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Pollution from Consumption and the Trade and Environment Debate

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Abstract

Pollution generated by consumption has largely been ignored in the trade and environment debate, despite the fact that it accounts for a large portion of total emissions. This paper develops a Heckscher-Ohlin model of international trade and pollution emissions and analyzes the impact of trade liberalization on pollution generated by production and consumption. The results indicate that pollution from consumption can increase when pollution from production decreases after a trade liberalization (and vice versa). This is due to a large change in the mix of industries (the composition effect), which dominates changes in the size of the economy and production technology (the so-called scale and technique effects respectively). Trade liberalization leads to a convergence in pollution levels from consumption and a divergence in pollution emissions from production. The more similar the countries liberalizing bilateral trade, the smaller the composition effect and the more scope there is for environmental regulations to reduce total emissions.

Keywords: trade and environment, north-south models, trade liberalization impacts

JEL Codes: F18, Q5

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1 Introduction

International trade's increasing importance to the world economy has come with growing focus on trade's impact on the environment. While this relationship has been widely studied, to date the literature has focused almost exclusively on pollution from the production of a good that is exported. If emissions from production and consumption respond to trade liberalizations in a similar way, this omission may not be important. The focus of this paper is to examine the impact of trade liberalization on pollution from production and consumption in a single framework. The results indicate that under fairly general conditions, a trade liberalization leads to an increase in pollution from consumption and a decrease in pollution from production (or vice versa). Expanding the standard model allows us to consider several pollutants primarily generated by consumption such as municipal waste, ground level ozone and carbon dioxide. These pollutants have been the subject of significant policy debates in recent years.

Data on emissions suggest that consumption is an important part of the pollution profile. The Inventory of New York City Greenhouse Gas Emissions (2007) calculated that just under half of the CO_2 emissions in New York City are generated by consumption. In North Carolina, between 35% and 54% of mercury emissions are by-products of consumption according to 1998-99 DAQ and Local Program Emissions Inventories. Data for developing countries is sparser, but Gopalakrishnan (1997) found that consumption generated at least 34% and as much as 52% of the air pollution in Kolkata (Calcutta), India. Results from Munksgaard *et al.* (2000) suggest that the importance of pollution from consumption is growing. The authors find that most of the growth in CO_2 emissions in the Netherlands over the period 1966-1992 has been due to consumption. Further, the authors note that this increase in emissions from consumption has been partially offset by reductions in emissions from production. Taken together these results suggest that pollution from consumption is a large and increasing portion of total emissions.

After several years of relative inactivity, research examining the relationship between trade and the environment was reignited by Grossman and

Krueger's (1993) examination of the environmental impact of the North American Free Trade Agreement.[1] The literature has separated the impact of trade liberalization on pollution emissions into three categories: the scale, technique and composition effects. These channels were first hypothesized by Grossman and Krueger (1993) and modeled explicitly by Copeland and Taylor (1994). The scale effect is the increase in pollution due to increased economic activity generated by a trade liberalization. The technique effect is a reduction in pollution due to increased demand for environmental quality (a normal good) after a trade liberalization. The composition effect is the change in pollution due to the changes in the production (or consumption) bundle generated by a trade liberalization. This effect may generate either increases or decreases in pollution.

Copeland and Taylor's 2003 book expands their 1994 model of trade and the environment. This model has become the standard for exploring the impact of international trade on environmental quality. The authors solve for each of the three channels through which trade liberalization can impact the environment. They use these solutions to analyze the conditions under which trade liberalization improves environmental quality. The empirical results in Antwieler *et al.* (2001) suggest a small but significant improvement in environmental quality associated with increased trade volumes.

The authors also note that their "focus on production-generated pollution meant [they] neglected consumption-generated pollution." They suggest that expanding their model to include pollution from consumption should allow for the study of different pollutants. Copeland and Taylor do not speculate on how this extension would affect their results. Cole (2004) suggests that "future research should focus on the environmental impact of consumption at the expense of the more traditional emphasis on production."

There have been several efforts to consider the impact of international trade on pollution generated by consumption. Copeland and Taylor (1995) shows that the pollution haven hypothesis (polluting industries relocating en masse to developing countries to take advantage of lower levels of regulation) is a concern when emissions are generated by production or consumption. This paper seeks to expand their treatment by considering pollution levels rather than plant movements. McAusland (2008) examines the impact of environmental regulation on trade flows for emissions from tailpipe (consumption) and smokestack (production). The results suggest that the same

[1]See Baumol (1971), Markusen (1975) and Siebert (1977) for early references.

environmental regulation could have opposite effects on trade flows when the pollution generation scheme is changed. The results of this paper are complementary, suggesting that the same trade policy will lead to different levels of pollution when the pollution generation scheme changes.

This paper contributes to the literature by examining pollution from production and consumption of both imports and exports in the same framework to ease comparisons. The results will focus on cases in which trade liberalization leads to differential changes in pollution from production and consumption, which I will term pollution reversals. The next section will develop a model of trade and the environment including pollution from consumption. Section 3 will outline a computable general equilibrium version of the model and discuss the results. Section 4 will calculate the channels through which trade liberalization impacts the environment. The final section will conclude and consider empirical implications.

2 Conceptual Framework

The model is based on a traditional 2x2x2 Heckscher-Ohlin model. There are two countries, the capital abundant North and the labor abundant South. Consumers in the two countries have identical preferences over consumption goods and environmental quality. There are two goods, X and Y. X production is relatively labor intensive and Y production is capital intensive. The production technology for each good is the same in each country. The North will export Y (the capital intensive good) and the South will export X.[2] Each country can set a tariff on imports τ_N and τ_S. Therefore domestic prices of imported goods are: $p_X^N = p_X^S(1+\tau_N)$ and $p_Y^S = p_Y^N(1+\tau_S)$. Tariff revenue is lump sum redistributed to the domestic consumers.

Pollution emissions (Z) are a function of a constant emissions intensity (e) and the source of pollution. Let X_{ij} be commodity X produced in country i and consumed in country j. The pollution generation equation for emissions from X production in the North is $Z_N = e(X_{NN} + X_{NS})$. The emissions generation equation for pollution from X consumption in the North is: $Z_N = e(X_{NN} + X_{SN})$.

