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Free Trade and Arms Races: Some Thoughts Regarding EU-Russian Trade

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Abstract

As NATO expands eastward, Russia has expressed growing concerns over what it sees as a threat to its national security. At the same time Russia is transitioning to a market economy, with the aim of becoming a free trade partner with the West. The question of concern to European nations is; how will Russia allocate the wealth it gains from freer trade with the west? Will the new found wealth make Russians feel more confident and secure, allowing for a reallocation of wealth towards consumption goods, or will the newly created wealth be allocated towards a new round of military build up? We examine these questions by modeling for the first time the effect of free trade between two potential political rivals, on their respective accumulation of weapons. Our model includes a rich setup in which utility maximization, the economics of trade and comparative advantage, production of weapons and consumption goods, depreciation of weapons stocks, technological spillover from production to national security, and the accumulation of capital are represented in an infinite horizon setting. The paper adopts a neoclassical two goods model of trade in which each actor specializes in producing the good of its comparative advantage and engages in trade. In the model, each country derives positive utility from consumption and its own stock of weapons. The impact of the foreign country`s weapons stock on the home country`s utility is negative (in the case of rivals). At each point in time, each actor chooses how to allocate its resources between the production of consumption goods and defense expenditures. Applying dynamic optimization, we find that whether free trade leads to a rise or a decline in each country`s stock of weapons relative to no trade depends on the relative marginal utilities of the consumption goods and weapons. The implications of these results to the trade and conflict debate are considered.

1. Introduction

The study of arms races is at the center of the field of international relations. Analysts have investigated the theoretical and empirical dynamics of arms races, the behavior of specific nations and dyads engaged in an arms race, and the relationship between arms races and the escalation of military disputes. The link between arms races and national and international economic factors has received much less attention. In particular, while there are several examples in which political rivals trade with each other, the relationship between trade and the accumulation of weapons has not been investigated.

Consider, for example, contemporary EU-Russian relations. As NATO expands eastward, Russia has expressed growing concerns over what it sees as a threat to its national security. At the same time Russia is transitioning to a market economy, with the aim of becoming a free trade partner with the west. The question of concern to European nations is; how will Russia allocate the wealth it gains from freer trade with the west? Will the new found wealth make Russians feel more confident and secure, allowing for a reallocation of wealth towards consumption goods, or will the newly created wealth be allocated towards a new round of military build up?

This paper not only contributes to the investigation of the impact of trade on bilateral political relations. It also contributes to the literature concerning the modeling of arms races. Intriligator and Brito (1990) suggest challenges for future arms races modeling. The present paper most directly answers their challenge to investigate the link between economic factors and arms races. In this spirit, some researchers have investigated qualitatively the link between technology and the arms race.[1] These studies do not, however, formally attempt to model the link between arms races and trade. To our best knowledge, this paper represents the first step in the formal investigation of the link between arms races and free trade.

To be able to address such questions, we integrate neoclassical trade theory with arms race theory. We construct a formal model of bilateral trade and arms race and focus on the link between the two. We trace the impact of trade on the accumulation of weapons stocks when traders view each other as potential rivals. Employing dynamic optimization, we arrive at an interesting result: there are conditions under which trade among rivals results in a reduction of weapons stocks. There are, however, conditions under which such trade results in an increase of weapons stocks. We are able to link these different outcomes to parameter values in the model.

Our paper differs from other arms race models in that we link trade to the arms race, and analyze the dynamic relationship between free trade and the arms race formally and explicitly. We consider two countries whose goal is to maximize the present and future utilities of their citizens.[2] We examine cases in

1. Thee (1990), for instance, argues that high technology contributes to countries` ability to accumulate weapons. Hammond (1993:67) argues that capital accumulation affects weapons accumulation because the fundamentals of production characterize military organization.

2. Our model is bilateral as are most arms race models (Intriligator and Brito, 1990). This is a simplification as trade is multilateral. Since we focus on a change in relative prices and the allocation of wealth creation due to trade, our insights could be applied to a more general setting.

which countries are political allies and rivals. Our main focus, however, is on the case of rivals. The two countries are subject to dynamic constraints imposed by production technology, and capital and weapons accumulation. Agents within each country are assumed to have the same utility over consumption and national security, or equivalently, countries are conceptualized as unitary actors. National security is assumed to rise in the home country`s weapons stock and fall in the foreign country`s weapons stock.[3] Importantly, in our model the process of arms accumulation or reduction is not a result of some error in calculation or wrong assumptions regarding goals of the other country.

The analysis proceeds in two stages. At the first stage, the two countries operate in autarky (i.e., no trade).[4] At the second stage, they open their economies to trade. Following neoclassical trade theory, each country specializes in producing the good of its comparative advantage in order to maximize its absolute gains from trade. We refrain from assuming trade competitions of any sort, or that countries maximize the relative gains from trade as in realist theory. Nor do we assume that resources or markets are scarce as in Neo-Marxist theory. Hence, our trade model is purely liberal. Our goal is to find out whether, under conditions of the liberal trade paradigm, the amount of resources allocated to weapons production under free trade will rise, fall, or remain unchanged, relative to the case of no trade.

