1999), who find in a directed search setting that firms respond to greater labour market risk by offering lower quality jobs that are easier for workers to find. This has a welfare cost since it distorts the allocation of resources away from optimal while we highlight that the interaction between risk and welfare is present even if there are no changes in resource allocation, such as in our endowment economy.

There is a growing literature on the role of search frictions in international trade. Early examples are Davidson, Martin and Matusz (1987) and Davidson, Martin and Matusz (1988) and more recently, Felbermayr, Prat, and Schmerer (2011), Helpman and Itskhoki (2010) and Helpman, Itskhoki and Redding (2010). These papers have focused upon search frictions in environments with risk neutral workers so the effects we focus upon are absent. Finally a number of papers examine the welfare costs of trade in settings in which workers are immobile or partially immobile across regions or in which other adjustment costs exist. Examples include Artuç, Chaudhuri and McLaren (2010), Caliendo, Dvorkin and Parro (2019), Dix-Carniero (2014), Alessandria, Choi and Ruhl (2014), Guren, Hémous and Olsen (2015), and Galle, Rodriguez-Clare and Yi (2017). These papers focus upon the distributional issues associated with trade, while our paper emphasises aspects related to uncertainty and risk aversion. While these issues are clearly related, our analysis is conceptually distinct.

2 A Static Endowment Economy with Uncertainty

We build a simple one-period, two-sector model of trade. Sectors are denoted by $i \in \{1, 2\}$ and workers are assigned to a specific sector and each sector produces a distinct good. There is a mass of workers normalised to size one with π_i workers in sector i. Individuals in sector i receive a stochastic amount of output of good i that will be denoted by the random variable X_i with a particular realisation denoted by x_i. Realisations across individuals within a sector are i.i.d. To keep matters simple assume $X_i = \bar{x}_i$ with probability h_i and $X_i = \underline{x}_i$ with probability $1 - h_i$. Assume without loss of generality that $\bar{x}_i > \underline{x}_i$. Note that with a continuum of workers and i.i.d. shocks that there is no aggregate uncertainty.

Each worker combines output from each sector into a composite consumption good,

$$C = \left((1-\alpha)^{\frac{1}{\eta}} c_1^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} c_2^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}. \tag{1}$$

Further, assume each worker is an expected utility maximiser with identical preferences over this composite consumption good that are described by a utility function, $U(C)$. Our focus will be upon an economy in which workers are risk averse so that $U'(C) > 0$ and $U''(C) < 0$.

In this static model workers consume all of their income. This implies the budget constraint for a worker in sector i is

$$p_i x_i = p_1 c_1 + p_2 c_2,$$

where p_i is the price associated with good i. With a risky endowment, an individual's composite consumption is a random variable. Denote C_i as the random variable describing composite consumption of an individual in sector i. As is standard, there is an ideal price index, P, that describes the expenditure required to purchase one unit of the aggregate consumption good. Explicitly,

$$P = \left((1-\alpha) p_1^{1-\eta} + \alpha p_2^{1-\eta} \right)^{\frac{1}{1-\eta}} \tag{2}$$

and define $c_1^*(p_1, p_2)$ and $c_2^*(p_1, p_2)$ the optimal quantities of good 1 and 2, respectively, to minimize expenditure to purchase one unit of the composite consumption good. Note that consumption of the composite good of a worker in sector i with realised output of x_i is given by $\frac{p_i x_i}{P}$. Here, it is worthwhile to point out that for a worker in sector i that

$$E[C_i] = \frac{p_i}{P} E[X_i]$$

and

$$Var[C_i] = \left(\frac{p_i}{P} \right)^2 Var[X_i].$$

Hence, an increase in p_1 due to trade will raise both the mean and variance of C_1 and simultaneously lead to a fall in the mean and variance of C_2. When evaluating welfare with risk averse workers, compensation must account for changes in both the mean and the variance of consumption.

We consider two methods of price determination. First, prices adjust to equate supply and demand in our autarky equilibrium. In particular, consumer optimization and market equilibrium imply

$$\left(\frac{p_1}{p_2} \right)^{\eta} = \frac{1-\alpha}{\alpha} \cdot \frac{(1-\pi)E[X_2]}{\pi E[X_1]}$$

Second, we consider a trade equilibrium for a small open economy in which prices are exogenous. In both cases we normalise $p_2 = 1$.

Our welfare comparisons are based on the Kaldor-Hicks concept of compensating variation. We allow the government to compensate individuals by making non-state contingent lump transfers. Specifically, we allow transfers to depend upon an individual's sector but not upon the realisation of their stochastic endowment. In both the autarky and free trade we can calculate the expected utility of an individual in each sector. We then calculate the transfer required to compensate an individual for moving from an autarky to a free trade equilibrium and aggregate over individuals to derive the net transfer required in a trade equilibrium to provide compensation. We define trade as welfare improving if the size of the net transfer is negative, implying that all individuals can be compensated in the trade equilibrium with resources to spare. If net transfers are positive, then individuals can only be compensated with an input of resources into the economy. In this case, trade reduces welfare. We have two initial propositions.

Proposition 1. *In the absence of labour market risk, that is if $\bar{x}_i = \underline{x}_i$ or if $h_i = 1$ for all i then, a move from autarky to free trade is welfare improving in the sense that net transfers required to fully compsenate workers are non-positive.*

This result is not surprising. It is our standard result that trade is welfare improving for a small open economy. In an economy with certainty, changes in relative prices affect the real wages of workers; some gain while others lose. However, in an endowment economy with free trade the total resources available are at least as much as in autarky. As a result the government can redistribute to ensure everyone is compensated from the change in prices without requiring a net positive inflow of resources into the economy.

Before we continue, we make the following assumption:

Assumption 1. *The size of the lump-sum transfers that must be extracted from workers who gain from trade (to return them to their autarky expected utility) is less than the value of their endowment in all states of the world.*

This assumption ensures when extracting compensation from individuals that gain from trade, we can ignore binding credit constraints. These credit constraints could, in principle, restrict transfers across individuals. Relaxing this assumption makes it more difficult for trade to be welfare improving by placing additional constraints on redistribution. But we show below in Proposition 3, that even without these additional constraints, trade can reduce welfare.

Proposition 2. *In a model with risk neutral workers (that is, $U(C) = C$) the movement from autarky to free trade is welfare improving in the sense that net transfers required to fully compensate workers are non-positive.*

These two propositions demonstrate that this economy satisfies standard trade results. In the absence of labour market risk or with risk neutral workers, the movement from autarky to free trade is welfare improving in the sense that workers can be compensated by using lump-sum transfers without requiring additional resources. Before proceeding, we define

$$\zeta_i = \frac{cov(U'(C_i), X_i)}{E[X_i]E[U'(C_i)]}$$

In our setting, $\zeta_i \leq 0$ since as the size of the endowment increases, so does consumption, which reduces the marginal utility of consumption and makes $cov(U'(C_i), X_i) < 0$. ζ_i can be interpreted as a measure of the price of risk associated with the endowment in sector i. Formally, suppose an individual in sector i was able to trade a share of their endowment at a price q in return for a safe asset that provided one unit of their sectoral output at a price normalised to one. Then $\zeta_i \leq 0$ is the price penalty (in percentage terms) the endowment would need relative to the safe asset to convince the individual to hold the endowment and not diversify their risk. Details of this result are in the Appendix in Section 7.1.

Proposition 3. *In an endowment economy with risk averse workers in autarky. Without loss of generality let*

$$\zeta_1 > \zeta_2. \tag{3}$$

Then a negative net transfer is required to compensate workers when moving from autarky to trade if there is a marginal increase in the relative price of good 1 and a positive net transfer is required to compensate workers if there is a marginal decrease in the relative price of good 1.

This proposition outlines under what conditions a net inflow of resources will be needed to compensate individuals following a small change in relative prices due to a movement from autarky to a free trade equilibrium. If a small change in the relative price favours the sector in which the equilibrium price penalty for holding the endowment is small, then transfers can compensate individuals for the price change with resources to spare. If a small change in the relative price favours the sector in which the equilibrium pirce penalty for holding the endowment is large, then transfers can not compensate individuals for the price change. The proof is in the Appendix. It uses the implicit function theorem to calculate the transfer required to keep an individual indifferent to a relative price change and then aggregates over individuals.