Figure 1, based on Antweiler *et al.* (2001), summarizes the model for the North. The upper panel illustrates trade, while pollution is graphed on

[2] This result is a simple application of the Heckscher-Ohlin theorem, which states that a country will export the good that uses intensively its relatively abundant factor.

the bottom. Assume that the North sets τ_N high enough to choke off trade. q_a is the autarky price ratio in the North and A is the consumption and production point for the economy. In the bottom panel, emissions increase down the axis. The pollution level in the North is E_a. Consumption and production must be equal in autarky so the source of pollution is not an issue. A reduction in τ_N allows trade, shifting the price ratio to q_w. The production point for this new price ratio is B and the consumption point is C.

The bottom panel illustrates the importance of the pollution generation mechanism. If pollution is generated from X production the emissions level is E_p. If pollution is generated by X consumption the pollution level is E_c. Liberalizing trade in the North can reduce pollution from production, but increase pollution from consumption. This suggests emissions changes created by a trade liberalization may be sensitive to the pollution generation mechanism. Figure 2 illustrates that pollution from production and consumption can move in different directions after a trade liberalization in the South as well. Figures 1 and 2 represent special cases in which pollution reversals can occur. The rest of this section will develop a simple model that can be used to examine the conditions under which trade liberalizations are likely to lead to differential changes in pollution from production and consumption.

2.1 Estimating the Impact of Liberalization

I will begin testing the impact of trade liberalization under different pollution emissions by considering pollution generated from X production. The pollution generation equation is $Z = e(X_{NN} + X_{NS})$ in the North and $Z = e(X_{SS} + X_{SN})$ in the South. To find the impact of trade liberalization on emissions, I use the HO Theorem to sign the change in X production and consumption after a move from autarky to free trade. To economize on notation I assume that both countries' tariffs on each good are equal.

After a liberalization, X production in the North will decrease, as X is imported from the South instead of being produced domestically, therefore $\frac{dX_{NN}}{d\tau} < 0$. In the South, trade liberalization allows export of X to the North, thus $\frac{dX_{SN}}{d\tau} > 0$. Unfortunately the impact of liberalization on X consumption in the South is indeterminant. Liberalization will lead to an increase in X production, but some of this output will be exported to the North. If the increase in production is larger than exports, then liberalization will lead to an increase in X consumption;[3] in other words the income effect must outweigh the substitution effect. If the increase in exports is larger than the increase in production, then liberalization will lead to a decrease in X consumption.[4]

We can analyze the impact of a trade liberalization on pollution from X production by comparing the emissions level before and after a Northern tariff reduction ($'$ represents post-liberalization quantities):

$$e(X'_{NN} + X'_{NS}) - e(X_{NN} + X_{NS}) =$$

$$e(X'_{NN} + X_{NN}) - e(X'_{NS} + X_{NS}) =$$

$$e(\frac{dX_{NN}}{d\tau}) + e(\frac{dX_{NS}}{d\tau}) < 0$$

The first term is negative and the second term is zero, therefore the net change must be negative. A reduction in tariff leads to a reduction in X production in the North, which means a reduction in pollution. Liberalization will not lead to X exports from the North, so there is no change in the pollution level from X_{NS}. The net effect of a trade liberalization is a reduction in emissions in the North when pollution is generated by X production. Similarly, from pollution generated by X consumption in the North:

$$e(X'_{NN} + X'_{SN}) - e(X_{NN} + X_{SN}) =$$

$$e(X'_{NN} + X_{NN}) - e(X'_{SN} + X_{SN}) =$$

$$e(\frac{dX_{NN}}{d\tau}) + e(\frac{dX_{SN}}{d\tau}) > 0$$

The first term is positive and the second is negative. If X is a normal good and trade is welfare improving, we know that a liberalization must lead to an increase in consumption of the imported good. This suggests that the first term must be larger in magnitude than the second and that trade liberalization leads to an increase in pollution from X consumption in the North. These results suggest that changing the pollution generation

[3] X_{NS} must equal 0 so I can refer to X_{SS} as X consumption in the South. For the same reason trade liberalization will have no impact on X_{NS}.

[4] As long as the two countries are the same size, there will be a reduction in X consumption, but I will refrain from making that assumption in this section.

mechanism can reverse the impact of a trade liberalization.

The analysis of the impact of trade liberalization on pollution generated by X in the South is less straightforward due to the difficulty in signing the impact of tariffs on Southern X consumption. Trade liberalization must lead to a decrease in X production, and thus emissions, in the South. If pollution is generated by X consumption then the effect of a trade liberalization is indeterminate. The income effect of trade liberalization has a positive impact on consumption, but the price increase from the autarky to world price has a negative impact. If the price effect dominates, X consumption will fall after the liberalization and with it pollution emissions. This represents another pollution reversal.

A similar approach can be used to sign the impact of liberalization on pollution generated by good Y, the capital intensive good. Trade liberalization will lead to an increase in Y production in the North and a decrease in the South. Assuming Y is a normal good and liberalization improves welfare, its consumption must increase in the South. Changing the pollution generation scenario from production to consumption will cause a pollution reversal. In the North a pollution reversal will occur if the price effect outweighs the income effect.

Summarizing the results from this section, if pollution is generated from production of the good in which a country does not have a comparative advantage (the import good), a trade liberalization will lead to a reduction in pollution. If emissions are generated by the consumption of the imported good, trade liberalization will lead to an increase in emissions. If emissions are generated by the export good pollution then reversals will occur when the price effect outweighs the income effect. In that case liberalization will lead to an increase in emissions from production and a decrease in emissions from consumption.

2.2 More Than Two Goods, Factors and Countries

Not all results from the 2x2x2 HO model generalize to higher-dimension versions of the model. This section will analyze the impact of expanding the model on the pollution reversals described in the previous section. With 2 factors, 2 countries and n commodities, the direction of trade for any single good becomes indeterminant. With the simple model described in the previous section, if a single good generates pollution, we can no longer be sure of the impact of trade liberalization on emissions.

The simplest way to address this issue is to break the n commodities into two groups divided by capital intensity. As long as the polluting goods are segregated in one of the groups and the relative prices within groups remain unchanged, then the results from the previous section will hold.[5] A similar approach can be used to address a model with multiple countries. This requires defining each country's factor abundance relative to the world endowments. Now trade liberalization by a single country can be treated as equivalent to the model described above. Meaning pollution reversal can occur.