We find it is not necessarily the case that trade will be associated with a reduction in weapons stocks. Since trade increases the efficiency of resource allocation, the stocks of weapons held in the trade equilibrium may actually increase relative to the no trade equilibrium. Whether or not countries will increase their weapons stocks in trade relative to no trade depends on the marginal utility derived from weapons relative to that derived from consumption, for each country. As long as the preferences of countries for national security relative to consumption do not change, trade may not take them out of the security dilemma.

While we investigate the link between free trade and arms races, there is a vast literature on the link between trade and conflict. To the extent that arms races contribute to the likelihood of dispute escalation and wars, our model identifies the conditions under which trade is likely to generate peace among potential rivals and when trade may generate conflict.[5]

The remainder of our paper is organized as follows. Section 2 reviews the literature. Section 3 motivates our argument and discusses the general framework. Section 4 formulates our model. Section 5 analyzes the case of autarky. Section 6 analyzes the case of trade. In the final section we discuss the implications of our results for the trade and conflict debate, and offer concluding remarks. The model is

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3. For allies, the contribution of the foreign weapons stock to their own utility is positive.

4. In autarky each country consumes its entire production and does not engage in trade.

5. Our actors do not explicitly consider the possibility that weapons accumulation may heighten the chance of an undesirable war. This adaptation would not alter the validity of our results. Equilibrium weapons stocks would be lower, but they would be lower under both autarky and free trade, and may still rise under trade relative to autarky. However, war is implicitly included in our model through the structure of actors utility. As we show, for political rivals actors utility falls with the foreign weapons stock. This happens because actors dislike facing a stronger opponent in a possible future war.

solved mathematically in the Appendix.

2. Literature Review

Three strands of the literature are relevant for the present paper. The first deals with arms races, the second with trade and conflict, and the third debates the prospects of trade between political rivals. We review these strands of the literature in turn.

Arms Races

The literature on arms races includes three types of models.[6] In the first type, authors specify actors` behavioral differential or difference equations without modeling maximizing behavior (e.g. Cusack and Ward, 1981; Majeski, 1983). Beginning with Richardson (1960), actors are assumed to reciprocate positively to each others` military expenditures, and are also affected by their own past decisions (inertia). In the second type, actors have been modeled as maximizing an objective function from a constrained static optimization as in McGuire (1965), or dynamic optimization as in Brito (1972), Intriligator and Brito (1976) and Simaan and Cruz (1975). Actors` objectives are typically assumed to depend on consumption and national security (measured by the stock of weapons). A third type of model features game theoretic structure in which the accumulation of weapons is connected specifically to the decision to start a war (e.g. Andrew et al., 1993; Brito and Intriligator, 1985; Intriligator and Brito, 1984). Acting under various assumptions on the order of actors` moves and the structure of information, these studies establish the conditions for peaceful and a warlike equilibria. We follow those studies which operationalize national security as a state objective which depends on the domestic and foreign weapons stocks.

Another branch of the arms race literature investigates specific dyads. The arms race of the US-USSR is the most studied. Other arms races investigated include those of Britain-Imperial Germany, 1930s France-Germany, US-China, India-Pakistan, India-China, Iran-Iraq, Greece-Turkey, and Israel-Egypt.[7] As is apparent from this partial list, countries that engage in arms races often trade with each other. Britain and Imperial Germany or the US and China, for instance, constitute extremely important trading relationships. Yet, their relations are characterized by both hostility and friendliness. Indeed, trading partners may aim their weapons stock at one another and invest a considerable amount of resources in doing so. At the same time, in other rival dyads (e.g. post-1945 France-Germany, USSR-Germany) trade seems to be associated with a decrease in weapons stocks over the long run. We show that both of these behaviors are rational,

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6. Intriligator and Brito (1990) and Isard and Smith (1988) review the literature on arms races models. Siverson and Diehl (1989) review the literature on the link between arms races and military disputes.

7. On the US-USSR arms race see, for instance, Ward (1984); on pre-World War I races see Choucri and North (1975); on the US-China see Cusack and Ward (1981); on India-Pakistan see Ward and Mahajan (1984) and Ghosh (1994); on India-China see Ward and Mahajan (1984); on Iran-Iraq see Abolfathi (1978); and on Middle East arms races see Rattinger (1976).

and identify when each is to be expected.

In the concluding section of our paper we consider the implications of our model to the trade and conflict debate. To facilitate that discussion, we review the final branch of the arms race literature which considers whether militarized disputes tend to escalate more into wars in the presence of arms races, and whether such disputes tend to be peacefully resolved when arms races are not present.[8] The literature on arms races and war is filled with heated debate. Huntington (1958) investigates 11 arms races from 1840 to the mid 1950s. He finds that some arms races end in a war and some do not. He argues that arms races are dangerous and may lead to war in particular in their beginning stage, when uncertainty is greatest, or when they are quantitative and prolonged.[9] Choucri and North (1975) find that arms races were important in elevating tensions and thus contributed to the causes of World War I.

Table 1 reports results from several studies which used a more extensive sample of 99 militarized disputes from 1815 to 1965. Wallace (1979, 1980, 1982, 1983) finds that arms races increase the probability that militarized disputes will escalate to war. Most disputes that did not involve an arms race did not escalate. Wallace`s results became a subject of controversy centered around the issues of how to identify an arms race and which races are independent. Weed (1980) groups dyads from a single war and repeats Wallace`s test. This reduced the number of disputes in which arms races were associated with the escalation of disputes to wars. But, the percent of such arms races was still 55%. Altfeld (1983) uses a stricter standard to identify an arms race. He finds that all the disputes that included an arms race escalated to war. But, there were also wars that broke out without an arms race. Diehl (1983) devises a new index to identify arms races and concludes that arms races and wars are not correlated. All these studies find, however, that disputes which do not involve an arms race are not likely to escalate to war.

