

The Economics of Decoupling

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Non-technical summary: Who gains, who loses?

This paper analyses the welfare consequence of decoupling, defined as a complete ban of imports, in a three-country version of the standard Krugman, 1980, model of trade in differentiated products under monopolistic competition.

The main results are:

1. The rest of the world always gains from any form of decoupling.
2. Even in a unilateral decoupling (e.g. US stops imports of Chinese goods, but China remains open), both sides involved lose. But the country that shuts off imports from one partner loses more than the intended victim.
3. The losses for both sides are greater in a symmetric, tit-for-tat decoupling (i.e. when both sides shut off imports from the other). The country that is the victim of a unilateral decoupling thus has no incentive to respond with tit-for-tat.
4. The country that initiates the decoupling does not gain from forming a coalition with the rest of the world as long as the intended victim does not engage in tit-for-tat.

The first result implies that rest of the world, in particular the EU should be relaxed about the prospect of a China-US trade war. If two countries decouple symmetrically from each other, exporters from the EU (and in general the rest of the world) obtain an advantage on the markets of both the two countries engaged in decoupling.

The second result is that unilateral decoupling not only brings costs for the country that shuts off imports, but these costs are larger than those of the intended victim. Decoupling is thus counterproductive if it is intended to weaken the trading partner relative to the home economy.

The simple reason for this result is if the US shuts off imports from one partner (China), it limits the choice of consumers and invites higher priced imports from the rest of the world (e.g. Europe). By contrast, the consumers in the intended victim, China, or in general the country whose imports are targeted by the 'decoupler' retains a wider choice of imports as long as it does not engage in tit-for-tat. This is the reason why the cost of decoupling is higher for the country that initiates it.

Tit-for-tat, i.e. responding to another country's decoupling by shutting off imports from that source only increases the loss. There is thus no incentive (except grand-standing and the usual game theoretic considerations) to engage in tit-for-tat.

The fourth result implies that the US has no economic incentive to force the EU to decouple from China as this does not change the loss from access to Chinese goods that the US suffers anyway.



Abstract¹

This paper analyses the impact of decoupling in a three-country world of differentiated products under monopolistic competition as in Krugman 1980. Two cases are considered:

- A. Bilateral (or reciprocal) decoupling: Two countries stop trading with each other but leave trade with the rest of the world undisturbed.

The main result in this case is that the decoupling countries suffer a terms-of-trade loss on their trade with the rest of the world. This deterioration of the terms of trade can be viewed in two ways. One way would be that the goods in the two countries that decouple are in excess supply in the rest of world as a large part of their market disappears with the decoupling. Another way to view the situation is that the exporters of the rest of the world face less competition and can thus increase their prices in the decoupling countries.

Consumers in the rest of the world continue to have access to all the varieties as before, but consumers in the decoupling countries lose access to a substantial share of the varieties available to them before the decoupling.

- B. Unilateral (or asymmetric) decoupling: One country stops imports from one trading partner who does not respond tit for tat.

The main result in this case is similar to that above: the country that decouples unilaterally loses access to the varieties from one trading partner and the 'victim' suffer a terms-of-trade loss. The losses for the 'perpetrator' are larger than for the 'victim'. The loss for the 'victim' would increase if it engages in tit-for-tat by also stopping imports from the perpetrator. There is thus no economic incentive for decoupling to spread.

The rest of world gains under any scenario.

The overall result is that decoupling, in whether reciprocal or not, leads to a welfare loss for consumers in the decoupling countries, but a welfare gain for the rest of the world. This result is in line with existing literature since decoupling can be viewed as a reversal of bilateral trade liberalization, that should cause a loss for the rest of the world as shown in the more advanced model of Melitz and Ottaviano (2008).

¹Daniel Gros is the Director of the Institute for European Policymaking @ Bocconi University. Many thanks to Erik Jones and Gianmarco Ottaviano for insightful comments.



Motivation

Growing geopolitical tensions between major trading blocs have led to the view that trading with a geopolitical rival or enemy creates dependencies that should be avoided by decoupling, i.e. reducing trade with that country as much as possible.

The rationale for considering decoupling is mostly geopolitical, not economic self-interest, as for example in the optimal tariff literature. For example, Krugman (1991) analyses a world composed of a variable number of trading blocks. He finds that world welfare is minimized when there are three of them. At the time, this seemed to correspond to the dominant position in global trade of the US, Japan and Europe. Today, China has supplanted Japan as a new member of the three major trading powers, but the dominant trading powers are still 3.

The analysis of Krugman (1991) assumed that each trading block would adopt the optimum tariff in a non-discriminatory way, i.e. levying the same tariff on all imports. This does not correspond to today's world in which trade policy is used in a discriminatory way because it is viewed as a geo-political weapon. The most important case of discriminatory tariffs is of course the trade war between the US and China, initiated by the first Trump administration in 2017.

While neither the administrations of Trump or of Biden have aimed at stopping all trade with China, it is still useful to consider what the implications of a full decoupling would be on the welfare of the two countries and the rest of the world.

Related literature

Simulations with large global trade models have been used to evaluate the impact of a decoupling (Felbermayr et al. 2023, Wu et al. 2021). All these evaluations arrive at the result that the two countries that decouple experience welfare losses. Some of them also find that the rest of the world also loses from the decoupling. However, these models are based on special functional forms and relationships estimated from the past that might not hold under conditions of decoupling.

It thus remains important to investigate the general principles governing the economic impact of decoupling on trade and welfare in a standard model of international trade.

It is tempting to regard decoupling as an extreme case of the inverse of the formation of a customs union in a world with high tariffs.

The customs union literature emphasized that eliminating trade barriers between two countries could lead to trade being diverted away from the rest of the world to intra-CU trade.



A decoupling should thus be expected to increase trade with the rest of the world as trade between the two countries that decouple disappears. The trade diversion caused by a customs union is generally regarded as welfare reduction for the rest of the world because it reduces the demand for rest of the world products.

The increase in trade with the decoupling countries is today widely regarded as a threat, rather than an opportunity.

For example, European policymakers have emphasized that the (perceived) damage from 'a flood of imports from China' that might materialize as the US market closes for Chinese products (Bounds and Fleming (2024)).

The results of this note confirm that one would expect decoupling to result in more imports of the rest of the world from both two countries that decouple. However, these increased imports would come at lower prices, thus benefiting consumers in the rest of the world.

More in general, a key difference between decoupling and the formation of a customs union is that the starting point of a Customs union is a second-best situation in which tariffs distort trade. By contrast, the starting point of decoupling is the first best of free trade.

The next section briefly presents a standard one sector version of the canonical Krugman model of trade in differentiated products. This model is then used in a three-country world to calculate the impact of decoupling on the terms of trade, the welfare and the degree of openness of the bystander country and the two countries that are decoupling from each other.

The Model

The model used here is the standard one sector version of Krugman (1980, 1981) in which there is only one industry producing a differentiated good with increasing returns to scale.