Whether gains from trade exist depends upon the direction of the price change and the relative sectoral value of

$$\zeta_i = \frac{cov[U'(C_i), X_i]}{E[U'(C_i)]E[X_i]} \tag{4}$$

Intuitively, a change in relative prices affects workers within a sector by altering the real value of their endowment. The change in the value proportional to the size of the endowment (X_i). The impact upon expected utility depends upon how much the value of the endowment changes combined with the marginal utility of consumption in each state of the world. As a result, the effect of a small change in relative prices upon expected utility depends upon the covariance of the marginal utility of consumption with the size of the endowment. This is reflected in the numerator of equation (4). On the other hand, compensation takes the form of non-state contingent lump sum transfers. At the margin, the impact of these transfers on expected utility depends on the expected marginal utility. This is captured in the denominator of equation (4). As a result, the size of a transfer to compensate for a small change in relative prices will be proportional to ratio of the covariance of the marginal utility of consumption and the endowment to the expected marginal utility of consumption. Since, in general, this ratio will vary across sectors it implies that movements in relative prices in one direction will cause a welfare gain and movements in the opposite direction will generate a welfare loss. This implies, unlike the standard model without risk or with risk neutral workers, that there is a first-order welfare impact for small changes in relative prices due to trade.[4]

We highlight a number of points. First, our key condition relies upon a sectoral comparison of ζ_i rather than a sectoral comparison of the variance of the endowments. These concepts are related but conceptually different. For example, one sector may have a large variance of endowment but if consumption is a range in which there is only small variation in marginal utility, then this sector may have a small value of ζ (in absolute value) relative to another sector with a smaller variance of the endowment over a range of consumption in which the marginal utility is more varied. Second, if transfers were conditional upon realised endowments then a planner could ensure that trade integration improves welfare by replicating a complete markets outcome. Although this may seem reasonable in a simple endowment economy, we find it less compelling in a dynamic production economy where conditional transfers may generate moral hazard. Finally, our analysis has focused upon small price changes in a small open economy. Are the gains from trade in a global economy positive? Here we note that the direction of trade is based upon comparative advantage but, at least for small price changes, the gains are determined by the equation (3). Hence, the direction

[4] In the standard model with risk neutral workers, there is a zero first-order impact of a change in prices on welfare. This reflects the envelope condition and the fact that individuals are optimising their consumption decisions in the autarkic equilibrium. Also note that with risk neutrality (or complete financial markets) or without uncertainty

$$\frac{cov[U'(C_1), X_1]}{E[U'(C_1)]E[X_1]} = \frac{cov[U'(C_2), X_2]}{E[U'(C_2)]E[X_2]} = 0$$

which implies that a marginal change in relative price in either direction can be compensated without positive transfers as implied by our first two propositions. Equivalently, there is no first order welfare effects from a small change in prices in economies with risk neutral workers or complete markets.

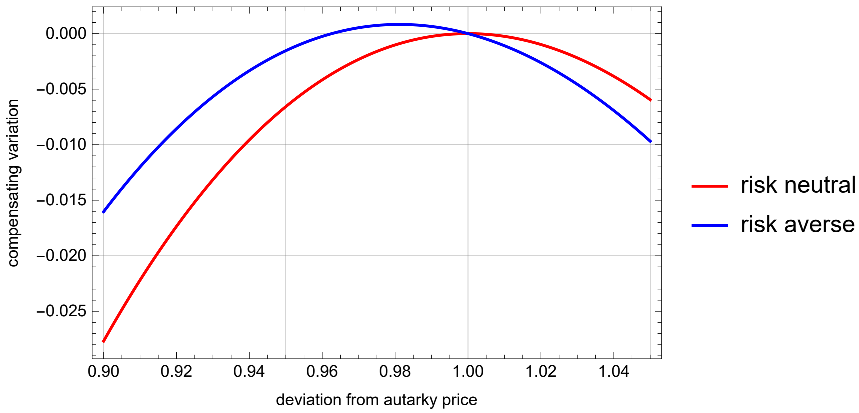

Figure 1: Welfare Gains from Trade - Risk Neutral relative to Risk Averse

and the gains from trade are determined by different forces. It's possible to construct a two-country model in which a reduction in trade barriers reduces welfare in both countries.[5]

Figure 1 illustrates the difference between the standard risk neutral setting and our environment with risk averse workers. Our aim here is to describe qualitative rather than quantitative differences that arise from risk aversion. In this numerical example, we keep the expected productivity the same across sectors and set output in sector 2 as more volatile.[6] This implies $\zeta_2 < \zeta_1$ so there is a larger price penalty for holding the endowment in sector 2. If individuals are risk neutral (red line), then as the trade price deviates from the autarky price, there is always an increase in welfare as workers can be compensated with a net negative transfer. Furthermore, the potential gains from trade increase in the size of the price change relative to autarky. This is our standard result. In contrast, if workers are risk averse (blue line), then as the trade price deviates from autarky, there is a first order impact upon welfare. Whether there are gains or losses from trade will initially depend upon the direction of trade and the magnitude of price changes induced by trade. In particular, if trade increases the price of sector 1 output, then trade is always welfare improving while if trade lowers the price of sector 1 output, then trade is welfare reducing for small price changes. If trade leads to a large change in prices then, regardless of the direction of trade, gains from trade exist.

This static model is stylised along several dimensions. First, as an endowment economy, one of the traditional gains from trade of reallocating factors of production to the sector in which the relative price increases is absent. However, potential gains from trade still exist because workers may

[5] As a simple, if somewhat trivial example, consider a case in which sector 1 has no uncertainty in country 1 and sector 2 has no uncertainty in country 2. If trade integration results in country 1 exporting good 2 and country 2 exporting good 1 then both countries will lose if the resultant price changes from trade are small.

[6] In this numerical example, we set $\pi = 0.5, \alpha = 0.5, h_1 = h_2 = 0.5, \eta = 5, \gamma = 2, \overline{x}_1 = 2.25, \underline{x}_1 = 1.75, \overline{x}_2 = 2.5$, and $\underline{x}_2 = 1.5$

reallocate consumption towards the good that has become relatively less expensive due to trade. Second, the static model abstracts from mechanisms that may reduce the impact of uncertainty and risk, such as self-insurance. To examine the quantitative relevance of the welfare effects associated with trade in a model with labour market risk we construct a dynamic model with production in Section 3 and calibrate the model and examine the effect of large changes in prices in Section 4 and 5.

3 A Dynamic Production Economy with Labour Market Risk

Here, we add two new elements to our previous analysis. First we consider a production economy where we allow the allocation of resources to respond to prices. Second, we allow workers to access two forms of insurance. They are able to buy or sell an annuity that allows them to self-insure against future income shocks. Also, we introduce a system of unemployment benefits that provides some insurance against job loss. Time is continuous. There are two types of agents: workers and firms. These agents interact in three markets. First, workers and firms match in a frictional labour market in the tradition of Mortensen-Pissarides. Second, individuals trade an annuity in a financial market in the tradition of Blanchard-Yaari. Finally, goods are traded in a competitive product market.

As before, there are two sectors denoted by $i \in \{1, 2\}$ and workers are allocated to a specific sector that produces a specific good. The mass of workers in sector i is denoted π_i and we normalise $\pi_1 + \pi_2 = 1$. Workers die at a rate of d and are replaced by an inflow of newly born workers who enter the economy unemployed with zero assets and attached to the same sector as the individual they replace.[7] Unemployed workers search for jobs in a frictional labour market and employed workers produce output and earn a wage w_i. Workers face labour market risk in the form of stochastic job finding and separation that occur at a rate h_i and δ_i, respectively. Workers have a consumption-saving decision. They are able to mitigate labour market risk by participating in an incomplete financial market in which they are able to trade an annuity that offers a fixed rate of return r.

There is a large mass of firms able to enter either sector by creating a vacancy. To do so, they purchase an amount of sector i output as capital, k_i, prior to searching for a worker. We adopt a directed search paradigm with firms posting wages and workers directing their search as in Moen (1997) and Acemoglu and Shimer (1999). The number of job matches formed per unit of time in

[7] The death of individuals in this economy is required to attain a steady state distribution since assets for an individual are expected to drift upwards at a constant rate over time.

sector i is determined by a matching function, $m_i(u_i, v_i)$, that features constant returns to scale in u_i and v_i. Once a worker is employed, output is produced with the amount of output, $f_i(k_i)$, dependent on the level of capital stock.

In a closed economy, the total demand equals the supply for each good and this determines the equilibrium interest rates and relative prices across sectors. Also, the net wealth held by workers will equal the value of firms. In a trade equilibrium, we consider a small open economy so that the interest rate and the relative price between sectors are exogenous. The demand for good i may differ from supply due to trade and net domestic wealth may differ from the value of domestic firms due to either international borrowing or lending.[8]

3.1 Worker's Problem

We first solve the problem of an individual worker problem in an arbitrary sector. As a result, we temporarily suppress sectoral subscripts. We show how it is possible to aggregate worker behaviour and then solve for endogenous worker transition rates and prices.