When the model is expanded to include multiple factors and countries, as well as commodities, these groupings may no longer be sufficient to ensure these reversals. Under these conditions, ranking goods by factor intensity is no longer straightforward. A commodity may be low on the capital to unskilled labor ratio ranking, but high in the capital to high skill ratio ranking. Generating two groups with similar behavior here would be impossible. Fortunately, the factor-content theorem (sometimes called the Heckscher-Ohlin-Vanek Theorem) can be of help. It states that for an arbitrary (but equal) number of factors and commodities, a ranking of the content of any factor in net exports divided by its content in total output will duplicate the ranking of relative factor endowments. This suggests that as long as emissions are associated with particular factors, the impact of a trade liberalization on emissions can be found. When the number of factors and commodities is not equal, additional assumptions are needed to ensure that the factor-content theorem holds. See Either (1984) for a full discussion of these issues.

3 Computable General Equilibrium Model and Results

This section will develop a CGE version of the model outlined in the previous section using the model described by Markusen (2002) as a starting point. This requires assuming functional forms for production functions and consumer preferences, along with plausible assumptions for parameters. These assumptions will allow for simulation of trade liberalization for a variety of pollution generation mechanisms.

[5]Not all goods in a category must be generate pollution, but all polluting goods must be in the same group.

Consumer preferences will be constant elasticity of substitution over consumption goods and environmental quality. Environmental quality is modeled by endowing consumers with "clean air." Pollution (however it may be generated) reduces the endowment of clean air and thus consumer utility. Emissions intensities are assumed to be the same in each country.[6] Initially the elasticity of substitution between X, Y and environmental quality will be 1. The utility function simplifies to Cobb-Douglas under these conditions:[7] $U_N(X, Y, Z) = X_N^{\alpha} Y_N^{\beta} (1 - Z_N)^{\gamma}$, where $X_N = X_{NN} + X_{SN}$ and $Y_N = Y_{NN} + Y_{SN}$ are the total consumption of those two goods in the North. The endowment of clean air has been normalized to 1. In the baseline specification the weights chosen for the utility function are $\alpha = 0.4$, $\beta = 0.4$ and $\gamma = 0.2$. The impact of a trade liberalization on emissions is not sensitive to changes in these weights. Large values of γ can affect the welfare impacts of trade liberalization, which is discussed in detail below.

On the production side, consumers in the North are endowed with nearly twice as much capital as labor. The consumers in the South have the opposite endowment, nearly twice as much labor as capital. Total endowments are equal in the two countries. X and Y production are constant elasticity of transformation and production technologies are the same in both countries. The elasticity of substitution between capital and labor is 1 for both X and Y. Again, the production function simplifies to Cobb-Douglas.

Estimating the channels through which trade liberalization impacts the environment requires the introduction of a pollution tax. The tax rate is a function of the consumption of capital intensive goods.[8] The pollution tax rate is τ_N =0.1*(YNN + YSN) and similarly for the south. The incidence of the tax shifts with the pollution generation scenario. If pollution is generated by production, then the tax is assessed on production of the polluting good. If the pollution is generated by consumption then the tax is assessed on the consumption of the polluting good.

[6]Relaxing this assumption does not qualitatively impact the results.

[7]The results are robust to varying the elasticity of substitution between the consumption goods and environmental quality. I also created a nested-CES utility function with a higher elasticity of substitution between X and Y than between consumption goods and environmental quality. The results show some changes in the magnitude of pollution and welfare, but do not alter the conclusions regarding the impact of trade liberalization on the environment.

[8]This generates an endogenous pollution tax, with a higher rate in the North than the South in autarky. Trade liberalization leads to the same tax in both countries.

3.1 Pollution from X production

The initial pollution specification is that emissions are generated by X production. The model was run over Southern tariff rates from 0 to 120%. Moving from autarky to free trade leads to a worldwide 3% increase in production and due to the symmetry of the model, each country enjoys a 3% increase in consumption as well. The consumption bundles in the two countries become the same in free trade due to the identical preferences.

A unilateral trade liberalization in the South shifts production from Y to X (due to the South's comparative advantage in X production) as described in section 2. This shift generates an increase in pollution in the South. In response to the South's liberalization, the North shifts resources from X production to Y, which leads to a decrease in pollution in the North. These results lead to the South becoming a pollution haven. If the South lowers their import tariff, pollution emissions will increase as they produce more of the polluting good for export to the North. See figure 3 for the pollution profile in both countries in response to a liberalization in the South. This is the pollution haven effect. A unilateral trade liberalization in the North generates the same result, suggesting that a less-developed country could become a pollution haven without making a policy change.

The welfare results of trade liberalization are summarized in Figure 4. Welfare increases in the North and decreases in the South after liberalization. The consumption bundles are the same in free trade, so the difference in welfare is due to the higher pollution level in the South. The South's welfare illustrates the optimal tariff argument with a peak around 50%. At low tariff rates there are two effects reducing welfare, the terms of trade effect and the increase in pollution.

3.2 Pollution from X consumption

In this specification, pollution is generated by consumption of the X good, no matter where it is produced. The pollution level is determined by domestic production net of imports and exports. The pollution level is then subtracted from the endowment of clean air as in the previous specification.

A trade liberalization in the South generates an increase in pollution in the North and a decrease in the South. This outcome is the opposite of the previous pollution generation scheme. The results for pollution levels in both countries are summarized in Figure 5. The liberalization allows the South to consume less of the polluting good as their consumption bundle becomes more diverse. The North endures increased pollution as their consumption of the polluting good increases. The results of this section suggest that introducing pollution from consumption generates substantially different results for pollution levels, but similar results for welfare. While welfare results will determine the equilibrium tariff levels, pollution impacts are important from a policy perspective.

In this pollution generation scenario, welfare converges along with pollution emissions (see figure 6). Pollution from consumption leads to welfare convergence, unlike pollution from production. In all scenarios consumption converges due to the identical preferences in the two countries. When pollution is generated by consumption, welfare will converge as well. The welfare results can be altered by the consumers' preferences over the consumption goods and environmental quality. For the damage from pollution to outweigh the gains from trade the weight on environmental quality in the utility function must be three times greater than the weights on either production good ($\alpha = \beta = 0.2$ and $\gamma = 0.6$). This implausibly high preference weighting suggests that in most cases consumers will be better off after trade liberalization, despite an increase in pollution.