The utility function of consumers is given by:

$$U = \sum_i^\infty c_i^\theta \text{ with } 0 < \theta < 1$$

1

where c_i is consumption of good i of this industry. The number of potential products is infinite and thus much larger than the number of products actually produced.

The production function for each product is given by:

$$x_i = f(\ell_i) \quad 0 < \ell$$

2

where ℓ_i represents labor used to produce a certain amount x of good i . The function $f(\ell) > 0$ is



the same for all goods. This symmetry makes it possible to concentrate on the market for any one good. In the following, the subscript i will therefore be suppressed.

The function $f(\ell)$ is assumed to exhibit increasing returns to scale in the sense that the elasticity of output with respect to labor input exceeds one, i.e., $f' \ell / f > 1$.

This assumption ensures that each product is produced by only one firm; the number of firms is thus equal to the number of different varieties actually produced.

Given equation (1), the demand curve (for any one good) will have a constant price elasticity, equal to $\sigma = 1/(1-\theta)$ if the number of products is large.

The profit maximizing price will therefore involve a constant markup over marginal cost:

$$q = [f'(\ell)] w / \theta$$

3

where q is the price of a product and w the wage rate. Free entry drives profits to zero:

$$0 = qx - \ell w$$

4

Combining this with equation (3), implies that the output of each firm is equal to a constant, determined by the parameters of the cost and demand functions. In the monopolistically competitive equilibrium, the degree of economies of scale, $f'(\ell)\ell/f(\ell)$, is equal to the degree of monopoly power, which in this case is equal to $1/\theta$.

The equilibrium number of firms, denoted by N , is determined by the full employment condition:

$$N\ell = L.$$

5

where L represents the given economy-wide labor supply. For notational convenience the labour employed per firm/product is normalized to 1 so that the number of varieties produced N also indicates the size of the economy in terms of the overall labour force.

Krugman (1980) shows that this equilibrium represents a social optimum. This would not be the case if there exists a second sector without returns to scale (Melitz and Ottaviano (2008), Nocco et al. (2019)).

If an economy of this type opens to trade with another similar economy, each economy will exchange its home-produced varieties against the foreign produced varieties. Trade does not affect the elasticity of demand facing each firm, which implies that the equilibrium level of output of each firm does not change, but the number of varieties available to consumers increases. The same argument applies to the reverse of opening to trade: decoupling does not



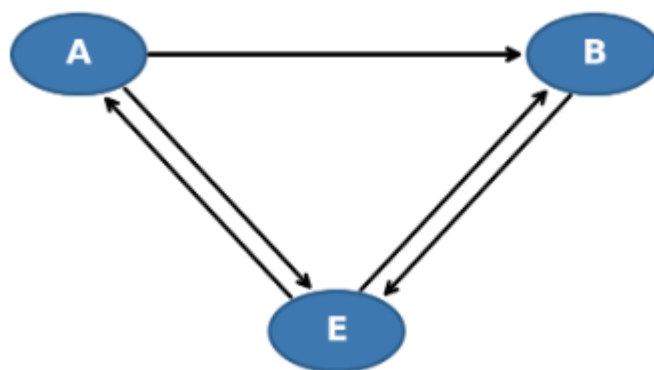
affect the elasticity of demand, only the number of varieties available to consumers.

A three-country world

The key innovation of this paper is to consider a global economy that consists of three countries, labelled A, B and E. 3 is the minimum required to be able to represent the case of decoupling. All countries share the same technology and preferences.

Diagram with trade flows for asymmetric or unilateral decoupling

Trade flows for the three countries case with asymmetric decoupling (A prohibits imports from B)



In the case of symmetric decoupling the arrow indicating exports from A to B disappears.

This is the case considered first.

Symmetric or reciprocal decoupling

A and B decouple from each other, resulting in zero trade between them. But trade with the rest of the world (trade of A and B with E) is not affected by the decoupling.

At first it is assumed that all countries are also of the same size (normalized to 1), but this assumption is relaxed later.

Equilibrium in the markets for goods produced in the decoupling countries and the rest of the world:

Production of goods produced in E (rest of the world) equals home consumption in E plus consumption in the two decoupling countries (which is equal in A and B).



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$$x^E = c_E^E + 2c_A^E$$

6

The market clearing conditions for the goods produced in A and B have to take into account that for both these countries exports can only go toward E. For country A this implies:

$$x^A = c_A^A + c_E^A$$

7

Only the market clearing condition for A is relevant because that of B is the same, substituting just B for A.

Balance of payment equilibrium for E implies also balance of payments equilibrium for A, and B. Exports of E are given by the difference between production and home consumption, imports come from B and A, with A's exports to E also given by the difference between production and home consumption as exports from A to B are not possible. Goods produced in E are the numeraire, p designates the relative price of goods produced in A (or, by symmetry, in B):

$$x^E - c_E^E = 2p(x^A - c_A^A)$$

8

For each individual consumer in E the ratio of consumption of domestic to imported goods (those from A) depends on their relative price:

$$\frac{c_E^E}{c_E^A} = p^{\frac{1}{1-\theta}}$$

9

The same applies, mutatis mutandis in A (here the goods are those from E):

$$\frac{c_A^E}{c_A^A} = p^{\frac{1}{1-\theta}}$$

10

These 5 equations determine the four quantities (for each of the two goods the quantities consumed at home and abroad) plus the relative price of the two goods. The latter is the key variable of interest.

Equations (1) and (2) in (3) yields:

$$c_A^E = pc_E^A$$

11

Trade is balanced when the exports of E, which are equal to the consumption of E's product in A, equal the value of the imports of E from A.



Equilibrium

The demand conditions (4) and (5) can be used in the goods market equilibrium conditions (1) and (2). Starting with goods from region E, this yields (the country superscript for x is henceforth omitted as the amount produced by each firm is the same in all regions):

$$x = c_A^E \left(\frac{c_E^E}{c_A^E} + 2 \right) = p c_E^A \left(\frac{c_E^E}{p c_A^A} + 2 \right) = p c_E^A \left(p^{\left(\frac{1}{1-\theta}-1\right)} + 2 \right)$$

12

Where the second equality sign comes from using the balance of payments equilibrium condition above.

For the goods of A this yields:

$$x = c_E^A \left(\frac{c_A^A}{c_E^A} + 1 \right) = c_E^A \left(\frac{p c_A^A}{c_E^E} + 1 \right) = c_E^A \left(p^{\left(\frac{-1}{1-\theta}+1\right)} + 1 \right)$$

13

Combining the last two equations and cancelling out c_E^A yields a solution for the price of foreign goods (those of A or B) in terms of the domestic good, i.e. the (inverse of the) terms of trade.

$$p^{\left(\frac{-1}{1-\theta}+1\right)} + 1 = p^{\left(\frac{1}{1-\theta}\right)} + 2p$$

14

This result implies that p , the price of goods from A in terms of goods of EU, must be below 1. An heuristic proof is as follows. At $p=1$ the LHS of this equation equals 2 whereas the RHS equals 3. The LHS increases as p falls whereas the RHS falls as p assumes lower values. As p goes towards 0 the LHS goes towards infinity whereas the RHS goes towards zero. Both sides are monotonic, implying that, for any given value of θ there is one solution for p in the interval $(0,1)$.