Table 1. Empirical results on the relationship between arms races and wars

	Wallace, 1979		Weede, 1980		Wallace, 1982		Altfeld, 1983		Diehl, 1983	
	War	No War	War	No War	War	No War	War	No War	War	No War
Arms race	23	3	6	5	11	2	11	0	3	9
No arms race	5	68	2	68	4	63	15	73	10	64

Evaluating these results, Vasquez (1987) argues that arms races escalate disputes between relative equals but less so between nonequals. Siverson and Diehl (1989) argue that the definitive conditions which determine which arms races are more likely to be associated with dispute escalation to war are unclear.

8. For an informative review of this literature see Siverson and Diehl (1989).

9. Huntington distinguishes between qualitative races (better weapons) and quantitative races (more weapons). A long quantitative race is more likely to end in war (1958: 75-76).

Morrow (1989) notes that disputes preceded by an arms race tend to escalate to war, but the tendency is not overwhelming. Yet, as the amplitude of the race grows and when one state holds a temporary advantage, the likelihood of war increases. Russett and Starr (1996) conclude that the critiques of Wallace`s work qualify but do not fully refute its conclusions. They argue that arms races raise tensions and, especially in times of crisis, may escalate political disputes into violent conflict.[10]

Trade and Conflict

To the extent that arms races are associated with dispute escalation, we believe that our model has implications for the debate on the relationship between trade and conflict. Liberals argue that trade causes peace since conflict leads to a loss in trade gains. Some realists argue that trade causes conflict as nations maximize relative gains from trade, and warn that trade may strengthen rivals through technological diffusion and increased vulnerability to trade disruption. Other realists argue that trade has no effect on conflict because the causes of conflict and military disputes are non-economic (i.e. strategic or structural). For NeoMarxists, trade causes conflict since it enhances the competition over scarce resources and markets. Some economists argue that as trade increases economic growth, governments intervene in markets. This may generate conflict.

The empirical trade and conflict literature offers conflicting evidence.[11] Some studies find that trade causes peace. Others find that it causes conflict. A third group finds that trade may cause conflict or cooperation. A fourth group finds that the causality is such that conflict inhibits trade. We focus on empirical studies which argue that trade causes peace or hostility.

Polachek (1980) portrays nations as rational actors whose utility grows with consumption and hostility. Nations maximize utility by choosing hostility and consumption. From a static optimization, he concludes that governments will be averse to conflict with trade partners. Arad, Hirsch, and Tovias (1983) consider potential rivals who engage in trade. Since trade is beneficial to both, if hostility leads to less trade, both will lose. Therefore, trade reduces the propensity to be hostile. From a monadic analysis, Domke (1988) finds that exports inhibit the likelihood of war. Mansfield (1994) employs a systemic level of analysis and finds that the incidence of major power war declines with world trade. From a dyadic analysis for the post-1945 period, Oneal et al. (1996) and Oneal and Russett (1997) find that bilateral trade inhibits the likelihood of military disputes from a sample of politically relevant dyads. Oneal and Russett (1998a) extend this analysis to include all the dyads for which data are available and report similar findings. Oneal and Russett (1998b) extend the analysis to the period from 1870 to 1989. Using total (not bilateral) exports, they find that trading nations are less likely to be involved in military disputes.

The view that trade causes conflict is argued, for instance, in Choucri and North (1975), Ashley

10. Cashman (1993:184) offers a similar summary.

11. Our review is not all-inclusive. See McMillan (1997) and Sayrs (1990) for full reviews.

(1980), Feld (1979), and Park et al. (1976). In these models, nations compete for scarce resources and markets, or use trade for influence. In Sen (1984:7), competition over shares of strategic goods generates tension due to their significance for arms build ups. Borrus and Zysman (1992) argue that trade shares of leading goods generate expertise or spillovers which could be used to produce weapons. The competition over these sectors creates conflict. In Gowa (1994), the pursuit of relative gains is associated with political rivalry. Asymmetric or high trade interdependence could also induce conflict, as demonstrated in Hirschman (1980), Baldwin (1985), Barbieri (1996), Gasiorowski (1986), and Vries (1990). Mansfield and Pevehouse (1998) extend Oneal and Russett`s (1997) statistical analysis by indicating if traders belong to the same preferential trade agreement (PTA). He finds that asymmetric trade is a potent source of military disputes for non-PTA members. The effect of trade on conflict for PTA members is partly insignificant.

The above trade and conflict models recognize trade`s ability to motivate conflict or cooperation. However, these models do not investigate the ability of trade to enable (or pay for) conflict by making countries wealthier. This effect of trade is investigated here. At the same time, the link between the trade and conflict literature and our paper is indirect as we do not model the choice of conflict. Yet, as we have already mentioned, to the extent that arms races are linked to the escalation of political disputes, we believe that our paper also has implications to the trade and conflict debate. We will return to this point in the last section of our paper.