3.3 Pollution from Y production and consumption

The previous two pollution generation mechanisms rely on pollution from a labor intensive good, exported by the South. While this scenario addresses policy concerns about pollution havens and a "race to the bottom" in environmental policy, it may not be realistic. There is a growing consensus that pollution intensity is higher for capital intensive goods. Cole and Elliott (2005) and Levinson and Taylor (2006) find that emissions intensity is positively associated with physical capital. Cole *et al.* (2005) finds that emissions intensity is also positively associated with human capital, even after controlling for physical capital. The final two pollution generation schemes will consider pollution generated by the capital intensive Y good.

The results from these scenarios mirror those from the X pollution scenarios. A unilateral liberalization in the South generates an increase in pollution in the North and a decrease in the South (see Figure 7). In this pollution generation scenario the North becomes the pollution haven. The trade liberalization causes the North to switch production to the polluting good (in which they have a comparative advantage). The results are the opposite of pollution from X production. When pollution is generated by Y consumption there is another pollution reversal. The South sees an increase in pollution and the North a decrease, which is the opposite of emissions from Y production.

The results in this section suggest that the source of pollution plays a crucial role in determining the direction of change in emissions after a trade liberalization. In fact pollution from consumption and pollution from production move in opposite directions. While there is concern about the possibility of pollution havens, a trade liberalization in the south may lead to decreases in pollution under certain generation scenarios.

Figure 8 summarizes the results for all pollution generation scenarios. If pollution is generated by X production, a trade liberalization leads to a decrease in pollution in the North (a '-' in the table) and an increase in pollution in the South (a '+'). If pollution is generated by X consumption the results are reversed; a trade liberalization leads to an increase in pollution in both the North and a decrease in the South.

If pollution is generated by the capital intensive (Y) good, the results are reversed. A trade liberalization leads to an increase in pollution from Y production in the North and a decrease in the South. If pollution is generated by Y consumption, the South sees an increase in pollution and the North sees a decrease.

Taken together the figures show that pollution from consumption converges, while pollution from production diverges. This reflects convergence in consumption bundles after trade liberalization due to identical preferences in both countries. Pollution from production tends to diverge with trade liberalization as the countries specialize in producing the good in which they have a comparative advantage.

4 Quantifying the Channels

Recall that the previous literature has separated the impact of trade liberalization into three channels. I now estimate the scale, composition and technique effects for each of these pollution generation scenarios. The CGE results allow me to calculate the increase in production (consumption) after a trade liberalization. Holding the pollution tax constant, I multiply the increase in production (consumption) by the autarky production ratio to find the technology neutral increase in production of the polluting good. This increase is used to find the scale effect. The residual change in pollution can be attributed to the composition effect. Finally I rerun the model with the endogenous pollution tax and compare the free-trade pollution level to the free-trade pollution level without a tax. This change is the technique effect. The technique effect is calculated with the other country's pollution tax held constant.

Table 1 summarizes the three effects in both countries for every pollution scenario for the parametrization described above. When pollution is generated by production, trade liberalization leads to a net increase in world pollution. When pollution is generated by consumption, liberalization leads to a decrease in world pollution. This is due primarily to the composition effect which is substantially (between 1.2 and 1.8 times) larger for pollution generated by production than consumption. In autarky countries are consuming and producing nearly equal amounts of each good. Trade liberalization leads to production specialization, but consumption continues to be split relatively equally between goods. This generates a larger shift in the production bundle than the consumption bundle and thus a larger composition effect for production generated pollution.

The sign of the change in pollution is perfectly predicted by the sign of the composition effect. This effect tends to be an order of magnitude larger than the scale and technique effects. Changing the source of pollution from production to consumption switches the sign of the composition effect. This is the source of the pollution reversals described in the previous section. Trade liberalization generates roughly a 3% total increase in production (and consumption), which is the source of the scale effect. This relatively small increase hides larger changes in the production structure. Trade liberalization generates a roughly 35% shift in production in each country.

The technique effect typically is slightly larger than or equal to the scale effect. This suggests that technologically neutral economic growth will generate small decreases in pollution. This result corresponds to the conclusions of Antweiler *et al.*'s empirical work, suggesting that the model is correctly calibrated. The technique effect is sensitive to the pollution tax rate. The baseline tax rate was chosen to generate a technique effect that was slightly larger than the scale effect to calibrate the model to ACT's results. Increasing the tax rate can increase the size of the technique effect. Tax rates that are large enough to generate a technique effect that outweighs the combined scale and composition effects (and thus generate net reductions in emissions), have large negative impacts on welfare in the country that has a comparative advantage in producing the polluting good. The more similar the factor endowments, the lower the tax rate that generates a decrease in pollution after a liberalization. This suggests that pollution taxes and environmental regulations can be more effective when trade is between similar countries.

The magnitude of the composition effect is sensitive to the North-South specification of the model. The composition effect is much larger than the scale and technique effects due to the large difference in factor endowments between the countries. Trade leads to large shifts in the production (and consumption) bundles and thus large shifts in the quantity of emissions. The more similar the initial factor endowments, the smaller the composition effect becomes. Making the countries more similar also reduces the gains from trade, which reduces the scale and technique effects. As the factor endowments converge, the impact of a trade liberalization becomes smaller and all three effects converge to zero.

5 Conclusion

This paper has shown that the response of pollution emissions to a trade liberalization is sensitive to the source of that pollution. The previous literature on trade and the environment focused almost exclusively on pollution generated by consumption. Trade liberalization leads to specialization in production while consumption bundles become more similar. The differential response of production and consumption to liberalization gives rise to potential differential responses of pollution from those activities.

When the composition effect of trade liberalization is large relative to the scale and technique effects, trade liberalizations will cause pollution from production and consumption to move in different directions. Large composition effects are most likely to occur when the nations liberalizing trade are very different. Trade barriers between developed countries are already very low, so liberalizations in the future are more likely to be between the developed and developing world. For these reasons this paper has modeled the impact of North-South trade on pollution from production and consumption.