A higher value of θ increases the slopes of both RHS and the LHS side, bringing the equilibrium value of p closer to one. A lower value of θ , which implies a higher mark-up thus implies a lower value for p . Figure 1 below shows the numerical approximation of p for the interval $0.1 < \theta < 0.99$.

The result $p < 1$ implies that that a bilateral decoupling leads to an improvement in the terms of trade for the rest of the world. Consumers in E thus experience an increase in their purchasing power while still having access to both A's and B's varieties.



Consumers in both A and B experience not only a deterioration in their purchasing power but also lose access to one third of the globally available varieties.

Decoupling and indicators of trade openness

Overall (global) trade contracts when two countries engage in a bilateral decoupling, given that bilateral trade between A and B disappears. But the degree of openness of the 'bystander' country E increases. The value of imports from A as a share of national income (that is given by x times the number of firms, in turn normalized to one) can be calculated from equation (13) above:

$$\frac{pc_E^A}{x} = \left(p^{\left(\frac{\theta}{1-\theta}\right)} + 2 \right)^{-1}$$

15

Given $p < 1$, this implies that the share of imports from each of the two decoupling countries in the income of E is larger than the value of $1/3$ under global free trade, and the overall degree of openness is larger than the $2/3$ under free trade. As p goes towards zero, the share of imports from each country increases towards one half, with overall openness going towards one.

This is the result of two factors of opposite sign.

The share of the domestic varieties consumed at home falls in the bystander country as imports become cheaper.

The improvement in the terms of trade reduces the value of each unit of imports, relative to the value of domestic production.

Global trade contracts of course as a share of income in the two countries engaged in the decoupling. The goods market equilibrium condition of country A, equation 13 above, can be rewritten as:

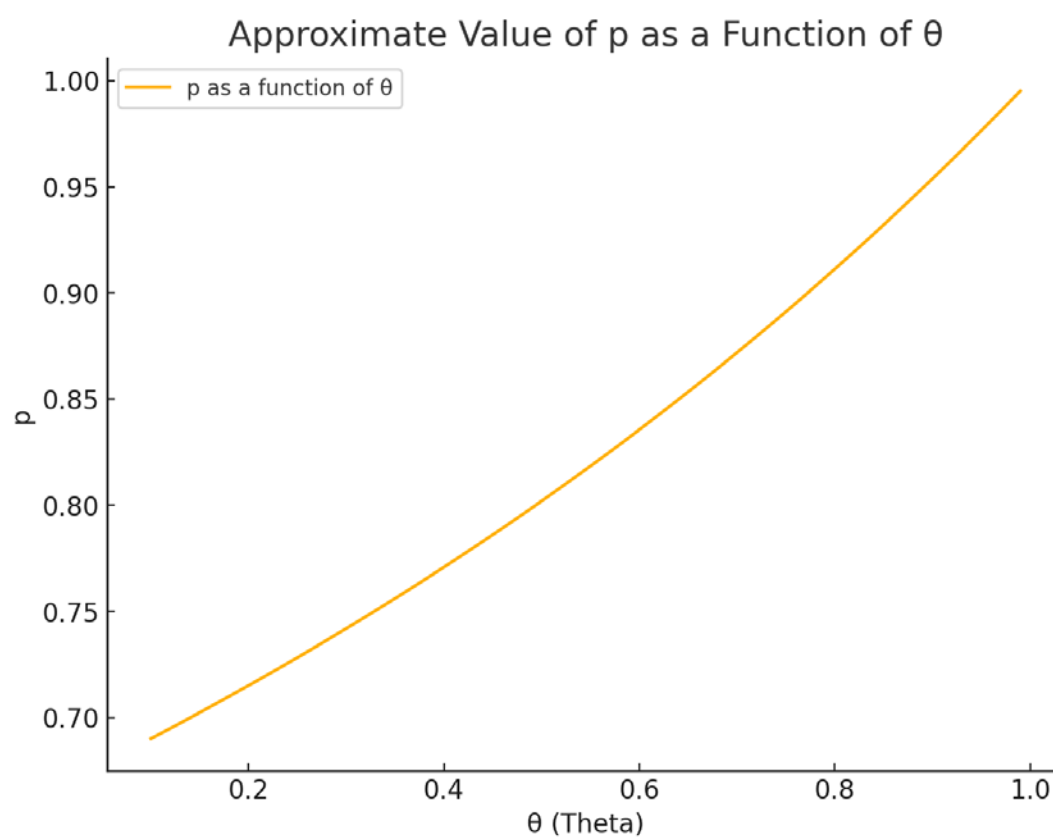
$$\frac{c_E^A}{x} = \left(p^{\left(\frac{-\theta}{1-\theta}\right)} + 1 \right)^{-1}$$

16

The share of exports (and imports) in national income of the decoupling countries A and B, thus falls (as both have only one export market left). Given the negative exponent on p , equation (16) above implies that openness of the decoupling countries falls to a value below one half, compared to the free trade value of $2/3^{\text{rd}}$.



Figure 1



Relative size matters

This section shows what happens when the rest of the world is larger (or smaller) than the two decoupling countries. The constellation of three countries (or trading blocks) of equal size represents a very special case. For example, when considering a decoupling between China and the US, the rest of the world would be much larger than either the US or China (both of which account for about one quarter of global GDP).

The size of country E is indicated by N. A value of N=1 means that the rest of the world is of the same size as each of the two countries that are decoupling. A value of N=2 would imply that the rest of the world is as large as the two decoupling countries combined. Allowing for N>1 seems important to check whether the results also depend on the (relative) size of the countries involved in the decoupling.

The market clearing conditions for each good now become:

$$x^E = Nc_E^E + 2c_A^E$$

17

And the market clearing for the goods produced in A (those for B are identical).

$$x^A = c_A^A + Nc_E^A$$

18

As above, it is necessary only to consider the balance of payment equilibrium condition for one country. As before, exports of E are given by the difference between production and home consumption, imports come from B and A. Goods produced in E remain the numeraire. The relative price of goods produced in A (or, by symmetry, in B) is again indicated by p:

$$N(x^E - Nc_E^E) = N2c_A^E = 2p(x^A - c_A^A) = 2pNc_E^A$$

19

Simplifying yields again:

$$c_A^E = pc_E^A$$

20

The relative demand conditions are not affected by the relative sizes of the countries.