Workers discount future utility at a rate of ρ. They receive utility from consuming both goods which are combined into an aggregate consumption good denoted C using a constant elasticity of substitution aggregator. Let c_i denote the consumption of sector i output and p_i the corresponding price. Individuals have CARA utility with respect to the consumption aggregator with parameter γ determining the degree of absolute risk aversion. The employment state of a worker is denoted $j \in \{e, u\}$ where $j = e$ indicates an employed worker and $j = u$ indicates an unemployed worker. Workers lose a job at a Poisson arrival rate of δ and find a job at a Poisson arrival rate of h. Although the rate of job loss remains exogenous, we will endogenise the rate of job finding when discussing firm entry. Workers may lend or borrow using an annuity, a, that offers a fixed rate of return equal to r. Formally, workers face the following consumption-saving problem:

$$\max_{\{c_1,c_2\}} E_0 \int_0^{\infty} -e^{-(\rho+d)t} e^{-\gamma C} \, dt$$

subject to C determined by equation (1) and

$$\dot{a} = ra + y_j - c_1 p_1 - c_2 p_2.$$

When employed, they will receive a wage income of $y_e = (1-\tau)w$ where τ is a labour income tax rate and we will assume that workers receive unemployment benefits, b, when unemployed so $y_u = b$. In

[8]If households lend internationally, then the value of assets owned by the household will exceeds the value of domestic firms and their total consumption will exceed domestic production. If households borrow from overseas, the value of assets owned by households is less than the value of firms and some of the output produced by firms will be exported for overseas consumption. A proof of this result is available on request.

equilibrium, unemployment benefits will be set so that the value of government expenditure equals the value of taxation raised. The solution to the intratemporal problem of allocating expenditure between c_1 and c_2 at a given point in time is well known. For a given level of expenditure X,

$$c_1 = (1-\alpha)\left(\frac{p_1}{P}\right)^{-\eta}\frac{X}{P}$$
$$c_2 = \alpha\left(\frac{p_2}{P}\right)^{-\eta}\frac{X}{P}$$

where P is an ideal price index given by (2). Using the solution to the intratemporal CES problem, the worker's problem can be restated as:

$$\max E_0 \int_0^\infty -e^{-(\rho+d)t}e^{-\gamma C}\,dt$$

subject to

$$\dot{a} = ra + y_j - PC$$

and an associated transversality condition. The value function associated with a worker in employment state $j \in \{e, u\}$ and asset level a is denoted $V_j(a)$ and is defined recursively below,

$$\rho V_j(a) = \max_c \left(u(c) + (ra + y_j - PC)V_j'(a) + \phi_{jj'}(V_{j'}(a) - V_j(a)) + d(0 - V_j(a))\right)$$

where $\phi_{jj'}$ is the transition rate from employment state j to state j'. That is, $\phi_{ue} = h$ and $\phi_{eu} = \delta$. Following Wang (2007) and Uren (2018), a guess and verify approach can be used solve for the value function,

$$V_j(a) = -\frac{exp\left(-\frac{\gamma}{P}\left(ra + b_j + P\left(\frac{\rho+d-r}{\gamma r}\right)\right)\right)}{r}, \tag{5}$$

and the corresponding solution to the intertemporal consumption problem is given by

$$C_j = \frac{1}{P}\left(ra + b_j + P\left(\frac{\rho+d-r}{\gamma r}\right)\right) \tag{6}$$

for $j \in \{e, u\}$ where (b_e, b_u) solve:

$$he^{-\gamma b_e/P} = \left(h + \frac{\gamma r}{P}(y_u - b_u)\right)e^{-\gamma b_u/P} \tag{7}$$
$$\delta e^{-\gamma b_u/P} = \left(\delta + \frac{\gamma r}{P}(w - b_e)\right)e^{-\gamma b_e/P}. \tag{8}$$

With CARA utility, consumption can be broken into three components. First, workers consume all of their interest income $(r \cdot a)$.[9] Second, consumption depends upon a component that reflects

[9] If debt is large enough, then consumption may be negative. This is inconsistent with equation (1). On this issue we make two points. First, in our calibration the number of individuals with negative consumption in steady state is of the order of 10^{-25} so the issue is of little practical importance. Second, the model we outline is identical to a model in which individuals consume a good, C, that is produced by combining intermediate inputs, c_1 and c_2. The intermediate inputs are produced by firms hiring in a frictional labour market but are combined into a final good in a perfectly competitive market for the intermediate inputs. In that case, there are no theoretical inconsistency with $C < 0$.

expected labour income flows over time captured by b_e and b_u. This component is essentially a permanent income component adjusted for precautionary savings. Finally, consumption also reflects the difference between the rate of time preference and the market discount rate.

A useful result that arises due to the CARA utility specification is that

$$\begin{aligned}\dot{a} &= ra + y_j - PC \\ &= y_j - b_j - P\left(\frac{\rho + d - r}{\gamma r}\right)\end{aligned}$$

where $j \in \{e, u\}$. This implies that the level of savings depends upon employment status but is independent of asset holdings. Uren (2018) shows how to use this property in a one sector economy to derive a steady state distribution of assets. A similar result applies in this setting and the equilibrium level of assets of workers in sector i is:

$$A_i = \frac{1}{d}\left((\pi_i - u_i)(y_{ie} - b_{ie}) + u_i(y_{iu} - b_{iu}) + \pi_i P\left(\frac{r - \rho - d}{\gamma r}\right)\right) \tag{9}$$

where u_i is the level of unemployment in sector i and the notation x_{ij} represents a variable, x, for a worker in sector i and employment state j. The aggregate level of assets held in this economy is,

$$A = \sum_i A_i.$$

This environment captures the key elements of our static model. Most importantly, workers are risk averse and face labour market uncertainty in the form of employment shocks. Workers can partially self-insure themselves by accumulating assets during good times and running down assets while unemployed. They also have access to social insurance in the form of unemployment benefits. The above discussion solves a consumption-saving problem of workers subject to exogenous wages and labour market transition rates. We now endogenise job finding rates and wages by discussing firm behaviour.

3.2 Firm's Problem

The labour market is frictional. To create a vacancy a firm in sector i purchases an amount of sector i output as capital, k_i, to be used in the production process.[10] A worker-firm match in sector i with capital k_i produces $f_i(k_i)$ units of output of good i. Workers and firms are matched according to a constant returns to scale matching function $m_i(u_i, v_i)$ that has the standard properties[11] such

[10] Capital in sector i is created from sector i output. We follow this convention so that in the absence of frictions, changes in relative prices do not affect optimal investment decisions within a sector.

[11] Explicitly, $m_i(u_i, v_i)$ is increasing in each of its arguments and features constant returns to scale.

that the job finding rate of workers and the worker finding rate of firms in sector i can be expressed as functions $h_i(\theta_i)$ and $q_i(\theta_i)$ where θ_i is the vacancy-unemployment rate in sector i.

Once a match is created, the firm earns revenue of $p_i f_i(k_i)$ and a wage w_i is paid to workers. A job match is destroyed exogenously at a rate δ or if a worker dies at a rate of d. In either case, the capital investment is lost. The interest rate that firms pay on their capital debt is r_f. We define the value of a filled position to a firm in sector i with capital k_i and wage of w_i as $F_i(k_i, w_i)$ and the value of a vacancy that has a posted wage of w_i as $N_i(k_i, w_i)$. Using standard arguments the steady state values can be represented as

$$r_f F_i(k_i, w_i) = p_i f_i(k_i) - w_i + (\delta_i + d)(-F_i(k_i, w_i))$$
$$r_f N_i(k_i, w_i) = q_i(\theta_i)(F_i(k_i, w_i) - N_i(k_i, w_i)).$$

We assume that a large number of firms are prepared to enter the market so that the value of a vacancy equals the cost of vacancy creation. Hence, $N_i(k_i, w_i) = p_i k_i$ since the purchase of capital stock is a cost that must be paid prior to the creation of a vacancy. Following Moen (1997) and Acemoglu and Shimer (1999) we assume a directed search environment in which firms post wages to attract workers. They show that competition between firms ensures that in equilibrium the wages, capital and level of vacancy creation maximise the value of unemployment subject to a zero profit condition. Formally,

$$\max_{\{k_i, w_i, \theta_i\}} V_{u,i}(a)$$

subject to $q_i(\theta_i)(F_i(k_i, w_i) - p_i k_i) = r_f N_i(k_i, w_i)$.

The following first order conditions pin down sectoral wages, w_i, capital per firm, k_i and the vacancy-unemployment rate, θ_i:

$$f_i'(k_i) = \frac{q(\theta_i) + r_f}{q_i(\theta_i)}(r_f + \delta_i + d) \tag{10}$$

$$p_i k_i = \frac{q(\theta_i)}{q(\theta_i) + r_f} \cdot \frac{p_i f_i(k_i) - w_i}{r + \delta_i + d} \tag{11}$$

$$\frac{\partial V_u(a; w, \theta)/\partial w}{\partial V_u(a; w, \theta)/\partial \theta} = \frac{q(\theta) F_w}{q'(\theta)(F_i - N_i)} \tag{12}$$

The first equation reflects an optimal capital intensity choice. As frictions disappear $(q(\theta_i) \to \infty)$ this equation corresponds to the standard marginal benefit equals the marginal cost of capital. The second equation is a restatement of the free entry condition. The final equation arises since the marginal rate at which unemployed workers trade off higher wages against a higher probability of job finding should correspond to the rate at which firms are able to trade off higher wages against the probability of a worker finding employment given the zero profit condition.

3.3 Labour Market Equilibrium

Unemployment in sector i evolves according to the following differential equation,

$$\dot{u}_i = (\delta + d)(\pi_i - u_i) - h_i(\theta_i)u_i$$

so steady state unemployment in sector i is

$$u_i = \frac{(\delta + d)\pi_i}{\delta + d + h_i(\theta_i)}. \tag{13}$$

3.4 Goods and Financial Market Equilibrium

We now turn to discuss equilibrium in the goods and the financial market. We consider a Blanchard-Yaari economy with actuarially fair annuities. This allows us a tractable method of introducing self-insurance. The Blanchard-Yaari structure implies that workers receive a premium relative to the rate of return that firms are able to provide but when an individual dies, their wealth is redistributed to the population.[12] In particular,

$$r = r_f + d. \tag{14}$$

Note that r_f is the interest rate at which firms discount profits. The value of firms in the closed economy will equal the value of assets so in the absence of death individuals would earn an interest rate of r_f on their capital holdings. However, with finite lifetimes and an annuity market, individuals die at rate d and their assets are redistributed to households in the form of higher interest payments. As a result households earn an actuarially fair interest rate of $r_f + d$.