The results suggest the importance of including pollution from consumption in estimating the impacts of trade liberalization on emissions. If concentrations of pollutants are used (rather than emissions data) there may be a bias towards finding no results for pollutants that are emitted by both production and consumption. These pollutants are likely to see an increase from one emissions channel and a decrease from the other. Unfortunately high quality measures of emissions from consumption rarely exist, making empirical work difficult.

This paper has considered countries with no technology differences. Future work may allow for technological differences between the north and south. This model may generate different predictions on the world pollution emissions in the wake of a trade liberalization. The underlying result that pollution from production and consumption can respond differently to trade liberalization should hold.

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Table 1: The Scale, Technique and Composition Effects

Country Source	South X Production	North X Production	South X Consumption	North X Consumption
Scale	3.5	0.9	1.7	4.3
Composition	105.2	-54.8	-68.7	31.3
Technique	-8.7	-7.8	-3.5	-2.6
Net	100.0	-62.6	-69.6	33.9

Table 1: The Scale, Technique and Composition Effects (cont.)

Country Source	South Y Production	North Y Production	South Y Consumption	North Y Consumption
Scale	1.7	6.1	2.6	4.3
Composition	-57.4	88.7	34.8	-73.0
Technique	-5.2	-12.2	-1.7	-4.3
Net	-60.9	83.5	35.7	-73.0

Emissions changes normalized so that the net change in the South when pollution is generated by X production is 100.