The amount of home consumption in E can then be calculated using the goods market equilibrium plus the relative price:

$$x^E = Nc_E^E + 2pc_E^A = c_E^E \left(N + 2p^{\frac{-\theta}{1-\theta}} \right)$$

21

Which yields:

$$c_E^E = \frac{x^E}{\left(N + 2p^{\frac{-\theta}{1-\theta}} \right)}$$

22

As before, the demand conditions (4) and (5) can be used in the goods market equilibrium conditions for goods produced in E and A (equations (1) and (2) above). Starting with goods from region E, this yields:

$$x = c_A^E \left(N \frac{c_E^E}{c_A^E} + 2 \right) = pc_E^A \left(N \frac{c_E^E}{pc_E^A} + 2 \right) = pc_E^A \left(Np^{\left(\frac{1}{1-\theta} - 1 \right)} + 2 \right)$$

23

With the same substitutions from the demand and balance of payments equilibrium condition as above.

For the goods of A this yields:

$$x = c_E^A \left(\frac{c_A^A}{c_E^A} + N \right) = c_E^A \left(\frac{c_A^A c_A^E}{c_E^A c_E^E} + N \right) = c_E^A \left(p^{\left(\frac{-1}{1-\theta} + 1 \right)} + N \right)$$

24

Combining the last two equations and cancelling out $\frac{A}{E}c$ yields a solution for the price of foreign goods (those of A or B) in terms of the domestic good, i.e. the (inverse of the) terms of trade.

$$\left(p^{\left(\frac{-1}{1-\theta} + 1 \right)} + N \right) = \left(Np^{\left(\frac{1}{1-\theta} \right)} + 2p \right)$$

25

This means that the implicit solution for p can be written as:

$$p^{\left(\frac{-\theta}{1-\theta} \right)} + N - \left(Np^{\left(\frac{1}{1-\theta} \right)} + 2p \right) = 0$$

26

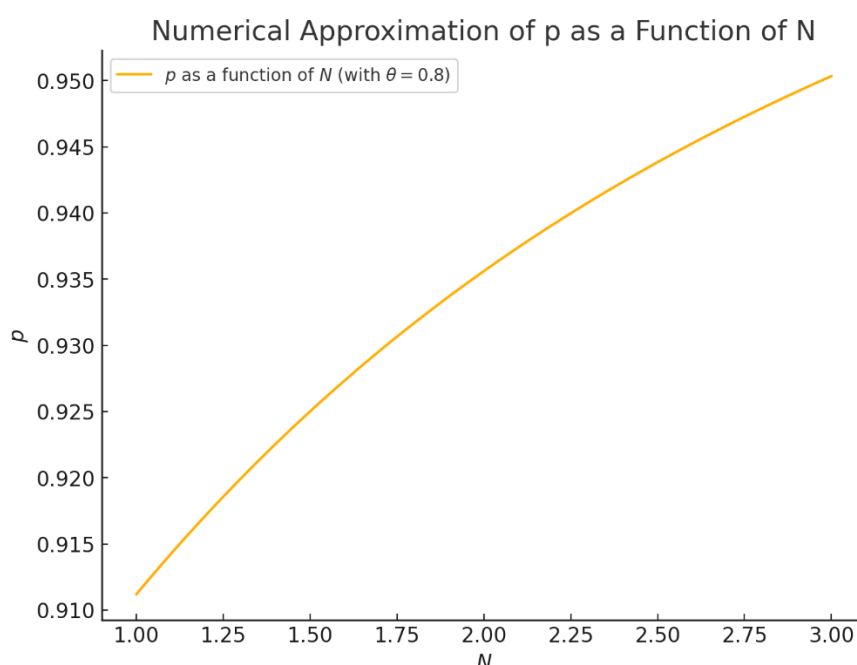
This result implies that the improvement in the terms of trade (the fall in import prices, p, for E) is lower the smaller the two decoupling countries are relative to the rest of the world. (The differential of equation 26 with respect to p is negative, but positive with respect to N (given



that $p < 1$). This implies that p increases with higher a higher N for any given θ .) The intuition is that less of a fall in the export prices of the decoupling countries is needed to offset the trade destroyed between them when the rest of the world is much bigger.

Figure 2 below shows the relationship between N and p , where N represents the size of the rest of the world relative to the size of one of the countries involved in the decoupling (A and B, which are assumed to be of equal size). In the limit of N towards infinity, p goes towards one because the decoupling is then only by two very small countries. In the limit of N going towards zero the solution for p tends towards $2^{-(1-\theta)}$. The terms of trade loss increase towards this limit as the relative size of the rest of the world that could provide an escape valve diminishes.

Figure 2



Impact of decoupling on welfare

Under free trade the representative consumer of all countries consumes the same share of the $N+2$ varieties available on the global market.

This symmetric distribution of consumption means that the utility level of a representative consumer can be calculated as the utility derived from the consumption of any one good, multiplied by the number of varieties available.



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$$W_{FT} = [(N+2)(c_E^E)^\theta]^\frac{1}{\theta} = \left[(N+2) \left(\frac{1}{(N+2)} \right)^\theta \right]^\frac{1}{\theta} = (N+2)^\frac{1-\theta}{\theta}$$

27

As emphasized by Krugman (1981) an increase in the size of the global economy (an increase in N) increases welfare.

Under the trade war equilibrium, the quantities consumed of the home and imported goods are no longer equal.

Welfare for a representative consumer in E (the rest of the world) is given by:

$$W_{TW}^E = \frac{1}{N} \left[N(c_E^E)^\theta + 2(c_E^A)^\theta \right]^\frac{1}{\theta}$$

28

This can be expressed in terms of the quantity of consumption of the home good alone by using the demand condition, equation 24:

$$W_{TW}^E = \frac{1}{N} \left[N(c_E^E)^\theta + 2 \left(c_E^E p^\frac{-\theta}{1-\theta} \right)^\theta \right]^\frac{1}{\theta} = \frac{1}{N} \left[(c_E^E)^\theta \left(N + 2 \left(p^\frac{-\theta}{1-\theta} \right) \right) \right]^\frac{1}{\theta}$$

29

Substituting out for the consumption of the home good found above yields:

$$W_{TW} = \frac{1}{N} \left[\left(1 + \frac{2}{N} p^\frac{-\theta}{1-\theta} \right)^\theta \left(N + 2 \left(p^\frac{-\theta}{1-\theta} \right) \right) \right]^\frac{1}{\theta}$$

30

Simplifying yields finally:

$$W_{TW} = \left[N + 2 \left(p^\frac{-\theta}{1-\theta} \right) \right]^\frac{1-\theta}{\theta}$$

31

The term $2 \left(p^\frac{-\theta}{1-\theta} \right)$ is larger than 2 as long as p is smaller than one. This implies that

$$W_{TW}^E = \left[N + 2 \left(p^\frac{-\theta}{1-\theta} \right) \right]^\frac{1-\theta}{\theta} > W_{FT} = (N+2)^\frac{1-\theta}{\theta}$$

32



Since $\left(p^{\frac{-\theta}{1-\theta}}\right) > 1$, (given $p < 1$) it follows that with the utility level of the rest of the world is higher when the other two countries engage in a trade war than under free trade. Decoupling can be viewed as a reversal of bilateral trade liberalization.