Trade among Political Rivals

Our model also deals with bilateral trade among political rivals. A third body of relevant literature to our paper evaluates the prospect of trade between political rivals. We focus on the studies of Grieco (1988, 1990), Gowa (1989, 1994), Gowa and Mansfield (1993) and Morrow (1997). Gowa (1989, 1994) argues that trade creates a security externality. Among rivals, this externality will be negative: the gains from trade could be translated to military strength. Rivals will attempt to maximize their <u>relative</u> gains from trade. Therefore, they are more likely to defect from trade agreements by imposing optimal tariffs.[12] These concerns are expected to reduce or eliminate profitable trade between rivals (Grieco, 1988, 1990). The risk of cheating is much lower for members in an alliance. Gowa and Mansfield (1993) and Gowa (1994) do not test directly the hypotheses on the impact of alliances on trade barriers (see Gowa, 1994: chapter 4). Instead, they test if trade follows the structure of alliances. They find that alliances are directly and positively related to the value of export.

Morrow (1997) offers a different view. Building on Powell`s (1993) and Gowa`s (1989, 1994) work, he considers the behavior of two rational trading rivals. Alternating, each period, one state or the other decides on military spending and in the next period on a war. The probability of victory rises with military allocations. Utility rises with consumption (which is reduced by military allocations). Trade generates a fixed

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12. For a discussion of optimal tariffs see Krugman and Obstfeld (1997) and Corden (1997).

exogenous income. Victory in a war fixes incomes where the winner`s income is larger. Actors also consider whether to impose optimal tariff (cheating) on their trade partner. A cheater gains more from trade and may therefore increase military allocation. Using this framework, Morrow investigates the conditions under which the vulnerability to cheating will cause the parties to refuse to trade. He finds that there are peaceful-trading equilibria in which the rivals do not cheat. Rivals refuse to trade only when gains are distributed very unequally, or when goods have direct military implications.

Gowa (1989, 1994), Gowa and Mansfield (1993), and Morrow (1997) agree that trade among rivals implies security externalities. They disagree on their empirical importance. Morrow argues that the size of the security externality is likely to be empirically insignificant (1997:31). It is therefore not likely that concerns over relative gains will stop trade between rivals in peacetime. Similar to Gowa (1989, 1994) he observes that during the cold war trade prospered within alliances but not across them. But, he attributes it to factors such as similar ideologies of trade partners (Dixon and Moon, 1993), or reduced risk to traders from trade disruption (Pollins, 1989a, 1989b; Morrow et al., 1996).

While the prospects of bilateral trade between political rivals are clearly debated in the literature, there are many real world cases in which political rivals do trade with each other. In the following sections we will show that this trade may generate a security externality which is endogenous to the trade process even when optimal tariffs are not used.

3. Motivation and General Framework

In this section we motivate our model by linking it to the above literature. Then, we provide an overview of the general framework of our model. We formally (i.e. mathematically) present the model and discuss its main result in the section 4, and fully solve it in Appendix.

As we have already noted, our model encompasses trade between allies and rivals. We, however, focus on the case of rivals. Consequently, we begin by discussing the likelihood of free trade between rivals. In fact, such trade is quite likely. Morrow (1997) demonstrates that the pursuit of relative gains is not likely to disrupt trade between rivals. There exists a peaceful trade equilibrium in which political rivals do not attempt to cheat on a trade agreement signed by both. He finds that, while actors periodically consider imposing optimal tariffs, there are many situations in which they decide not to do so. As a result, free trade between rivals can be stable. This conclusion fits well with real world evidence. Indeed, in many cases rivals engage in stable trade while at the same time allocating resources to produce weapons to be aimed at each other.

The use of optimal tariffs assumes an ability to affect trade prices. This ability implies that a nation must have a large share of the world market in the good upon which it will impose the optimal tariff (see Deardorff and Stern, 1987:37). Theoretically, the optimal tariffs argument is impeccable. In practice, the use of optimal tariffs is doubtful for several reasons. First, the ability of most countries to use optimal tariffs is limited since they do not have market power in world markets (Krugman and Obstfeld, 1997:226, Deardorff and Stern, 1987:34).[13] Second, the computation of optimal tariffs assumes knowledge of export supply and import demand price elasticities. This information needs to be statistically estimated. Yet, estimation results vary considerably across studies (i.e. Stern et al, 1976; Marquez, 1992; Corden, 1997). Last, the use of optimal tariffs may also impose costs on a nation`s allies. Hence, it assumes that a nation is able to use discriminatory trade policies. This, however, is not easy to do (Willett and Jalalighajar, 1984). In fact, it is hard to find any evidence demonstrating that countries cheat on trade agreements by using optimal tariffs.[14] Since the World Trade Organization (WTO) forbids trade wars and as most countries are WTO members, it is likely that in the future use of optimal tariffs will also be rare.

While the security externality associated with optimal tariffs may not be important, there is another important type of security externality which is endogenous to the trade process. This externality has not received much attention in the literature on international political economy, namely the allocation of trade-generated wealth to weapons production. According to standard (liberal) trade theory, to realize the gains from trade a country should specialize in producing the good of its comparative advantage and export it, and import the good of its comparative disadvantage. Trade along these lines allows countries to use their factor endowments more efficiently. The resources freed up relative to autarky could be used in one of three ways: (1) increase consumption while keeping military allocation at its autarkic level; (2) increase military allocation while keeping consumption at its autarkic level; or (3) increase both in some combination. Rational actors will find the optimal dynamic allocation of resources which maximizes their utility over an infinite horizon. A study of this allocation decision and its implications for arms buildups is at the center of our paper.