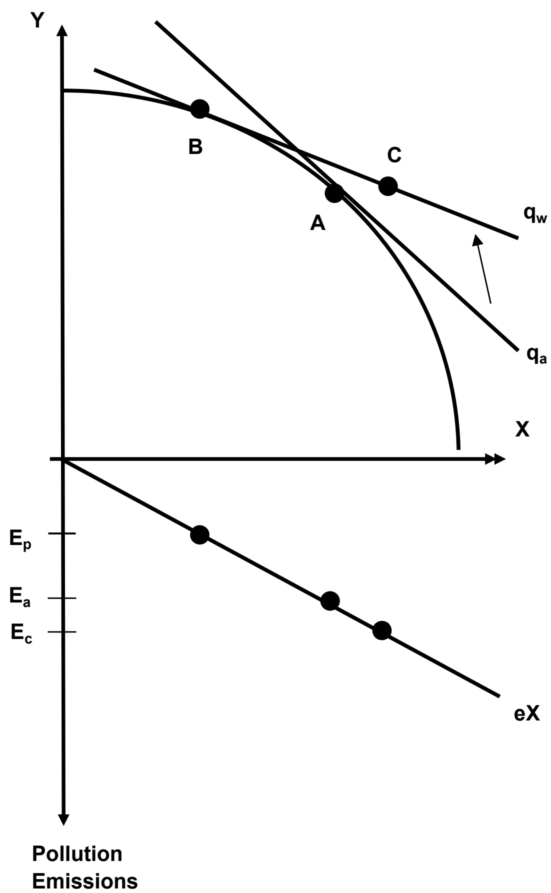

Figure 1: Trade Liberalization and Pollution in the North

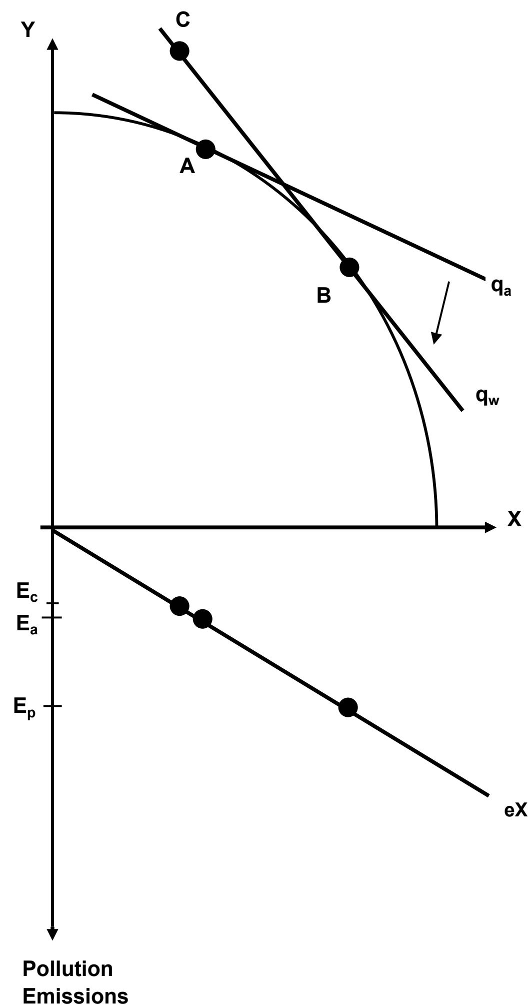

Figure 2: Trade Liberalization and Pollution in the South

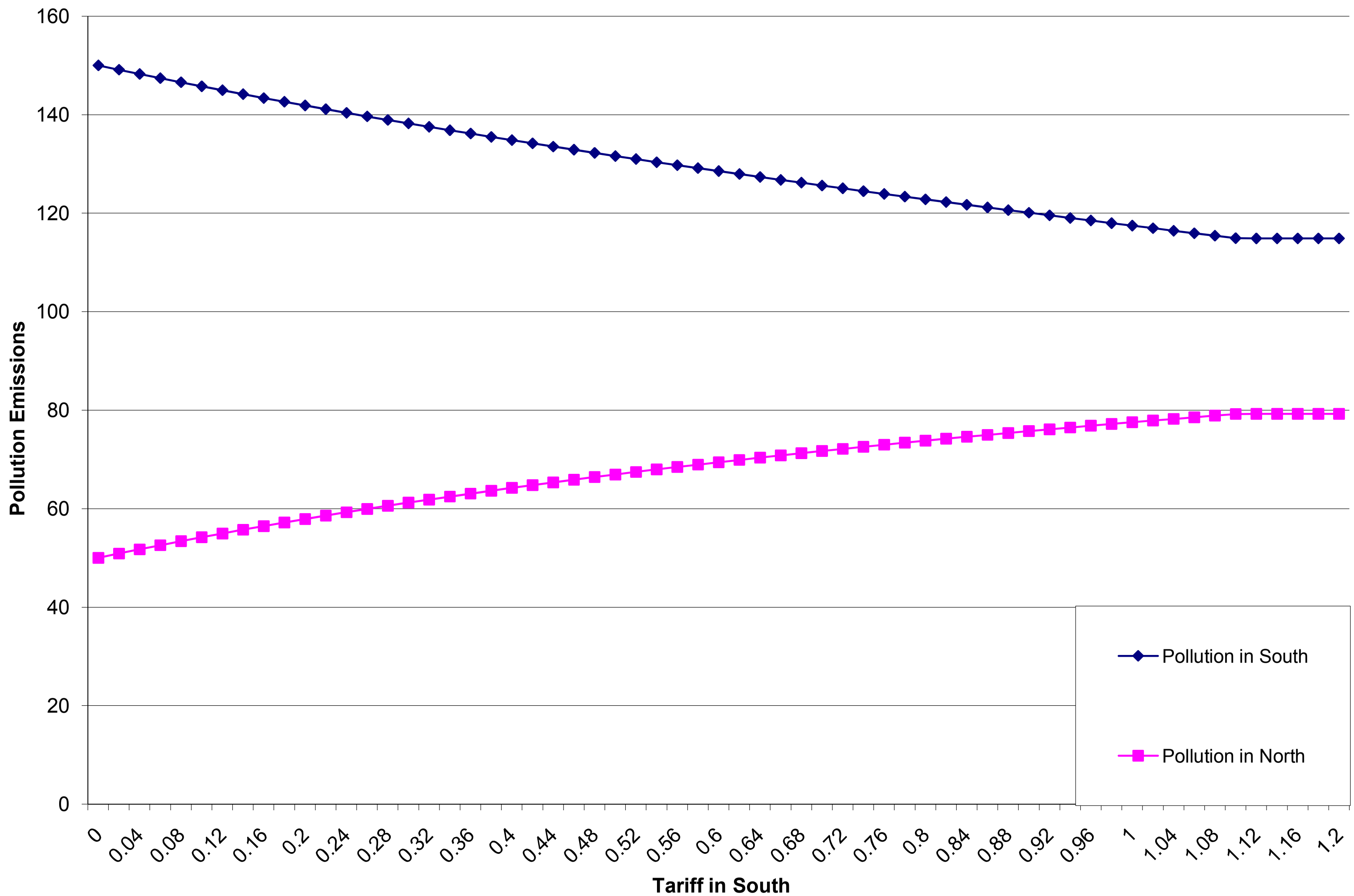

Figure 3: Pollution from X Production as the South Liberalizes