The result found here is thus entirely compatible with Melitz and Ottaviano (2008) who show, in a more advanced model that included differences in productivity across firms, that a preferential bilateral trade liberalization should cause a loss for the rest of the world, at least in the long run equilibrium, which corresponds to the zero profit condition imposed here.

If the rest of the world gains, both participants in the trade war are likely to lose as global welfare goes down. This can be verified by computing the welfare of one of them. Taking country A as the example one has:

$$W_{TW}^A = \left[N(c_A^E)^\theta + (c_A^A)^\theta \right]^{\frac{1}{\theta}} = \left[N \left(\frac{c_A^E}{c_A^A} c_A^A \right)^\theta + (c_A^A)^\theta \right]^{\frac{1}{\theta}} \quad 33$$

$$W_{TW}^A = \left[N \left(c_A^A p^{\frac{1}{1-\theta}} \right)^\theta + (c_A^A)^\theta \right]^{\frac{1}{\theta}} = \left[(c_A^A)^\theta \left(N p^{\frac{\theta}{1-\theta}} + 1 \right) \right]^{\frac{1}{\theta}} \quad 34$$

This requires determining the amount of home consumption in A, which can be achieved by transforming the goods market equilibrium condition for products from A.

$$x^A = c_A^A \left(1 + N \frac{c_A^E}{c_A^A} \frac{c_A^E}{c_A^A} \right) = c_A^A \left(1 + N p^{\frac{1}{1-\theta}-1} \right) \quad 35$$

Which implies:

$$c_A^A = x^A \left(1 + N p^{\frac{\theta}{1-\theta}} \right)^{-1} \quad 36$$

Substituting out for the consumption of the home good found above yields:

$$W_{TW}^A = \left[N p^{\frac{\theta}{1-\theta}} + 1 \right]^{\frac{1-\theta}{\theta}} < (N + 2)^{\frac{1-\theta}{\theta}} \quad 37$$

Consumers in both decoupling countries lose from the decoupling (given that the same result applies to country B).



Size and the welfare benefit from being a bystander

The rest of the world benefits from the decoupling of the other two. But this benefit depends on the relative size of the rest of the world relative to the two countries.

When considering the impact of a change in the relative size of the two countries involved in the reciprocal trade war, i.e. a change of N , one needs to consider that an increase in N also increases welfare overall since it increases the size of the global economy (the size of the two decoupling countries was fixed at unity).

To consider the impact of an increase in N on the welfare gain for the rest of the world one thus needs to consider how the ratio below changes with a change in N :

$$\frac{W_{TW}^E}{W_{FT}} = \frac{\left[N + 2 \left(p^{\frac{-\theta}{1-\theta}} \right) \right]^{\frac{1-\theta}{\theta}}}{(N + 2)^{\frac{1-\theta}{\theta}}}$$

38

The derivative of the $\frac{1-\theta}{\theta}$ root of this ratio with respect to N is given by:

$$\frac{\partial \frac{W_{TW}^E}{W_{FT}}}{\partial N} = \frac{(N + 2) \left(1 + \frac{\partial p^{\frac{-\theta}{1-\theta}}}{\partial N} \right) - \left[N + 2 \left(p^{\frac{-\theta}{1-\theta}} \right) \right]}{[(N + 2)]^2} < 0$$

39

$$\frac{\partial \frac{W_{TW}^E}{W_{FT}}}{\partial N} = \frac{(N + 2) \left(\left(\frac{-\theta}{1-\theta} \right) p^{\frac{-\theta}{1-\theta}-1} \frac{\partial p}{\partial N} \right) - 2 \left[\left(p^{\frac{-\theta}{1-\theta}} \right) - 1 \right]}{(N + 2)^2} < 0$$

40

The inequality sign results from the fact that $\frac{\partial p}{\partial N}$ is positive. This implies, as one would expect, that the rest of the world gains less if two small countries engage in a tariff war, than when two large countries do it. In terms of the US-China trade tensions this implies that the remaining countries gain if the US can convince some of its allies, notably Canada, Mexico or even the EU to join the US in imposing tariffs on imports from China.



The welfare loss of the decoupling countries depends symmetrically on relative size. The larger the rest of the world (higher N) the higher the welfare level of the decoupling countries (because it does not matter much to decouple from a small neighbour).

$$\frac{\partial \frac{W_{TW}^A}{W_{FT}}}{\partial N} = \frac{(N+2) \left(p^{\frac{\theta}{1-\theta}} + N \frac{\theta}{1-\theta} p^{\frac{\theta}{1-\theta}-1} \frac{\partial p}{\partial N} \right) - \left[N p^{\frac{\theta}{1-\theta}} + 1 \right]}{[(N+2)]^2} > 0$$

41

Gains for the rest of the world versus losses at home

The results so far imply that the rest of the world gains and the two decoupling countries lose. One would expect that the gain for the rest of the world is smaller than the loss for the two decoupling countries. This can be verified by comparing the sum of the welfare (of representative consumers) under the decoupling equilibrium to the free trade situation.

$$\begin{aligned} (W_{TW}^E) + (W_{TW}^A) &= \left[N + 2 \left(p^{\frac{-\theta}{1-\theta}} \right) \right] + \left[N p^{\frac{\theta}{1-\theta}} + 1 \right] = \\ &= \left[N \left(1 + p^{\frac{\theta}{1-\theta}} \right) \right] + \left[2 \left(p^{\frac{-\theta}{1-\theta}} \right) + 1 \right] < (N+2) + (N+2) \end{aligned}$$

42

Asymmetric or unilateral decoupling

The concrete case considered here is that country A shuts off imports from country B, which does not retaliate (i.e. it keeps importing from country A). Country E is not affected by the trade measure of A. The discussion here assumes that it is the importing country that decouples. But the situation would be exactly the same if it were the exporting country (B) that prohibits exports from to A. To keep the exposition tractable the size of the three countries is assumed to be the same (equal to 1).



Goods market equilibrium

To analyse this set-up it is again best to start with the equilibrium in the markets for the goods produced in the three countries.

Production of goods produced in E (rest of the world) equals home consumption in E plus consumption in the two other countries, which is no longer equal in A and B).

$$x^E = c_E^E + c_B^E + c_A^E$$

43

The market clearing condition for A's goods is similar.

$$x^A = c_A^A + c_B^A + c_E^A$$

44

The goods markets equilibrium for B, which is shut out of A's market is different as consumers of A no longer have access to goods from B:

$$x^B = c_B^B + c_E^B$$

45

Balance of trade equilibrium

The second element that characterizes the asymmetric decoupling is that the structure of the balance of payment is different for the three countries.