Morrow (1997), Gowa (1989, 1994), and Gowa and Mansfield (1993) do not model the economics of the gains from trade. Nor do they model the production of weapons and consumption goods. Dealing with these issues is our first goal. More important, in Powell`s (1993) model and Morrow`s (1997) variation of that model neither state responds to an increase in the other`s military allocation with an increase of its own...[T]here are no arms races in [the] model (Powell, 1993:125). This insensitivity, argues Powell, is an artifact of the model`s very simple structure. He calls for the alleviation of this limitation by developing richer models.

One criticism of our approach could be that we do not model the decision to fight, yet nations desire weapons. As shown by Morrow (1997), in a trade equilibrium countries hold weapons but do not fight. If trade leads to war, trade will not happen. This case is overruled by assumption (Morrow, 1997:33). The role of trade is our focus here. Even if we added the decision to fight to the model, our focus would still be on the peaceful equilibria. Thus, adding the decision to fight would complicate the model and detract us from our main goal, without adding any insight regarding trade and arms races. In addition, we follow many models (i.e. Brito, 1972; Simaan and Cruz, 1975; Intriligator and Brito, 1976; Richardson, 1960; Majeski,

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13. Hypothetically, the U.S. could have possibly gained from the use of optimal tariffs during the 1970s and 1980s, assuming Japan and the EEC did not retaliate. See Whalley (1985).

14. See Krugman and Obstfeld (1997) and Husted and Melvin (1997). Historically, optimal tariffs may have been used by Ancient Rome, during the Anglo-Hanse trade wars, and during the 17th century Anglo-Dutch wars. See Conybeare (1987).

1983; and others) in which countries accumulate weapons without deciding to go to war. In these models, however, actors do not trade. Hence, we extend a well-defined line of research.

The recent trade and conflict literature focuses on the role of trade in inhibiting or stimulating military disputes. A natural extension to studies which argue that trade brings peace is to claim that trade will reduce the weapons stocks which rivals aim at each other. Similarly, one may argue that if trade brings conflict, then trade will increase the weapons stocks that rivals aim at each other. To the extent that arms races are associated with the escalation of disputes, investigating the link between trade and arms races will shed light on the trade and conflict debate. If in trade rivals are found to hold more weapons compared to autarky, then trade can be viewed as a stimulator of conflict. If in trade rivals are found to hold less weapons relative to autarky, then trade could be viewed as an inhibitor of conflict.

We now present the framework for the model which is discussed in detail in the following sections. We consider trade between two nations, labeled (H) and (F) for home and foreign, respectively. The nations are conceptualized as unitary actors and are modeled as forward-looking utility maximizers. Each nation is assumed to have utility over its current and future consumption of two consumption goods (labeled x and y) and national security. Following Brito (1972), we model national security as the weighted difference (home minus foreign) between each nation`s weapons stock. Weights are used to reflect the power each respective stock has in generating national security. For example, an equal stock of US and Chinese weapons is likely to generate more security for the US because that stock would be technically superior, and therefore more able to inflict damage and create defense than its Chinese counterpart.[15]

Two standard microeconomic assumptions are made about each nation`s utility function. First, nations exhibit increasing utility in x and y. Second, nations exhibit diminishing marginal utility in the two goods.[16] These assumptions imply that, for each good, more is preferred to less, and that this preference is diminishing in the quantity of the good consumed. We also assume that utility is separable between the consumption goods and national security. This allows each nation to obtain positive utility from domestic consumption even when it feels its national security is under threat (i.e., utility generated from national security is negative). With respect to national security, we assume only that utility is increasing in its level. We examine the implications of assuming that the rate of increase of utility (marginal utility) is increasing or diminishing in national security. For the EU nations, and the United States, it seems natural to assume, in light of recent voluntary defense spending cutbacks, that marginal utility is diminishing in national security. Is this the case for Russia and China as well? While Russia's military is in decline, this decline is not voluntary. There are strong voices within Russia which advocate an increase in Military spending to return the nation to its former glory. While China's accumulation of weapons does not necessarily indicate that it exhibits increasing marginal utility of national security. However such a possibility cannot be ruled out.

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15. In the case of allies an enhancement in the stock of weapons by one nation creates national security for not only itself, but its trading partner as well. The implication here is that when examining trade between allies the weight on the foreign countries s weapons stock (as viewed by the home country) would be negative.

16. The marginal utility is the addition to utility from one more unit.

We begin the analysis by examining national behavior under autarky (i.e., no trade). In this case each nation decides how to allocate its capital stock across four potential uses - namely the production of x, the production of y, the production of weapons, and finally the production of capital to be used in future periods. This allocation decision is based on maximization of the sum of current and discounted future utilities. Consequently, we apply the methods of optimal control to solve the model.

The optimal allocation of capital across its four alternative uses will depend on the marginal value that each alternative generates. Recall that nations have utility over consumption goods and national security and not over capital per se. Thus the marginal value generated from a unit of capital devoted to each alternative is derived not only from the marginal utility associated with the alternative (e.g., the consumption of x), but also from the efficiency with which the nation can turn the capital into consumption goods or weapons. As a result, the optimal allocation of capital will depend on the relative efficiencies with which the nation can turn capital into its four alterative uses.