The government maintains a balanced budget so that the revenue gained through income taxation equals the expenditure on unemployment benefits. Formally,

$$\sum_i \tau w_i(\pi_i - u_i) = \sum_i b u_i$$

As before we consider two cases. First, in a closed economy the goods market clear in both sectors. With $p_2 = 1$ available as a normalisation, this allows us to determine the relative price of goods as well as the equilibrium interest rate. When we move to a small open economy we take the relative price of goods and the interest rate as exogenous. In this case the domestic demand for sector i output may differ from domestic supply due to trade. Furthermore with an exogenous interest rate,

[12] This structure also allows us a tractable way of redistributing assets of workers who die. Finite worker lifetimes are required for a steady state asset distribution to exist when workers have CARA utility.

the economy may borrow or lend on international financial markets so that the level of domestic wealth held by households may vary from the equilibrium value of firms.[13]

In a closed economy, demand equals supply in both sectors. Define C_i the aggregate consumption of workers in sector i. Using our solution to the worker's decision problem (6) and aggregating across workers implies,

$$C_i = \frac{1}{P}\left(rA_i + (\pi_i - u_i)b_{ie} + u_i b_{iu}\right) + \pi\left(\frac{\rho + d - r}{\gamma r}\right) \tag{15}$$

It follows that,

$$(\pi_1 - u_1)f_1(k_1) = (1-\alpha)\left(\frac{p_1}{P}\right)^{-\eta} C_1 + (1-\alpha)\left(\frac{p_1}{P}\right)^{-\eta} C_2 + k_1 h_1(\theta_1)u_1 \tag{16}$$

$$(\pi_2 - u_2)f_2(k_2) = \alpha\left(\frac{p_2}{P}\right)^{-\eta} C_1 + \alpha\left(\frac{p_2}{P}\right)^{-\eta} C_2 + k_2 h_2(\theta_2)u_2 \tag{17}$$

so that the output produced in each sector equals consumption plus investment.[14] Combining (16) and (17) and rearranging allows us to express the autarky equilibrium relative prices as,

$$\frac{(\pi_1 - u_1)f_1(k_1) - k_1 h_1(\theta_1)u_1}{(\pi_2 - u_2)f_2(k_2) - k_2 h_2(\theta_2)u_2} = \frac{1-\alpha}{\alpha}\cdot\left(\frac{p_1}{p_2}\right)^{-\eta}. \tag{18}$$

In an open economy the relative prices of goods and the equilibrium interest rate are exogenous. Hence, supply and demand will not necessarily be equated in the goods market. This reflects that a country may be a net importer or exporter of consumption goods as the value of firms in the economy may differ from the value of assets owned by households. Any difference reflects foreign ownership of domestic assets or domestic ownership of foreign assets.[15] In Section 5 we examine how welfare is affected by deviations in relative prices from autarky while holding interest rates fixed.

In equilibrium, we seek the consumption choices of individuals in different states (b_{ie}, b_{iu}), aggregate asset holdings, A_i, the level of wages w_i, vacancies v_i, unemployment u_i and capital k_i, for each sector. These are determined by equations (7) through (13). In a closed economy we seek to find the relative price of goods and the equilibrium interest rates, r and r_f. These are determined by equations (14), (16) and (17). These endogenous variables are consistent with optimal behaviour by workers and firms, and with market clearing in financial and product markets. In the open

[13]If an economy borrows on international capital markets, then the value of assets held by individuals in the economy will be less than the value of firms in the economy and this country will feature net exports to the rest of the world. If the economy lends to the rest of the world, then the value of assets held by individuals will exceed the value of firms. This country will feature net imports. We could solve an economy in which interest rates adjust and trade is balanced, but we view our experiment of altering relative prices while keeping interest rates constant as a natural analog to experiments studied in the trade literature.

[14]Investment is equal to $k_i h_i u_i$ since $h_i u_i$ is the rate at which new matches are formed and hence the rate at which vacancies are created in a steady state. Each vacancy requires investment of k_i.

[15]A formal derivation of this result is available upon request.

economy relative prices and interest rates are exogenous so we solve equations (7) through (14) given p_1 and r_f, and normalise $p_2 = 1$.

4 Calibration

We calibrate the model to match key stylised facts of the US economy. Although the US is not a small open economy our main point is that when trading with the rest of the world, there will be some change in domestic relative prices within the US. Treating the US as a large economy within a global economy would endogenise the size of this price change. This section focuses upon the welfare effects that arise from any given particular price change.

There are a number of potential interpretations that could be given to the sectors. A sector could be associated with a geographical area or with an industry. However, we focus upon sectors as being associated with educational attainment. We view this as consistent with a large trade literature that highlights countries differ in the ratio of skilled to unskilled workers and that the opening of an economy to trade will affect economic outcomes by altering relative product prices that vary in skill intensity in production.[16] To be concrete, sector 1 will be associated with high skilled workers and sector 2 will be associated with low-skilled workers. In our calibration, parameters will be set so that high skilled workers have characteristics similar to workers with a college education or higher. Low skilled workers are calibrated to match workers with high school degrees or less.

We calibrate the model at an annual frequency. Some of the aspects of our calibration follow Uren (2018). We set d, the arrival rate of death to equal 0.025. This implies that the average life expectancy of a worker in our economy is 40 years which we view as suitable for a Blanchard-Yaari model of perpetual youth. The average tenure of a worker in the middle of their career is approximately ten years (Farber (2008)), so we set $\delta = 0.1$. We set $\pi_1 = 0.36$ and $\pi_2 = 0.64$ which is consistent with the relative sizes of our education groups in the 2010 Current Population Survey.

In each sector the number of job matches formed is determined by a Cobb-Douglas matching function, $M(u_i, v_i) = \mu u_i^{\alpha_m} v_i^{1-\alpha_m}$, for $i \in \{1, 2\}$. We maintain a constant matching efficiency and elasticity of matching with respect to unemployment across sectors. We set $\alpha_m = 0.5$ which is within the range of estimates reported by Petrongolo and Pissarides (2001).[17] A worker matched

[16] Early studies such as Lawrence and Slaughter (1993) find small effects of trade on the skill premium. This evidence has been re-evaluated by Krugman (2008) and Ebenstein, Harrison, McMillan and Phillips (2014).

[17] They obtain a range of estimated values from 0.12 to 0.81 for the elasticity of matching function with respect to unemployment using various methods. Our choice for this parameter is in the middle of the range of parameters observed in the literature. Shimer (2005), for instance, sets this parameter equals to 0.72 which is close to the top

with k units of capital stock produces $f(k_i) = x_i k_i^{\alpha_k}$ for $i \in \{1,2\}$. The labour market is imperfectly competitive. But given the production and matching technology and the wage formation mechanism, the labour share equals $1-\alpha_k$. Hence we set $\alpha_k = 0.4$ and normalise $x_2 = 1$ while x_1 is calibrated to match differences in labour market outcomes across sectors. We also set the size of unemployment benefits to target a replacement rate of 0.4 as in Shimer (2005).

We follow the literature in setting the elasticity of substitution between skilled and unskilled workers. The empirical literature relates the skill premium, which is defined as the ratio of college to high school wages, to the relative college to high school labour supply over time in the US. Katz and Murphy (1992) estimate $\eta = 1.4$. However, Acemoglu and Autor (2011) extend their work to more recent data and estimate a larger value of 2.5. We select a value of $\eta = 2$ which is within the range of the reported empirical values.

We assume that the weight of goods produced in the unskilled sector in the consumption aggregator is $\alpha = 0.6$. This is set so that the importance of goods produced in this sector is close to the relative size of this sector. Finally, we set the coefficient of absolute risk aversion, $\gamma = 5$. This parameter implies an average coefficient of relative risk aversion of 7.6 for employed skilled and unskilled workers when evaluated at the mean level of assets. This is within the range of plausible parameter values. Kimball, Sahm, and Shapiro (2008) use survey responses to hypothetical income lotteries in the Health and Retirement Study to estimate that the coefficient of relative risk aversion has a median of 6.3 and a mean of 8.2 (see table 4) of their paper. In the Appendix we investigate how sensitive our results are to changes in these pre-specified parameters.

This leaves us with the following parameters to be determined: (ρ, x_1, μ, τ). The time discount rate, productivity in the skilled sector, the efficiency of the matching function, and the tax rate are calibrated to match empirical facts. We choose these parameters to minimise the sum of squared percentage deviation of the model implied variables from a set of empirically observed moments.