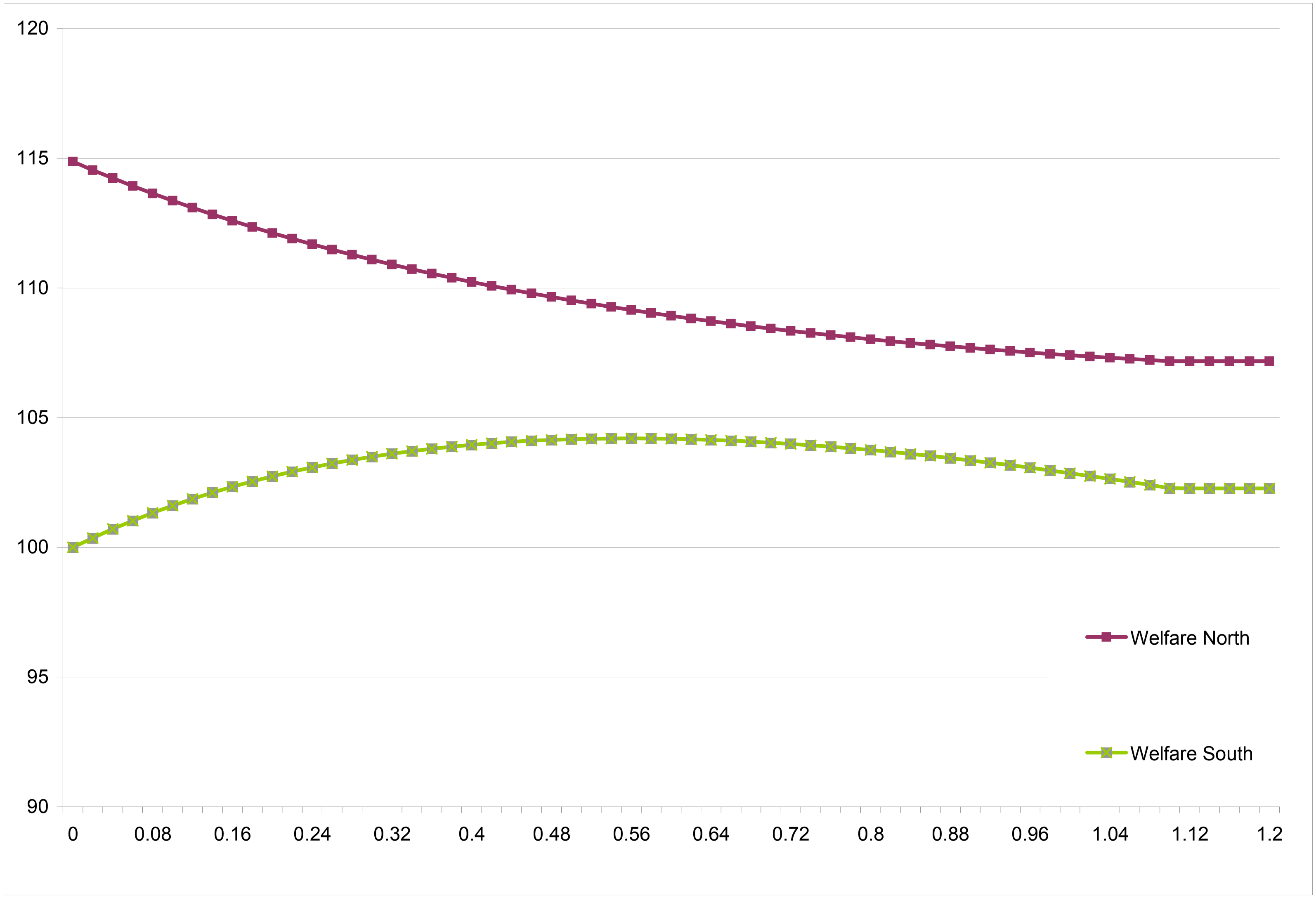

Figure 4: Welfare When Pollution is Generated by X Production

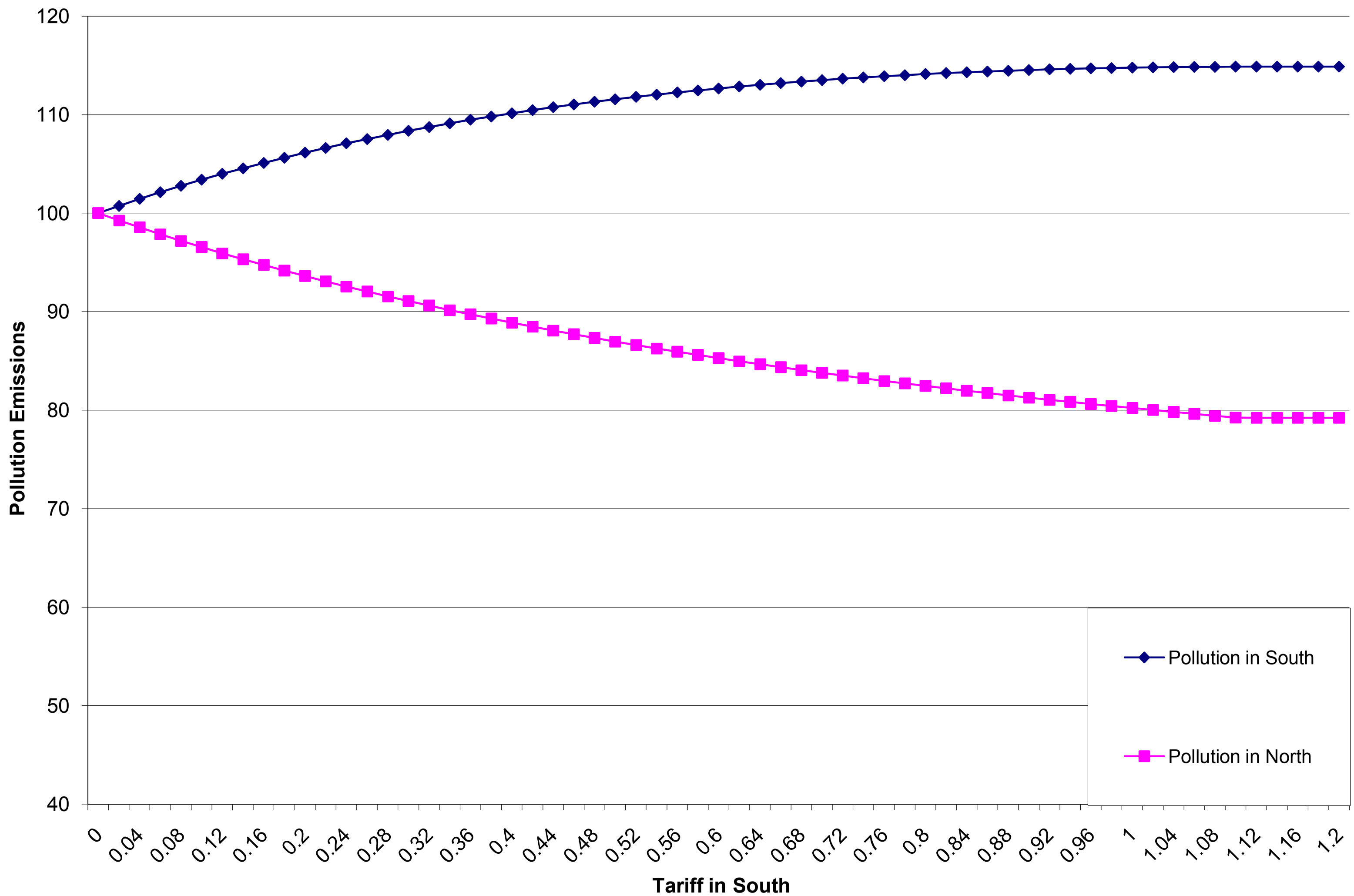

Figure 5: Pollution from X Consumption

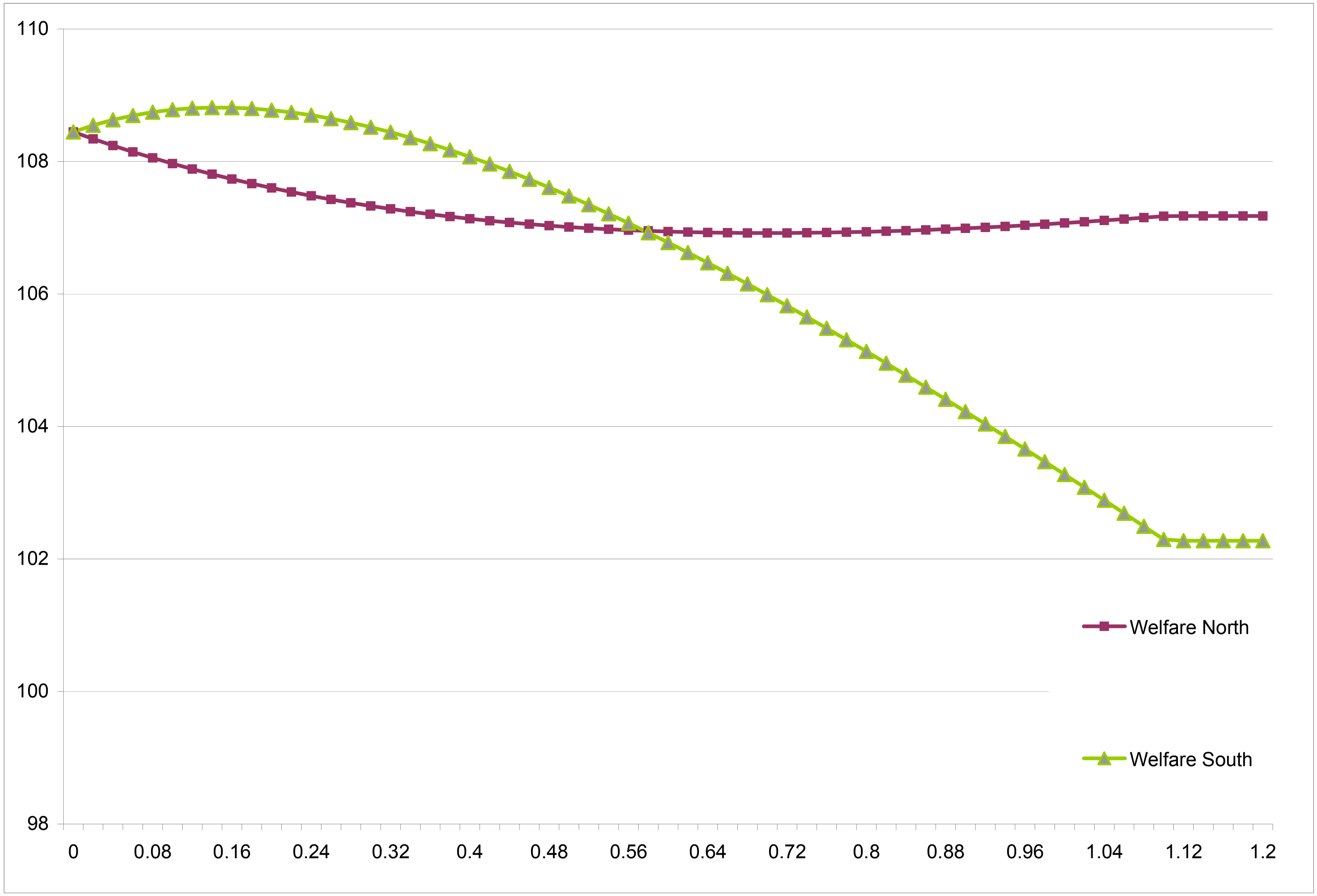

Figure 6: Welfare When Pollution is Generated by X Consumption