Of course, the allocation of capital will also depend on the relative marginal utilities associated with each alternative. We draw attention to the above relative production efficiencies because this is where we will see the impact of trade in the model. To generate trade, we assume that the country H is relatively more efficient at producing the x good, and the country F the y good. In the terminology of international trade, the home country has a comparative advantage in the production of x and the foreign country in the production of y. Under trade, each nation will be better off by specializing in the production of the good in which it holds a comparative advantage.[17] This specialization will generate an excess supply of that good in the domestic economy. This supply can then be traded for the alternative consumption good (which is in excess supply in the economy of the trading partner). Through specialization and trade each nation can generate more consumption of the x and y goods from the same amount of capital it devoted to the production of consumption goods in autarky.

In our model, rival states in autarky engage in an arms race. The question at the heart of our paper is: will each nation devote the same amount of capital to the production of weapons with trade as it did in autarky, or will it devote more or less? If with trade each nation devotes less capital each period to the production of consumption goods, and diverts the excess capital to weapon production, then trade will have intensified the arms race. We examine the conditions under which this will occur, and those under which capital will be pulled away from arms production to further boost consumption or capital accumulation.[18]

17. Assuming multiple tradeable goods have no impact on the qualitative results of the model. See Krugman and Obstfeld (1997:Chapter 2).

18. We assume that there are no tariffs. Tariffs will not change our results, as long as they are not prohibitive.

4. The Model

Our model includes a rich setup in which utility maximization, the economics of trade and comparative advantage, production of weapons and consumption goods, depreciation of weapons stocks, technological spillover from production to national security, and the accumulation of capital are represented in an infinite horizon setting.

In this section we fully formulate our model. The solution of the model for both the autarky and the trade equilibria is highlighted in the following two sections, and is presented in mathematical detail in the Appendix. We model and explain the link between arms races and free trade. As free trade allows countries to use their capital stock more efficiently, countries may allocate more resources to the production of weapons. Yet, those resources may also be allocated to produce consumption goods. Both weapons and consumption goods, however, contribute to national welfare. This tension is at the center of our model.

The model includes two countries.[19] Each country is modeled as a unitary utility-maximizing integrated household / production / governmental unit. Each country has utility over two consumption goods and national security. National security is assumed to depend on both countries` weapons stocks.

Each country produces an aggregate output Y using total amounts of capital (K) and labor (L). The production technology is given by the function F. The output (Y_H) of the home country is given by:

$$Y_H = F(K_H, L_H). \tag{1}$$

A similar equation may be written for the foreign country. Output is devoted to the production of goods and weapons, and is also invested to accumulate more capital. The national income identity of country H is given in (2), assuming there is no depreciation of capital.

$$Y_H = K_{HX} + K_{HY} + D_H + \frac{dK_H}{dt}. \tag{2}$$

In (2), K_{HX} is the amount of output devoted to the production of good x, K_{HY} to good y, D_H to weapons, and dK_H/dt is investment to accumulate more capital.

The accumulation of capital over time is modeled from a dynamic process. The growth rate of the capital stock is determined by the difference between national output and the sum of the allocations to x, y, and defense expenditures. Assuming for simplicity that the labor force equals the population and there is no population growth, (2) may be written in per capita terms as Equation (3),

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19. We modify and combine the arms race model in Brito (1972), the capital accumulation model in Blanchard and Fischer (1989), the trade and pollution model in Scotese and Maxwell (1996), and the Ricardian trade model (see Krugman and Obstfeld, 1997: Chapter 2).

$$f(k_i(t)) = k_{ix} + k_{iy} + d_i(t) + \frac{dk_i(t)}{dt} \quad i = \{H, F\} \tag{3}$$

where small letters denote per capita terms, f is a concave production technology with a diminishing marginal product of per capita capital, d denotes defense expenditures, and the subscript i={H,F} denotes the home or the foreign country, respectively.

To keep the model simple, we assume a linear technology of production that uses one input in the production of goods.[20] In the home country one unit of capital devoted to the production of x yields one unit of x, while a unit of capital devoted to the production of y yields p_H units of y. Similarly, in the foreign country, one unit of capital devoted to the production of y yields one unit of the consumption good y, while a unit of capital devoted to the production x yields $1/p_F$ units of x.[21] Note that a change in p_H represents a change in the productivity of capital devoted to the production of the y good. Specifically, an increase in p_H implies an increase in this productivity. This implies that the overall productivity of capital devoted to goods production in generating consumption will rise. A similar note applies, of course, to the foreign country (as p_F falls to p). Assuming competitive markets and given these production technologies, in autarky the price of good x relative to the price of good y (p_x/p_y) is given by p_H and p_F in the home and foreign countries, respectively.

Trade is generated in the model through the assumption of comparative advantage. The home country holds a comparative advantage in good x, while the foreign country holds comparative advantage in good y. This implies that in autarky the home country relative price of good x (p_H) is less than its counterpart in the foreign country (p_F). As trade opens between the two countries, and free markets are allowed to operate, goods will be traded at the same relative price p. As long as $p_H<p<p_F$, each country will specialize in the production of the good in which it has comparative advantage. Each nation then trades some of its product in order to realize gains from trade.