We target a unskilled to skilled wage ratio of 0.56 that corresponds to the mean wages of workers with some college or less education to the workers with at least college education from the 2010 Current Population Survey. We target unemployment rates in the skilled and unskilled sectors of 2.8% and 5.8% respectively which is the average unemployment rates for the defined groups over 1995-2015. In addition, we target an investment to GDP ratio of 0.2 and a real interest rate of 5% for firms. Finally, we target the ratio of average unemployment benefit to average after tax wage income of 0.41. This rate corresponds to the average ratio of annual weighted average weekly benefit

of the estimates reported in the Petrongolo and Pissarides (2001), and Borowczyk-Martins, Jolivet and Postel-Vinay (2013) estimate this parameter to be 0.3 which is close to the bottom range of estimates reported by Petrongolo and Pissarides (2001).

amount to weighted wage income reported by the Department of Labor for 1997–2010.[18] Table 1

Table 1: **Parameter values**

Parameter	Description	Value
Pre-specified Parameters		
d	Rate of death	0.025
δ	Job destruction rate	0.1
π	Size of a sector 1 & 2	$\{0.36, 0.64\}$
α_m	Matching function elasticity with respect to u	0.5
α_k	Elasticity of output with respect to capital	0.4
α	Unskilled sector's share in CES consumption	0.6
γ	Degree of Risk Aversion	5
η	CES elasticity	2
x_2	Sector 2 (education less than college degree) productivity	1
p_2	Price of sector 2's good	1
Calibrated Parameters		
τ	Tax rate	0.02
x_1	Sector 1 (education at least college degree) productivity	2.2576
μ	Match efficiency	1.695
ρ	Time discount rate	-0.019

summarises the complete list of pre-specified parameters along with the endogenously calibrated parameter values.[19] Table 2 shows the observed data and the model implied values. Overall, the model matches the targeted moments quite well.

Table 2: **Steady State Results**

Targets	**Model**	**Data**
Unskilled to skilled wage ratio	0.48	0.56
Skilled sector unemployment rate (%)	3.24	2.8
Unskilled sector unemployment rate (%)	4.9	5.8
Risk free interest rate (%)	5.6	5
Investment-gdp ratio	0.26	0.2
Unemployment benefit to wage ratio	0.43	0.41

[18] Please see https://workforcesecurity.doleta.gov

[19] Note that since the calibrated model is overidentified, it is difficult to assign each parameter to a specific moment. However, x_1 is the main parameter that is responsible for the relative wages of sectors and μ helps pin down the sectoral unemployment rates.

5 Results

We use our model to examine the welfare effects of changes in relative prices that arise from moving from autarky to a trade equilibrium. Our method is as follows: our baseline calibration solves for the autarky equilibrium. We then consider a permanent and unanticipated change in relative prices due to trade while holding interest rates fixed. Our welfare measure focuses upon newborn individuals entering the steady state of an economy.

5.1 Steady state welfare changes

Would newborn workers prefer to enter into an economy with or without trade? To answer this question, we solve for both equilibria and calculate the compensating variation required to make these workers indifferent. To begin, we describe the impact of trade integration on steady state outcomes. The effect of a change in relative prices on real wages and the vacancy-unemployment rate are displayed in Figure 2. Unsurprisingly, an increase in the relative price of sector 1 leads to an increase in the real wage of that sector. As sectoral output becomes relatively more valuable, firms are more willing to create vacancies within that sector leading to an increase in the vacancy-unemployment rate. An increase in the vacancy-unemployment rate leads to a decline in unemployment within that sector as illustrated in Figure 3. The converse effects happen in the sector in which the relative product price declines. Finally, capital per worker also responds. In our model, capital investment is in units of sectoral output. So as the relative price of a sectoral output increases, there is a simultaneous increase in both the cost and benefit of investment. In a frictionless labour market these effects would cancel out and overall capital stock per firm would be unchanged. With a frictional labour market an increase in the relative price of a sector raises the vacancy-unemployment rate and makes it more difficult for firms to hire workers. As a result, firms will reduce the amount of capital they purchase on a per worker basis. In our calibrated model, these effects are small. A 10 percent increase in the price of sector 1 output leads to decline in capital per worker of less than a 0.25 percent.

Before we examine the welfare results in detail, we focus upon how changes in prices affect the income risk.[20] A change in prices affects uncertainty through two mechanisms. First, as in the static model, a change in the price of output directly affects the real wages of workers and this flows through to alter their labour income volatility. In our model, the income of a worker evolves

[20] From a welfare perspective, workers are concerned about the variance of consumption. However, in this framework, consumption is a non-stationary process that drifts upward over time due to precautionary saving. As a result, we focus upon income uncertainty which is closely related to consumption volatility.

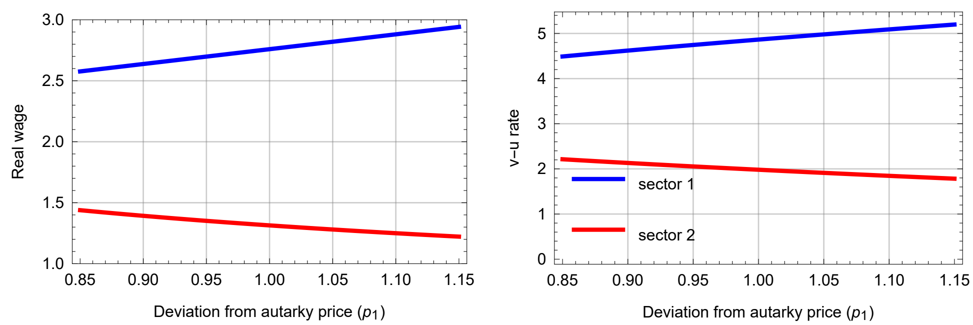

Figure 2: Response of real wages and vacancy-unemployment rate by sector to relative price changes

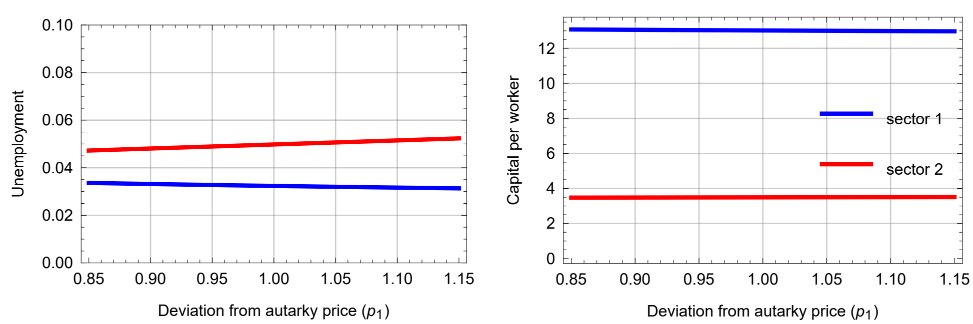

Figure 3: Response of capital per worker and unemployment rate by sector to relative price changes

according to a two-state Markov process. Given our specification for the matching and production function, workers in the sector i receive a wage,[21]

$$w_i = (1 - \phi)\frac{p_i}{P} \cdot x_i k_i^{\phi}.$$

As the relative product price of a sector increases, there is an increase in the gap between real wages of the employed relative to the unemployed within a sector. This corresponds to the effect highlighted in Section 2, in which changes in the value of the endowment affect the mean and variance of consumption.

Second, in this production economy there is an endogenous response of vacancies to changes in output prices. As the relative product price increases in a sector, it becomes more profitable to create vacancies within that sector. This endogenous response alters the job finding rate and the

[21]The derivation of this result is available on request and follows manipulation of the first order conditions combined with our specific functional forms.

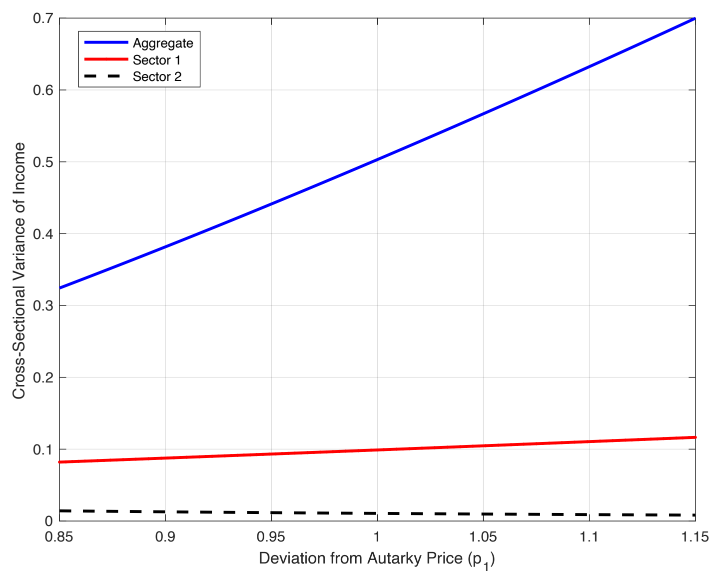

Figure 4: Cross-Sectional Variance of Wages, Aggregate and By Group

degree of uncertainty faced by workers. If workers lived forever, they would spend a fraction, $\frac{\delta}{\delta+h(\theta_i)}$, of time employed and a complementary fraction, $\frac{h(\theta_i)}{\delta+h(\theta_i)}$ unemployed. The cross-sectional distribution of income is informative of the risk that an individual worker faces since the distribution of income of a worker earns over their lifetime converges to the long run cross sectional distribution. Figure 4 displays the aggregate cross-sectional variance of income as well as the variance conditional upon group. An increase in relative price of sector 1 output raises within-group inequality of workers in sector 1 but lowers within-group inequality of workers in sector 2. In aggregate, there is an increase in the cross-sectional variance of income that is mainly driven by the between-group differences with only modest changes in within-group inequality.