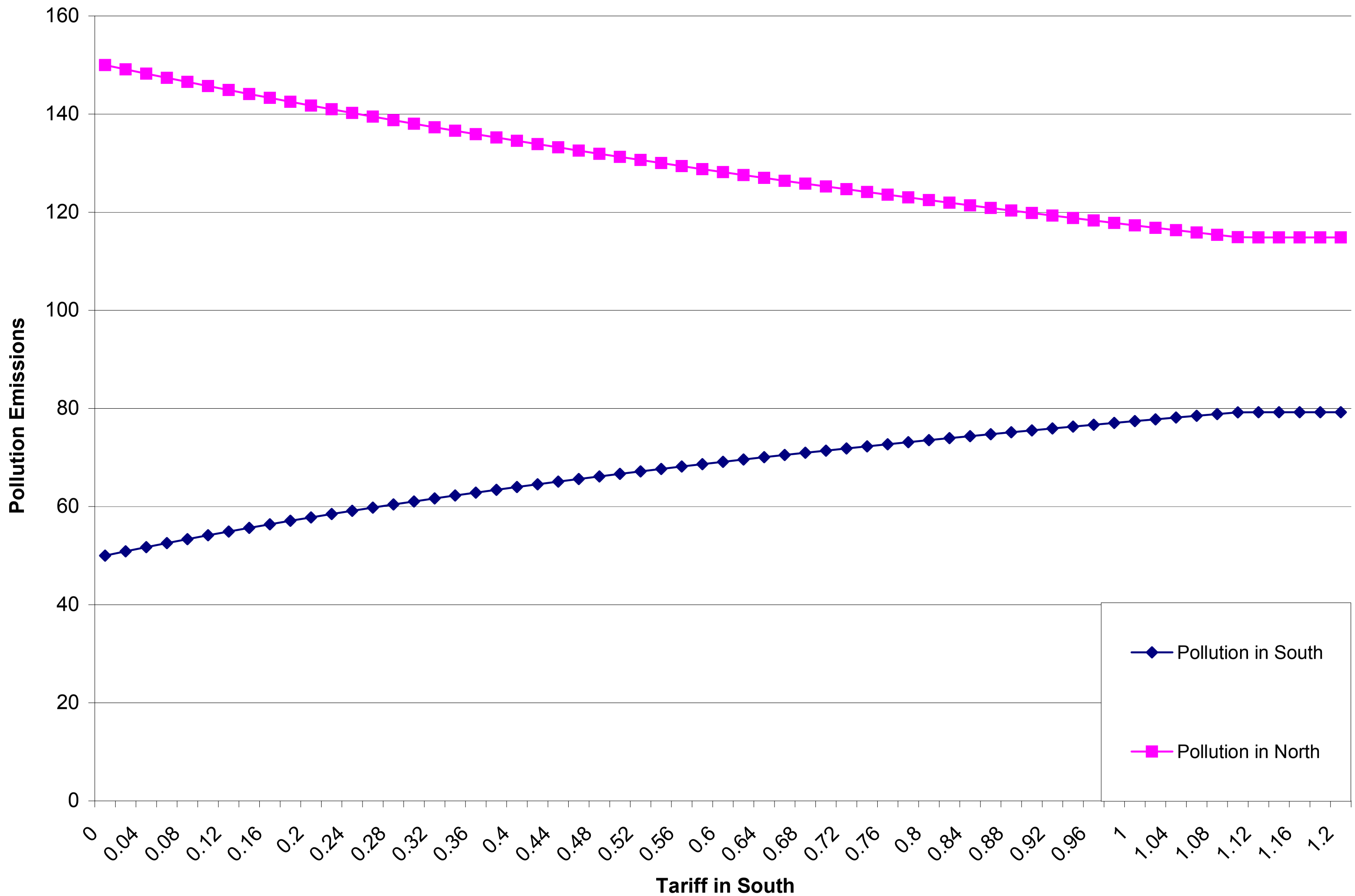

Figure 7: Pollution from Y Production as the South Liberalizes

Pollution Generated by:	Pollution in North	Pollution in South
X Production	-	+
X Consumption	+	-
Y Production	+	-
Y Consumption	-	+

Figure 8: Summary of Results