In the spirit of Brito (1972) and others, we operationalize national security as the weighted difference in weapons stocks between the two countries. National security of the home country is given by $\gamma_H w_H - \beta_H w_F$ where w_H and w_F represent the weapons stocks per capita of the home and foreign countries, respectively. The parameter γ_H is given by $e_H N_H$, where N_H is the population of the home country (assumed to be constant), and e_H is a country-specific technology parameter which represents the effectiveness or ability of the weapons stock to generate national security. An equal amount of weapons in the Europe and Russia, for instance, may yield greater security for the Europe since its weapon systems may be technically superior. The parameter β_H is given by $\beta_H = \varepsilon_H I_H N_F$, where ε_H is a technology parameter representing the effectiveness

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20. This technology is called Ricardian after David Ricardo. The driving force behind our results is that trade alters relative prices and frees up productive resources. Assuming more complicated forms of production (and utility, see later) will not alter our qualitative results.

21. All units of capital referred to in this paper are per capita units unless otherwise noted.

of the foreign country`s weapons stock (as seen by the home country), and I_H is an indicator variable that takes on the value 1 if the foreign country is viewed as a rival, and -1 if it is an ally. Using these notations, we write the national utility function for the home country as

$$U_H(x_H, y_H, W_H, W_F) = x_H^{a_x} \; y_H^{a_y} + (g_H w_H - b_H w_F)^{t_H}, \qquad (4)$$

where W_H and W_F are the weapons stocks of the home and foreign countries, respectively; $W_H=N_Hw_H$, and $W_F=N_Fw_F$. The foreign country has a similar utility. We assume that $\alpha_x+\alpha_y=1$, $0<\alpha_x<1$, and $0<\alpha_y<1$.[22] Utility is assumed to be separable between consumption and national security (or weapons). This allows for positive consumption utility even when national security has a zero (or even negative) value. The parameter τ_H is restricted to be positive allowing for either increasing ($\tau_H>1$) or decreasing ($\tau_H<1$) returns to national security, for each country. The importance of τ_H and τ_F in determining equilibrium weapons stocks and consumption, as countries open up to trade, is discussed in detail in the following sections.

Weapons production requires defense expenditures. This, however, is not the only input required. Recognizing that a stock of weapons requires "upkeep" and that weapons become obsolete with time, the second input into the production of weapons depends on the stock of weapons. The final component is modeled as a spillover from the stock of capital. Just as R&D devoted toward defense sometimes produces useful consumer products, the capital stock a country has (in particular its high-tech part) can contribute positively to the production of weapons. That is, industrial discoveries are often co-opted for military use. We operationalize this spillover by assuming that the stock of a country contributes positively to the weapons stock.[23] Integrating these components, the per capita weapons stock is assumed to evolve according to the following equation:

$$\frac{dw_i}{dt} = h_i k_i + g_i d_i^d - f_i w_i \quad i = \{H,F\}. \qquad (5)$$

The first term in (5), h_ik_i, models the spillover from the capital stock to the ability to accumulate weapons, where the spillover parameter h_i measures the extent of this spillover. Since this spillover may be goods specific (e.g., greater for high-tech than for food production) h_i is modeled as a positive function of parameters associated with the production of x and y. For instance, if x is a high technology, high spillover good and y is a low technology, low spillover good, specialization in x will cause h_i to rise to h_{ix}.[24]

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22. This assumption ensures diminishing marginal utility in x and y and is standard.

23. As pointed out by Morrow (1997:33), Powell s (1993) model and his own variation of it have a limitation in that they do not make a distinction between stocks and flows. Military allocations are modeled like stocks which depreciate to zero every round. This does not apply to our model. We distinguish between stocks and flows or both capital and weapons. Moreover, while we allow for some depreciation, the weapons stocks in our model do not depreciate to zero every period.

24. The change will be instantaneous since specialization is also instantaneous in the model.

This discussion links to the debate on the importance of some goods to national security, sometimes referred to as strategic goods (Baldwin, 1985). Some authors argue, however, that any imported good is strategic. The idea is that a country chooses to import goods because they can be produced more efficiently abroad, thus importing them frees up domestic resources to produce other goods (Schelling, 1958; Baldwin, 1985). Both these effects are captured in our model. That is, even if h_i were independent of the type of goods produced, we would still demonstrate that trade affects the equilibrium weapons stocks through productive resource reallocation.

The second term on the right-hand side of (5), $g_i d_i^{\delta}$, represents the production technology which turns defense capital or military expenditures into weapons. The parameter g_i is a technological efficiency parameter and is thus assumed to be positive. Depending on its parameter δ, this production function may exhibit everywhere increasing (δ > 1), constant (δ = 1), or diminishing (δ< 1) returns to scale. Since it is not common for production to exhibit everywhere increasing returns to scale, it is reasonable to choose between the later two specifications. We will present and analyze the model under the assumption of constant returns to scale (δ = 1) which is a common simplification in the production literature.[25]

The final term in Equation (5), $\phi_i w_i$, represents resources required to keep and/or use the weapons stock, or the fact that the weapons stock depreciates over time at a rate ϕ_i, where $0<\phi_i<1$. The linear form of weapon depreciation is assumed for simplification. Hence, the larger the weapons stock a country has, the larger will be the effect of depreciation on this stock.