As before, we use the concept of compensating variation as our welfare measure. For our steady state calculation we focus only upon newborn individuals who enter the economy. We ask the following question: what quantity of real assets (a'/P') would an individual require to enter an economy with trade in which relative prices are given by p'_1 and a corresponding aggregate price index of P' to provide the same expected lifetime utility as entering with zero assets in an economy without trade.

Calculating the compensating variation for an individual is feasible since we have an explicit solution for the value function given by (5). Let superscripts nt and t define the equilibrium values in the non-trade and the trade equilibrium, respectively (ie. $V_j^{nt}(a)$ and $V_j^t(a)$ are the values associated

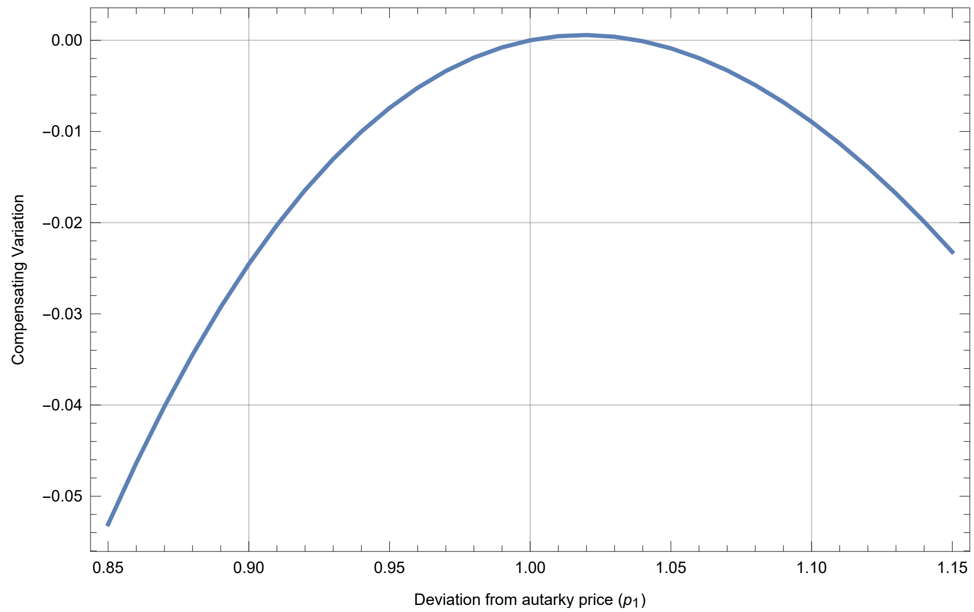

Figure 5: Compensating variation to relative price changes

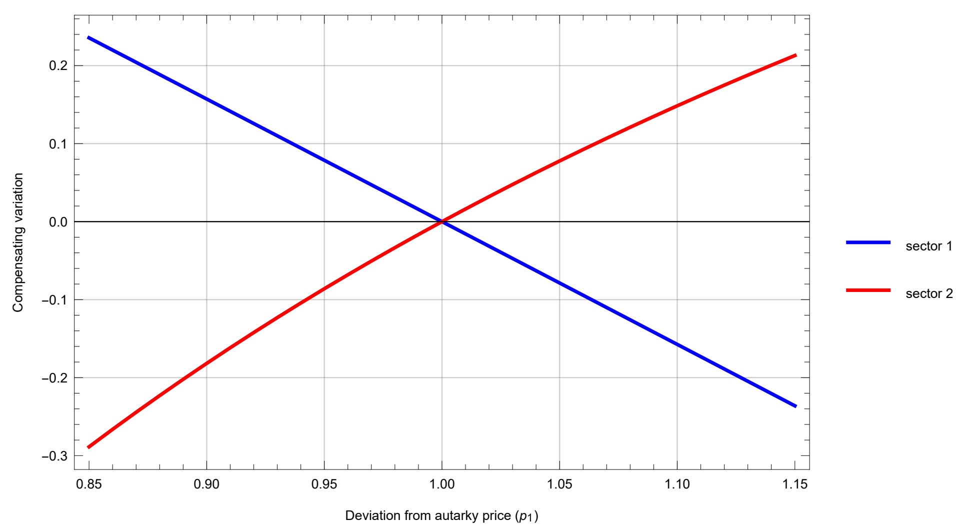

Figure 6: Compensating variation by sector to a relative price change

with employment status j, asset level a, in a non-trade and trade equilibrium). We then equate $V_u^{nt}(0) = V_u^t(a')$ to find the implied a' that yields the same expected utility in a trade equilibrium. With no change in interest rates, the compensating variation for a worker in sector i becomes

$$\frac{a'}{P'} - \frac{a}{P} = \frac{1}{r}\left(\frac{b_{ij}^{nt}}{P} - \frac{b_{ij}^{t}}{P'}\right).$$

We then aggregate over all future entrants into the economy by taking into account the rate at which newborns enter the economy, the relative size of each sector, and we discount payments to future generations of entrants at an interest rate of r.

The effect of changes in relative prices upon aggregate welfare is displayed in Figure 5. For this calibration, an increase in p_1 of about 3.5 per cent yields no welfare gains; smaller price changes in this direction lead to welfare losses. To put this into perspective, Amiti, Dai, Feenstra and Romalis (2017) estimate that China's entry into the WTO reduced the US manufacturing price index by around 7.6 per cent. This is larger than the 3.5 per cent value that would result in no gains from trade. The breakdown of compensating variation required by each sector is provided in Figure 6. Unsurprisingly, the sector that features a rise in relative price gains from trade and the workers in the sector that face a fall in relative prices lose if uncompensated.

We also examine how the degree of risk aversion alters the welfare implications of trade. To do so, we recalibrate our model and set $\gamma = 0.001$ so workers are almost risk neutral over the range relevant to our problem. We then recalibrate the model by selecting values for τ, x_1, μ, and ρ to match the same set of targets as our baseline calibration. Details of this process are in the Appendix. Finally, we then compare the welfare gains from trade in this calibration in which workers are approximately risk neutral with our baseline calibration in which workers are risk averse. The results of this exercise are shown in Figure 7. Here we find a feature similar to our static model described in Section 2. In particular, in the case in which preferences are approximately risk neutral, the first order impact of a change in prices is much smaller than in the case in which preferences are risk averse.

We have not calculated the welfare impact along the transition path on existing households as the economy moves from autarky to free trade. The key difficulty here is that workers and firms form job matches in a frictional environment. It is well known that a bilateral monopoly problem exists and wages need to be set to divide the surplus from trade between workers and firms. In our steady state environment, the surplus from trade is endogenously divided by assuming a directed search environment in which firms competitively post wages and workers direct their search to the best existing offers in the labour market. When dealing with an environment with shocks it is difficult

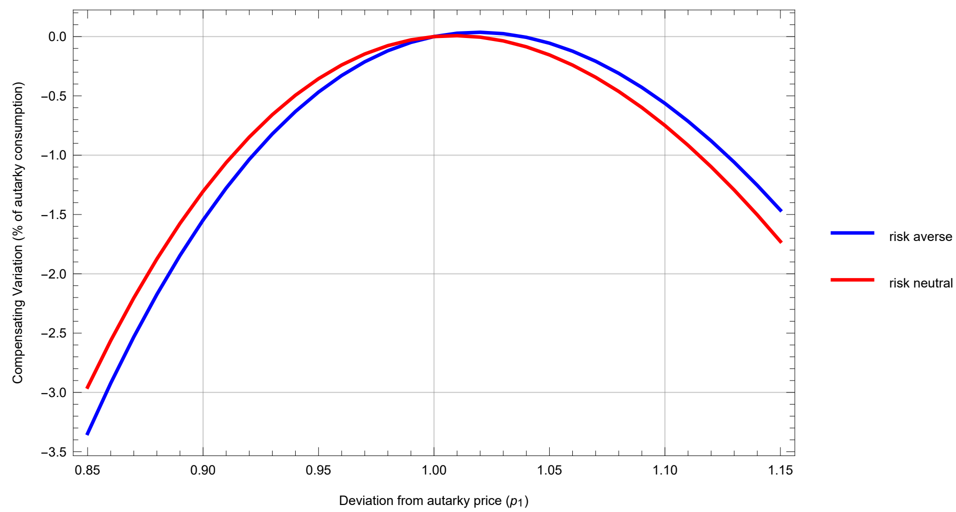

Figure 7: Comparing economy with approximately risk neutral workers with economy with risk averse workers

to endogenise how wages respond to changes in the economic environment.[22]

6 Conclusion

In this paper we examine how risk aversion affects the welfare gains from trade. The Theory of the Second Best applies if markets are incomplete. In particular, removing trade distortions changes the amount of risk faced in different sectors of the economy. These changes will in general, have a first order welfare impact upon the economy. We examine this in two frameworks. First, in a static economy we derive a condition under which a small change in relative prices will lead to either a welfare gain or loss. Second, in a dynamic economy with a frictional labour market we consider the impact of a change in relative prices due to trade in a setting in which workers have access to unemployment insurance and are able to partially insure themselves by using financial markets. As in the static model, we find that small changes in relative prices due to trade can reduce welfare. In our quantitative exercise we find that for small changes in relative prices that favour workers in the skilled sector that there are essentially no gains from trade. Gains from trade exist if changes in relative prices favour the unskilled, or if there are large changes in prices that favour the skilled.