Balance of payments equilibrium for E requires that the value of its exports, given by the difference between production and home consumption, equal the value of imports from B and A. Goods produced in E are the numeraire, p designates the relative price of goods produced in A and the price of goods produced in B, is denoted by p_B :

$$x^E - c_E^E = c_A^E + c_B^E = p c_E^A + p_B (x^B - c_B^B) = p c_E^A + p_B c_E^B$$

46

A imports only from E, but exports to both B and E:

$$p(x^A - c_A^A) = c_A^E = p c_B^A + p c_E^A = p(c_B^A + c_E^A)$$

47

B imports from both A and E but exports only to E.

$$p_B(x^B - c_B^B) = p_B c_E^B = p c_B^A + c_B^E$$

48



Trade of B is balanced if the trade balances of the other two countries (A and E) are in balance. The bop equilibrium condition for B thus does not provide any further information and will be disregarded henceforth.

Demand conditions

In E the ratio of consumption of domestic to imported goods (those from A and B) depends on their relative prices:

$$\frac{c_E^E}{c_E^A} = p^{\frac{1}{1-\theta}}$$

49

$$\frac{c_E^E}{c_E^B} = p_B^{\frac{1}{1-\theta}}$$

50

The same applies, mutatis mutandis in A (here the only goods available are those imported from E and thus consumers have only two varieties to choose from):

$$\frac{c_A^E}{c_A^A} = p^{\frac{1}{1-\theta}}$$

51

The indirect effects of the asymmetric decoupling show up in the price paid by consumers in B for goods from E and A.

$$\frac{c_B^B}{c_B^E} = p_B^{\frac{-1}{1-\theta}}$$

52

$$\frac{c_B^B}{c_B^A} = \left(\frac{p_B}{p}\right)^{\frac{-1}{1-\theta}}$$

53

These 10 equations (43 to 53, not counting 48) determine the 8 quantities (three for each of the two countries not subject to trade measures, E and A, plus two for country B) plus the two relative prices of the three goods. The latter are the key variables of interest.



Equilibrium

The 5 demand functions above can be used to simplify the three goods market equilibrium conditions, leaving only the 3 terms for the home consumption of the home goods.

Starting with the market for goods from E, this yields:

$$x^E = c_E^E + c_B^E + c_A^E = c_E^E + c_B^B p_B^{\frac{1}{1-\theta}} + c_A^A p^{\frac{1}{1-\theta}}$$

54

The market clearing condition for A's goods is similar.

$$x^A = c_A^A + c_B^A + c_E^A = c_A^A + c_B^B \left(\frac{p_B}{p}\right)^{\frac{1}{1-\theta}} + c_E^E p^{\frac{-1}{1-\theta}}$$

55

The goods markets equilibrium for B, which is shut out of A's market is different as consumers of A no longer have access to goods from B:

$$x^B = c_B^B + c_E^B = c_B^B + c_E^E p_B^{\frac{-1}{1-\theta}}$$

56

These three equations contain three quantities and two prices.

They can be combined with the two balance of payments conditions to solve for all unknowns.

However, a full solution is not necessary to derive the key results concerning the impact of an asymmetric decoupling on the welfare of all three countries. The first step is to reduce the size of the system of equations by recursive substitution. The first variable to be eliminated is c_B^B , using:

$$c_B^B = x^B - c_E^E p_B^{\frac{-1}{1-\theta}}$$

57

Substituting out for c_B^B in the goods market conditions of A yields:

$$x^A = c_A^A + \left(x^B - c_E^E p_B^{\frac{-1}{1-\theta}}\right) \left(\frac{p_B}{p}\right)^{\frac{1}{1-\theta}} + c_E^E p^{\frac{-1}{1-\theta}} = c_A^A + (x^B) \left(\frac{p_B}{p}\right)^{\frac{1}{1-\theta}}$$

58

Similarly, substituting out for c_B^B in the goods market conditions of E:

$$x^E = c_E^E + \left(x^B - c_E^E p_B^{\frac{-1}{1-\theta}}\right) p_B^{\frac{1}{1-\theta}} + c_A^A p^{\frac{1}{1-\theta}} = (x^B) p_B^{\frac{1}{1-\theta}} + c_A^A p^{\frac{1}{1-\theta}}$$

59



The equation describing the goods markets equilibrium for A (58) can be rewritten in terms of c_A^A :

$$c_A^A = x^A - (x^B) \left(\frac{p_B}{p} \right)^{\frac{1}{1-\theta}}$$

60

This can be substituted back into the equation describing the goods markets equilibrium for E (equation 59):

$$x^E = (x^B) p_B^{\frac{1}{1-\theta}} + p^{\frac{1}{1-\theta}} \left[x^A - (x^B) \left(\frac{p_B}{p} \right)^{\frac{1}{1-\theta}} \right]$$

61

It follows that (with x^E and x^A normalized to 1:

$$1 = p_B^{\frac{1}{1-\theta}} + p^{\frac{1}{1-\theta}} \left[1 - \left(\frac{p_B}{p} \right)^{\frac{1}{1-\theta}} \right] = p^{\frac{1}{1-\theta}} \Rightarrow p = 1$$

62

This is a key result. It means that the unilateral decoupling does not confer a gain in the terms of trade for the country that shuts off imports (from B). This is already an indication that country A cannot gain from the unilateral decoupling (under free trade its terms of trade are also equal to 1 since all prices are equal to 1). Its consumers have less choice, and its exporters cannot charge higher prices.

Another immediate implication that the price of A's exports remains equal to that of its imports (now only from E) is that the country will be less open to trade. Under free trade home consumption of the domestic good is one third of production. Under unilateral decoupling this rises to one half as consumers will distribute their total consumption equally between the only two goods at their disposal when their price is the same.

That domestic consumption increases to one half can be formally be proven by using the goods market condition of A together with the fact that the price, p , is equal to 1.

$$x^A = c_A^A \left(1 + p^{\frac{\theta}{1-\theta}} \right) \Rightarrow c_A^A = \frac{x^A}{2} = \frac{1}{2}$$

63

Using the balance of payments equilibrium condition for A, the fact that $c_A^A = \frac{1}{2}$ can be used to solve for the ratio of the two prices $\frac{p_B}{p}$:



$$c_A^A = \frac{1}{2} = x^A - (x^B) \left(\frac{p_B}{p} \right)^{\frac{1}{1-\theta}}$$

64

This yields (with $x^B = 1$)

$$\left(\frac{p_B}{p} \right)^{\frac{1}{1-\theta}} = \frac{1}{2} \Rightarrow \frac{p_B}{p} = \left(\frac{1}{2} \right)^{1-\theta} < 1$$

65

Given that $p=1$ this implies that country B experiences a terms of trade loss. One of its export markets (A) disappears, inducing its exporters to lower their price on the only market that remains, namely the rest of the world, E. Consumers in B retain access to all varieties, but exporters must accept lower prices. This combination implies that B loses from the unilateral decoupling inflicted on it by A.

A priori, it is not clear who loses more, A or B. This requires an explicit comparison of welfare levels under different states of the world.