[22] For example, it may be rational for workers and firms to continue in pre-existing match even after trade integration without wages adjusting. It could also be rational for workers to receive an change in wage that attributes all of the change in match surplus to changes in the value of the worker. In a previous version of the paper, we have calculated welfare along the transition assuming that wages at firms adjust instantanteously to the new equilibrium wage in each sector. In doing so, our results are qualitatively similar to those presented when restricting attention to the welfare of newborn individuals. Details of this analysis are available upon request.

Our quantitative model has some special features. In particular, there is no natural borrowing constraint. With CARA preferences we allow individuals to borrow a large amount and repay debt by permitting low (or even negative) levels of consumption. In this sense financial markets are not complete but they may provide a greater degree of insurance than what we may expect in reality. We suspect that if individuals had CRRA utility and were subject to a natural borrowing constraint that individuals would be less able to self-insure and that would have implications upon our quantitative results. In reality, we also expect that the degree of access to financial markets may vary by sector. High skilled workers with greater education may be better able to access financial markets. This is at least consistent with the work of Kaplan, Violante and Weidner (2014) who find that hand-to-mouth consumers have less education, on average.

A second feature that deserves mention is that labour is attached to a specific sector. Although the model could be extended to allow workers to transition between sectors of the economy,[23] we find our assumption plausible given that groups are based upon educational attainment. Attaining college education later in life is rare. The Current Population Survey reveals that in December 2018 less than one percent of high school graduates over the age of 25 were enrolled in college education. This puts a low upper bound on the transition rate from high school to college education. More broadly, sectors could be interpreted as geographical areas, industries or occupations. The evidence on industries suggests that although there are large gross flows of workers moving across industries, the size of the net flows are relatively small. Artuç, Chaudhuri and McLaren (2010) interpret this fact as indicating that idiosyncratic preference shocks are important in determining industry choice. These shocks slow down aggregate reallocation, and suggest the assumption of labour being attached to a specific sector may be a useful first pass even for these other interpretations.

In our work, the gains from trade arise from two sources. First, as relative prices change the economy can use more intensively factors of production in the sector that produces more valuable output. Second, consumers are able to substitute their consumption towards products that become relatively less expensive. Hence, the scope of our result is concerned with welfare implications associated with changes in prices that allow a more efficient allocation of resources in production or in consumption. These are the traditional gains from trade. Of course, there are other possible mechanisms via which an economy may gain from trade. Trade may facilitate the transfer of technology across borders, widen the variety of goods consumed, and increase the degree of product market competition.[24] Our paper is silent on the benefits of trade along these dimensions.

[23]Details are available from the authors on request.

[24]See Broda and Weinstein (2006), Grossman and Helpman (1991) and Feenstra and Weinstein (2017) for a discuss of the gains from trade from increased variety, technological spillovers, and increased competition.

Finally, we provide a brief comment on trade policy. In recent years, it has been popular in some parts of the world for politicians to support protectionist and trade inhibiting policies. Our work suggests that for the US economy has gained from trade, given the observed size of price changes. Efforts to reduce the relative price change from trade by imposing tariffs, or through other means, would move us away from our current trade equilibrium and lead to welfare losses in a Kaldor-Hicks sense.

7 Appendix

Proof of Proposition 1 This is a standard result in international trade. See Dixit and Norman (Chapter 3, Section 2) for a discussion. They show that a set of feasible transfers exist that allow workers to consume their autarky bundle in a free trade equilibrium.

Proof of Proposition 2 Let p_1 denote the autarky price and p_1' denote the price in a trade equilibrium and P and P' denote the aggregate price index in autarky and trade equilibrium respectively.

Consider the following transfer scheme for workers in the trade equilibrium:

$$T_1 = P'\left(\frac{h_1 p_1 \bar{x}_1}{P} + \frac{(1-h_1)p_1 \underline{x}_1}{P}\right) - h_1 p_1' \bar{x}_1 - (1-h_1)p_1' \underline{x}_1$$
$$T_2 = P'\left(\frac{h_2 \bar{x}_2}{P} + \frac{(1-h_2)\underline{x}_2}{P}\right) - h_2 \bar{x}_2 - (1-h_2)\underline{x}_2.$$

where T_i describes the amount provided to a worker in sector i. We want to verify that (i) this transfer scheme generates the same expected utility for the worker as autarky and (ii) this transfer scheme is feasible without any additional resources into the economy.

The transfer scheme implies that the income of workers in sector 1 in a trade equilibrium with endowment realisation x_1 is

$$\begin{aligned} p_1' x_1 + T_1 &= p_1 x_1 + P'\left(\frac{h_1 p_1 \bar{x}_1}{P} + \frac{(1-h_1)p_1 \underline{x}_1}{P}\right) - h_1 p_1' \bar{x}_1 - (1-h_1)p_1' \underline{x}_1 \\ &= p_1' x_1 + P'\left(\frac{p_1}{P}E[X_1]\right) - p_1' E[X_1] \end{aligned}$$

The expected income of an individual in sector 1 becomes

$$P'\left(\frac{p_1}{P}E[X_1]\right)$$

which implies that workers in the trade equilibrium are, in expectation, able to purchase the same amount of the aggregate consumption good as they did in autarky. With utility linear in C, workers are indifferent between autarky or the trade equilibrium with proposed transfers.

A similar argument applies for workers in sector 2. In a trade equilibrium their income when x_2 is realised output is

$$x_2 + T_2 = x_2 + P' \left(\frac{h_2 \bar{x}_2}{P'} + \frac{(1-h_2)\underline{x}_2}{P'} \right) - h_2 \bar{x}_2 - (1-h_2)\underline{x}_2$$
$$= x_2 + P'(\frac{E[X_2]}{P}) - E[X_2]$$

The expected income of an individual in sector 2 becomes

$$P' \left(\frac{E[X_2]}{P} \right)$$

whihc is sufficient income to allow the purchase of the same amount of the aggregate consumption good as they did in autarky. With utility linear in C, workers are indifferent between autarky or the trade equilibrium with proposed transfers.

We now show that this system of transfers is feasible without an inflow of additional resources into the economy. The total value of transfers is

$$\pi T_1 + (1-\pi)T_2 = P' \left(\pi \frac{p_1}{P} E[X_1] + (1-\pi)\frac{E[X_2]}{P} \right) - \pi p_1' E[X_1] - (1-\pi)E[X_2]$$
$$= P' C_A - \pi p_1' E[X_1] - (1-\pi)E[X_2] \leq 0$$

where I denote C_A the autarky aggregate consumption amount. The last inequality follows since $P'C_A$ is the smallest expenditure to achieve aggregate consumption of C_A. The amount $\pi p_1' E[X_1] + (1-\pi)E[X_2]$ is able to purchases an amount of aggregate consumption index equal to C_A (since the endowment is equal to the autarky value of consumption) when given prices $(p_1', p_2 = 1)$ but does not do so in a cost minimizing manner. Hence the amount $\pi p_1' E[X_1] + (1-\pi)E[X_2] \geq P'C_A$. This implies that the posited transfer system is feasible and enables workers to have the same level of expected aggregate consumption as in autarky.

Proof of Proposition 3

Note that in autarky using our normalisation that $p_2 = 1$, market clearing in the domestic economy requires that

$$\frac{1-\alpha}{\alpha} \left(\frac{p_1}{p_2} \right)^{-\eta} = \frac{\pi_1 (h_1 \bar{x}_1 + (1-h_1)\underline{x}_1)}{(1-\pi)(h_2 \bar{x}_2 + (1-h_2)\underline{x}_2)} = \frac{\pi E[X_1]}{(1-\pi)E[X_2]}$$
$$P = ((1-\alpha)p_1^{1-\eta} + \alpha)^{1/(1-\eta)}$$

Expected utility of a worker in sector j facing own price p_j and ideal price index P receiving a transfer τ_j is

$$U_j = h_j U(p_j \bar{x}_j / P + \tau_j) + (1-h_j) U(p_j \underline{x}_j / P + \tau_j)$$