The impact of unilateral decoupling on welfare

Given the utility function (1) the welfare can be written by treating the varieties from the different countries as different goods. The benchmark is everywhere the free trade equilibrium, which in this case of 3 countries of equal size gives a welfare level of (see above, equation 27):

$$W_{FT}^A = W_{FT}^E = W_{FT}^B = [1 + 1 + 1]^{\frac{1-\theta}{\theta}}$$

66

Welfare (the utility level of the representative consumer in each country can be calculated as a function of relative prices.

Starting with country A, this yields:

$$W^A = \left[(c_A^A)^\theta \left(1 + \left(\frac{c_A^E}{c_A^A} \right)^\theta \right) \right]^{\frac{1}{\theta}} = \left[(c_A^A)^\theta \left(1 + \left(p^{\frac{1}{1-\theta}} \right)^\theta \right) \right]^{\frac{1}{\theta}}$$

67



Where the ratio of imports of good from E to own country consumption can be substituted in terms of the price of A good. This expression can then be combined with the equation for home consumption of the home good in A (equation 55 above):

$$x^A = c_A^A \left(1 + p^{\frac{\theta}{1-\theta}}\right)$$

68

Combining the last two equations yields an expression for the welfare of (a representative consumer of) A:

$$W_{AD}^A = \left[p^{\frac{\theta}{1-\theta}} + 1 \right]^{\frac{1-\theta}{\theta}} < (1+2)^{\frac{1-\theta}{\theta}}$$

69

Consumers in the decoupling country lose as long as $p^{\frac{\theta}{1-\theta}} < 2$, i.e. the terms of trade of A would have to improve massively to make up for the loss of access to B varieties. Since p is in the one-side decoupling equilibrium equal to 1 it follows that that country A loses from decoupling from B.

The same procedure for B starts with:

$$\begin{aligned} W_{ASV}^B &= \left[(c_B^E)^\theta + (c_B^A)^\theta + (c_B^B)^\theta \right]^{\frac{1}{\theta}} = \left[(c_B^B)^\theta \left[\left(\frac{c_B^E}{c_B^B} \right)^\theta + \left(\frac{c_B^A}{c_B^B} \right)^\theta + 1 \right] \right]^{\frac{1}{\theta}} \\ &= \left[(c_B^B)^\theta \left[\left(p_B^{\frac{1}{1-\theta}} \right)^\theta + \left(\left(\frac{p_B}{p} \right)^{\frac{1}{1-\theta}} \right)^\theta + 1 \right] \right]^{\frac{1}{\theta}} \end{aligned}$$

70

Use:

$$x^B = c_B^B \left(1 + p_B^{\frac{\theta}{1-\theta}} + \left(\frac{p_B}{p} \right)^{\frac{\theta}{1-\theta}} \right)$$

71

$$W_{ASV}^B = \left[1 + p_B^{\frac{\theta}{1-\theta}} + \left(\frac{p_B}{p} \right)^{\frac{\theta}{1-\theta}} \right]^{\frac{1-\theta}{\theta}} = \left[1 + 1 + \left(\frac{1}{2} \right)^{\frac{\theta}{1-\theta}} \right]^{\frac{1-\theta}{\theta}} < (1+2)^{\frac{1-\theta}{\theta}}$$

72



The third term in the last bracket is smaller than 1. This implies that the sum of the three terms is smaller than three. Country B thus loses from being the victim of the one-sided decoupling of A).

However, country B is better off than country A since:

$$W_{ASV}^B = \left[1 + 1 + \left(\frac{1}{2} \right)^{\frac{\theta}{1-\theta}} \right]^{\frac{1-\theta}{\theta}} > W_{AD}^A = \left[p^{\frac{\theta}{1-\theta}} + 1 \right]^{\frac{1-\theta}{\theta}}$$

73

Consumers in the country that decouples thus lose more than those in B, the intended victim

The bystander country E is better off. The welfare level of its representative consumer is given by:

$$\begin{aligned} W_{ASV}^E &= \left[(c_E^E)^\theta + (c_E^A)^\theta + (c_E^B)^\theta \right]^{\frac{1}{\theta}} = \left[(c_E^E)^\theta \left[1 + \left(\frac{c_E^B}{c_E^E} \right)^\theta + \left(\frac{c_E^A}{c_E^E} \right)^\theta \right] \right]^{\frac{1}{\theta}} \\ &= \left[(c_E^E)^\theta \left[1 + \left(p_B^{\frac{-1}{1-\theta}} \right)^\theta + \left(p^{\frac{-1}{1-\theta}} \right)^\theta \right] \right]^{\frac{1}{\theta}} \end{aligned}$$

74

Use:

$$x^E = c_E^E \left(p^{\frac{-\theta}{1-\theta}} + p_B^{\frac{-\theta}{1-\theta}} + 1 \right)$$

75

This implies:

$$W_{ASV}^E = \left[1 + p^{\frac{-\theta}{1-\theta}} + p_B^{\frac{-\theta}{1-\theta}} \right]^{\frac{1-\theta}{\theta}} = \left[1 + 1 + 2^{\frac{\theta}{1-\theta}} \right]^{\frac{1-\theta}{\theta}}$$

76

The sum of the three terms is larger than 3, implying that the bystander country E gains from the unilateral decoupling going on between its two trading partners.



Comparison to bilateral decoupling

The gain for the rest of the world increases if the decoupling becomes bilateral, i.e. if the country that is object of a unilateral ban on its imports responds by also banning the imports from the other country.

This can be seen by comparing the two expressions for the welfare of E under the case of unilateral decoupling and a bilateral one (called above trade war).

$$W_{ASV}^E = \left[1 + 1 + 2^{\frac{\theta}{1-\theta}} \right]^{\frac{1-\theta}{\theta}} < W_{TW}^E = \left[1 + 2p^{\frac{-\theta}{1-\theta}} \right]^{\frac{1-\theta}{\theta}}$$

77

An aside: Forming a larger coalition.

Country A gains nothing if it succeeds in attracting country E into a coalition to also block imports from B.

The intuition for this indifference for country A is simple. Under the unilateral decoupling the terms of trade remain the same and one half of domestic output is consumed at home. If A can convince E to shut out imports from B, the two countries will effectively form a small autarkic world shut off from B.

In this two-country world, domestic consumers will still use one half of domestic production, and the terms of trade will also remain at unity. The welfare of A thus does not improve from forming a coalition.

However, E will clearly lose if it forms a coalition to isolate B as this would mean a loss of the terms of trade gain from the asymmetric decoupling and less choice for its consumers. B would of course lose even more since it would be thrown back into autarchy.

If the aim of A is to inflict the largest damage possible to B, it would pressure A to form a coalition. Forming this coalition to isolate B would have no (economic) cost (or advantage) for A, but it would need to find a way to compensate E for its loss from entering the coalition.