We use the implicit function theorem to show the change in τ_j required to keep expected utility constant as p_1 changes,

$$\frac{d\tau_j}{dp_1} = -\frac{h_j U'(p_j \bar{x}_j/P)\frac{d(p_j\bar{x}_j/P)}{dp_1} + (1-h_j)U'(p_j \underline{x}_j/P)\frac{d(p_j\underline{x}_j/P)}{dp_1}}{h_j U'(p_j\bar{x}_j/P) + (1-h_j)U'(p_j\underline{x}_j/P)}$$

and (again using our normalisation $p_2 = 1$) we can evaluate how the real wage responds to changes in prices:

$$\begin{aligned}
\frac{d}{dp_1}\left(\frac{p_1 x_1}{P}\right) &= \frac{Px_1 - p_1 x_1 \cdot \frac{d}{dp_1}P}{P^2} \\
&= \frac{x_1}{P^2}(P - p_1 c_1^*) = \frac{x_1}{P^2}\cdot c_2^* \\
\frac{d}{dp_1}\left(\frac{x_2}{P}\right) &= -\frac{x_2 \cdot \frac{d}{dp_1}P}{P^2} \\
&= \frac{x_2}{P^2}\cdot c_1^*
\end{aligned}$$

where we use the envelope theorem and definition of P in the above calculations.[25] In our general setting, the aggregate compensating variation required is

$$\pi\frac{d\tau_1}{dp_1} + (1-\pi)\frac{d\tau_2}{dp_1}$$

We can express this as:

$$\begin{aligned}
&-\pi\frac{h_1 U'(p_1\bar{x}_1/P)\frac{d(p_1\bar{x}_1/P)}{dp_1} + (1-h_1)U'(p_1\underline{x}_1/P)\frac{d(p_1\underline{x}_1/P)}{dp_1}}{h_1U'(p_1\bar{x}_1/P) + (1-h_1)U'(p_1\underline{x}_1/P)} \\
&-(1-\pi)\frac{h_2 U'(p_2\bar{x}_2/P)\frac{d(p_2\bar{x}_2/P)}{dp_1} + (1-h_2)U'(p_2\underline{x}_2/P)\frac{d(p_2\underline{x}_2/P)}{dp_1}}{h_2U'(p_2\bar{x}_2/P) + (1-h_2)U'(p_2\underline{x}_2/P)}
\end{aligned} \tag{19}$$

Using our expressions for how the real wage responds to changes in p_1 and factoring we find the sign of the above expression equals the sign of,

$$-\pi\frac{(h_1U'(p_1\bar{x}_1/P)\bar{x}_1c_2^* + (1-h_1)U'(p_1\underline{x}_1/P)\underline{x}_1c_2^*)}{h_1U'(p_1\bar{x}_1/P) + (1-h_1)U'(p_1\underline{x}_1/P)} + (1-\pi)\frac{(\bar{x}_2h_2U'(p_2\bar{x}_2/P)c_1^* + \underline{x}_2(1-h_2)U'(p_2\underline{x}_2/P))c_1^*}{h_2U'(p_2\bar{x}_2/P) + (1-h_2)U'(p_2\underline{x}_2/P)}$$

or equivalently,

$$-\pi c_2^*\frac{E[U'(C_1)X_1]}{E[U'(C_1)]} + (1-\pi)c_1^*\frac{E[U'(C_2)X_2]}{E[U'(C_2)]}$$

[25] As an aside, a number of special cases arise. If $h_j = 1$ (that is no uncertainty) then we find

$$\frac{d\tau_j}{dp_1} = \frac{dp_j\bar{x}_j/P}{dp_1}$$

and after some calculations we find,

$$\pi\frac{dp_1\bar{x}_1/P}{dp_1} + (1-\pi)\frac{dp_2\bar{x}_2/P}{dp_1} = 0$$

where we use $\pi = \pi_1$ to simplify notation. A similar result applies for the risk neutral case.

The sign of this depends equals the sign of

$$-\pi\frac{E[U'(C_1)X_1]}{E[U'(C_1)]} + (1-\pi)\frac{c_1^*}{c_2^*}\frac{E[U'(C_2)X_2]}{E[U'(C_2)]}$$

In autarky, $\frac{c_1^*}{c_2^*} = \frac{\pi E[X_1]}{(1-\pi)E[X_2]}$ since prices adjust to ensure supply equals demand. As a result, the sign of above equals the sign of

$$-\frac{E[U'(C_1)X_1]}{E[U'(C_1)]E[X_1]} + \frac{E[U'(C_2)X_2]}{E[U'(C_2)]E[X_2]}$$

or equivalently,

$$-\frac{E[U'(C_1)X_1]}{E[U'(C_1)]E[X_1]} - 1 + \frac{E[U'(C_2)X_2]}{E[U'(C_2)]E[X_2]} + 1$$

which can be rewritten as

$$-\frac{cov(U'(C_1), X_1)}{E[U'(C_1)]E[X_1]} + \frac{cov[U'(C_2), X_2]}{E[U'(C_2)]E[X_2]}$$

7.1 Interpretation of ζ_i

Suppose an individual in sector i could sell a portion of their risky endowment at a price of q and purchase one unit of the output they produce at a price normalised to one. With access to this market the decisionmaker would face the following problem:

$$\max E[U(C_i)] = \max E[U(\frac{p_i}{P} \cdot (\alpha X_i + (1-\alpha)q_i))]$$

where they retain a portion α of their endowment and sell a portion $1-\alpha$ of their endowment and in exchange purchase $(1-\alpha)q$ units of the commodity they produce. The first order condition associated with this problem is

$$\begin{aligned}
&E[U'(C_i) \cdot \frac{p_i}{P} \cdot (X_i - q_i)] = 0 \\
\rightarrow &E[U'(C_i) \cdot (X_i - q_i)] = 0 \\
\rightarrow &E[U'(C_i) \cdot X_i] = q_i E[U'(C_i)] \\
\rightarrow &q_i = \frac{E[U'(C_i) \cdot X_i]}{E[U'(C_i)]} \\
\rightarrow &\frac{q_i}{E[X_i]} - 1 = \frac{E[U'(C_i) \cdot X_i]}{E[U'(C_i)]E[X_i]} - 1 = \frac{cov(U'(C_i), X_i)}{E[U'(C_i)]E[X_i]}
\end{aligned}$$

The left hand side is the price penalty in percentage terms that the risky asset has relative to its expected value.

7.2 Robustness Checks

In this section we examine the sensitivity of our results to different parameter configurations, i.e γ, α, α_m and η. In deriving the results, we re-calibrate the model by varying the values of a single parameter and hold fixed the other parameters to their baseline calibrated values. Table 3 reports the results. The first row of the table reports the result of the baseline calibration. We showed that in our baseline calibration, table 1, the required size of price deviation for obtaining negative welfare loss following trade openness is about 3.5%. The rest of the table shows how the required price deviation to achieve welfare gains varies with model parameters.

Table 3: **Sensitivity Analysis**

Parameter	**Max p_1 increase that generates welfare loss**
Baseline	3.5 %
$\gamma = 4$	3 %
$\eta = 1.5$	6.4 %
$\eta = 2.5$	2.6 %
$\alpha_m = 0.3$	3.6 %
$\alpha_m = 0.7$	1.7 %
$\alpha = 0.5$	3.1 %

In the second and third rows, we investigate the effect of changing the risk aversion parameter, γ, by one unit around its baseline value. The required price deviation for welfare loss increases with the risk aversion. Decreasing the risk aversion in the model by one unit, $\gamma = 4$, increases the required size of deviation in price of goods produced in the skilled sector for generating the negative welfare by about 0.5 percentage point. We also experiment with varying the elasticity of substitution between sectors' goods. We first set this parameter to $\eta = 1.5$ which is close to the findings of the Katz and Murphy (1992). We then increase this value to 2.5 which follows from the more recent study by Acemoglu and Autor (2011). The result of this experiment shows that with an increase in this parameter the required deviation in the price of goods produced by skilled worker for generating the negative welfare declines.

Next, we experiment the sensitivity of our results to the elasticity of matching function with respect to unemployment. We report the results for $\alpha_m = 0.3$ and $\alpha_m = 0.7$. The former follows from the work by Borowczyk-Martins, Jolivet and Postel-Vinay (2013) and the latter is close to the value used by Shimer (2005). We find that with increase in this parameter the required price deviation of skilled goods decreases following trade openness. Finally we examine the sensitivity of results to changes in the relative share of goods produced by unskilled workers, i.e α. We lower this parameter to $\alpha = 0.5$ which implies equal shares of workers types in the aggregate consumption. We find that the required price deviation for generating negative welfare decreases by about 0.4 percentage point.

7.3 Risk Aversion versus Risk Neutral

We recalibrate the model for the case in which preferences are almost risk neutral. To do so we keep all of the pre-specified parameters unchanged except we consider $\gamma = 0.001$. The calibrated parameters are selected to match the same set of data targets that are used for the risk averse calibration.

Table 4: **Parameter values**

Parameter	**Risk Neutral**	**Risk Averse (baseline)**
Pre-specified Parameters		
d	0.025	0.025
δ	0.1	0.1
π	$\{0.36, 0.64\}$	$\{0.36, 0.64\}$
α_m	0.5	0.5
y_u	0	0
α_k	0.4	0.4
α	0.6	0.6
γ	0.001	5
η	2	2
x_2	1	1
p_2	1	1
Calibrated Parameters		
τ	0.0183	0.0191
x_1	2.1161	2.2576
μ	2.0161	1.695
ρ	0.0559	-0.019

Table 5: **Steady State Results**

Targets	**Risk Neutral**	**Risk Averse**	**Data**
Unskilled to skilled wage ratio	0.5	0.48	0.56
Skilled sector unemployment rate (%)	3.3	3.24	2.8
Unskilled sector unemployment rate (%)	4.4	4.9	5.8
Risk free interest rate (%)	5.6	5.6	5
Investment-gdp ratio	0.26	0.26	0.2
Unemployment benefit to wage ratio	0.45	0.43	0.41

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