Concluding remarks and the context of the US-China trade war

Decoupling taking literally means that all trade between two countries would cease. This is clearly an extreme situation that is unlikely to materialize between China and the US even if the tensions increase again. But an analysis of this extreme case is nevertheless interesting



because it illustrates general principles. This note has investigated the consequences of decoupling in the context of the canonical standard model of trade in differentiated products. The main result is that the rest of the world gains from decoupling because its terms of trade improve while it maintains access to all varieties.

The two countries engaged in decoupling clearly lose. This has two causes, the deterioration of the terms of trade and the loss of access to the varieties from the former trading partner. The deterioration of the terms of trade is just a transfer to the rest of the world, but the decoupling countries also experience a reduction in welfare because the number of varieties available to their consumers falls by a quarter (if the rest of the world is as large as the two decoupling countries together). Global welfare is clearly lower as the loss of the decoupling countries is larger than the gain for the rest of the world.

The model-based analysis implies, not surprisingly, that decoupling leads to less trade overall, but the trade to output ratio increases for the rest of the world as both imports from and exports to the decoupling countries increase.

Any decoupling of China and the US thus creates more trade opportunities for the rest of the world. This has already been observed in the case of the so-called connector countries, like Vietnam, whose exports to the US have increased strongly after the US first imposed tariffs on imports from China.

However, these Vietnamese exports contain little domestic value added as exports of intermediate goods from China to Vietnam have also increased. This re-routing of trade via 'connector' countries (Gopinath et al 2024) is different from trade creation described by the model of differentiated products used because in this model only domestic inputs are needed in production.

This model is thus much better suited to describe the case of Europe (or Japan) whose exports to the US and China contain only a small percentage of foreign value added and Chinese intermediate inputs constitute only a small share of all foreign value added contained in exports. For example, the OECD TIVA database shows that about 85 % of the value of EU exports is based on domestic value added. That percentage falls even further (to 10 %) if one considers all of Europe as one block.

By contrast, for Vietnam foreign inputs make up about one half of the value of exports. Moreover, Chinese intermediate products constitute only about 10 % of all foreign inputs in EU exports (Beaujeu et al. 2022), implying that EU exports contain only about 1.5 % of Chinese inputs. For Vietnam that percentage must be an order of magnitude higher. About 36 % of Vietnamese imports come from China, most of which are intermediate inputs.

The Chinese value-added content in Vietnamese imports must thus be on average about 18 %, but probably much higher for those products that were newly exported to the US after the imposition of the tariffs on China.



The re-routing of Chinese exports to the US via assembly in South Asia is thus a qualitatively different phenomenon than the gains of market share for European-made exports in the US (and China).

Europe is not a connector country, but rather a bystander that gains from geopolitically motivated bad policies elsewhere.



Appendix

Consider the function $f(N, p, \theta)$ which describes the equilibrium in the symmetric case:

$$f(N, p, \theta) = p^{\left(\frac{-\theta}{1-\theta}\right)} + N - \left(Np^{\left(\frac{1}{1-\theta}\right)} + 2p\right) = 0$$

78

$$\frac{\partial f(.)}{\partial N} = 1 - p^{\left(\frac{1}{1-\theta}\right)} > 0$$

79

The inequality sign results from the fact that $p < 1$, as shown above.

The derivative with respect to p is clearly negative:

$$\frac{\partial f(.)}{\partial p} = \left(\frac{-\theta}{1-\theta}\right)p^{\left(\frac{-\theta}{1-\theta}-1\right)} - \left(\left(\frac{1}{1-\theta}\right)Np^{\left(\frac{1}{1-\theta}-1\right)} + 2\right) < 0$$

80

It follows that an increase in N leads to an increase in p .

The derivative with respect to θ is somewhat more complicated to calculate.

$$\frac{\partial f(.)}{\partial \theta} = p^{\left(\frac{-\theta}{1-\theta}\right)} \left(\frac{-\theta - (1-\theta)}{(1-\theta)^2}\right) \ln(p) - Np^{\left(\frac{1}{1-\theta}\right)} \left(\left(\frac{1}{(1-\theta)^2}\right) \ln(p)\right) > 0$$

81

$$\frac{\partial f(.)}{\partial \theta} = -\ln(p) \left[p^{\left(\frac{-\theta}{1-\theta}\right)} \left(\frac{-1}{(1-\theta)^2}\right) + Np^{\left(\frac{1}{1-\theta}\right)} \left(\frac{1}{(1-\theta)^2}\right) \right] > 0$$

82

Since $p < 1$ this expression is positive.



References

- Beaujeu, Raphaël, Olivier Besson, Laure Decazes, Aymeric Lachaux, (2022) Decoupling of US and China Value Chains: Challenges for the EU, Ministère de l'économie, Trésor Economics, No. 308, June 2022
<https://www.tresor.economie.gouv.fr/Articles/c39528ee-253e-43ba-bcd5-07ff0218a098/files/4b48c625-6ea7-4bc1-8c6d-9e89377301de>
- Andy Bounds and Sam Fleming (2024), EU presses for new powers to combat threat of Chinese import surge, Financial Times, London December 16 2024,
https://www.ft.com/content/2ca1158f-c14e-48ee-986d-5d797daa48fb?utm_source=chatgpt.com
- Felbermayr, G., Mahlkow, H. and Sandkamp, A., 2023. Cutting through the value chain: The long-run effects of decoupling the East from the West. *Empirica*, 50(1), pp.75-108.
- Gopinath, Gita, Pierre-Olivier Gourinchas, Andrea F Presbitero, Petia Topalova (2024) Changing Global Linkages: A New Cold War?, IMF Working Paper,
<https://www.imf.org/en/Publications/WP/Issues/2024/04/05/Changing-Global-Linkages-A-New-Cold-War-547357>
- Kemp, M., and H. Wan. " An Elementary Proposition Concerning the Formation of Customs Unions," International Economic Review, 1976. pp. 95-97.
- Krugman, P., 1980. Scale economies, product differentiation, and the pattern of trade. *American economic review*, 70(5), pp.950-959.
- Krugman, P.R., 1981. Intraindustry specialization and the gains from trade. *Journal of political Economy*, 89(5), pp.959-973.
- Krugman, P. " Is Bilateralism Bad?' in E. Helpman and A. Razin, eds.. International Trade and Trade Policy, Cambridge: MIT Press, 1991.
- Melitz, M.J. and Ottaviano, G.I., 2008. Market size, trade, and productivity. *The review of economic studies*, 75(1), pp.295-316.
- Nocco, A., Ottaviano, G.I. and Salto, M., 2019. Geography, competition, and optimal multilateral trade policy. *Journal of International Economics*, 120, pp.145-161.
- Viner, J. The Customs Union Issue. New York: Carnegie Endowment for International Peace, 1950.
- Wu, J., Wood, J., Oh, K. and Jang, H., 2021. Evaluating the cumulative impact of the US–China trade war along global value chains. *The World Economy*, 44(12), pp.3516-3533.



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