The home country maximizes the sum of its discounted utilities at all times by choosing the level of per capita consumption (goods x and y) and defense expenditures (d), subject to (s.t.) the production technology constraints of goods x and y, and the dynamic constraints of the time evolution of the per capita capital and the weapons stocks. This dynamic optimization problem is written below,

$$\begin{aligned} &\max_{x_H, y_H, d_H} \int_0^{\infty} [\, x_H^{a_x} \; y_H^{a_y} + (g_H w_H - b_H w_F)^{t_H} \,]\, e^{-rt}\, dt \\ &\quad s.t. \quad \frac{dk_H}{dt} = f(k_H) - x_H - \frac{y_H}{p_H} - d_H \qquad (6) \\ &\quad \frac{dw_H}{dt} = h_H k_H + g_H d_H - f_H w_H , \end{aligned}$$

where the production technology of consumption goods was already substituted into the problem, and ρ is the discount rate of future utilities.

Summarizing, the term in square brackets in (6) is utility. The first constraint represents the capital stock growth. Capital can be devoted to, the production of capital (k_H units of capital generates $f(k_H)$ units of the same capital), the production of x (k_{Hx}), the production of y (k_{Hy}), or defense (d_H). The second

25. Assuming δ= 1 simplifies the analysis of the transition path between steady states but does not alter the qualitative aspects of the equilibrium solution. An assumption of diminishing returns to scale (δ<1) in the production of weapons will not alter the qualitative results of the model, but will significantly complicate the mathematical solution.

constraint represents the weapons stock growth, where ϕ_H is the depreciation in the current stock, $g_H d_H$ is the amount of weapons produced from d_H units of capital, and h_H shows the spillover from the capital to weapons. The last two constraints show the production functions of consumption goods. The foreign country faces a similar optimization problem with the appropriate subscripts changed, which we omit for the sake of brevity.

5. National Behavior in Autarky

In this section we focus on the behavior of rivals in autarky by solving the optimization problem stated in (6). The main results are presented here. The mathematical treatment is available in the Appendix. It involves writing a set of equations (first order conditions), the solution of which determines a certain allocation of resources between consumption goods, defense, and the generation of capital. This allocation, in turn, implies certain amounts of consumption goods, capital stocks, and weapons stocks (in each country). While mathematically complicated, the solution is intuitive. Its main features are described next.

The first order conditions (Equations 13 through 17 in the Appendix) specify when a resource allocation is optimal at each point in time. These equations capture three notions. First, each unit of capital devoted to the production of weapons results in one less unit that can be devoted to consumption and to capital accumulation. Second, each country chooses its consumption such that the value of consuming an extra unit of x or y (marginal value) equals the cost of that unit (marginal cost). Third, the optimal allocation of capital is such that the marginal value of devoting a unit of capital to each alternative use (producing consumption goods, weapons, or more capital) is equal across all alternatives. Failure of these relations for a given nation would imply that this nation could be better off by readjusting its allocation of capital.[26]

In equilibrium, the two countries are at a stationary point. Mathematically, this implies that the growth rates (or time derivatives) of all the variables in the model are zero. When some parameter in the model changes, the system will move to a new equilibrium. Using the first order and the equilibrium conditions, we solve for the equilibrium levels of the capital and weapons stocks and the actor`s allocations to consumption and defense.

The optimal level of capital stock in equilibrium (k_H, determined by 22 in the Appendix) is found to depend on the discount rate of society (ρ), the productivity of defense expenditures in producing weapons (g_H), and the spillover parameter from capital to weapons (h_H). Specifically, the higher ρ is (the future is less valued), the smaller is its capital stock. The higher g_H is (defense expenditures more productive), the more will be allocated to produce weapons and the smaller the capital stock will be. The larger h_H is (larger spillovers), the larger will be the capital stock in equilibrium. In the absence of spillovers from capital stock to the weapons stock ($h_H = 0$), the model produces the standard Golden Rule result of optimal capital

26. Along the optimal path, the marginal value of devoting capital to an alternative, say production of x, is affected not only by the utility function, but also by the relative productivity of capital devoted to that alternative.

accumulation for the case of no population growth (i.e., the marginal product of capital equals the discount rate of society).[27] In our case, however, the spillover from capital to weapons stocks represents a positive externality. This causes the agent to accumulate a larger stock of capital in equilibrium compared to the case of $h_H = 0$.

The complete equilibrium of the model also requires solving for the weapons stocks, the amounts of x and y, and the defense expenditures. The resource allocation to consumption and defense in each country is affected by the weapons stock of the other country. This is so because the production of weapons and consumption goods is linked to the utility from national security, which is a function of the foreign weapons stock. Hence, we need to find the weapons stocks of each country. This is our next task.

We assume that each country takes the weapons stock of the other country as given in calculating its own equilibrium weapons stock. This is a standard assumption as in Brito (1972), Simaan and Cruz (1975), and Brander and Spencer (1985).[28] Using it, we produce reaction functions for each country:

$$w_H = \frac{1}{\gamma_H}\left(\left[\frac{\zeta_H(r+\phi_H)}{\gamma_H \tau_H \gamma_H}\right]^{\frac{1}{\tau_H - 1}} + \beta_{H} w_F\right), \tag{7}$$

and

$$w_F = \frac{1}{\gamma_F}\left(\left[\frac{\zeta_F(r+\phi_F)}{\gamma_F \tau_F \gamma_F}\right]^{\frac{1}{\tau_F - 1}} + \beta_F w_H\right), \tag{8}$$

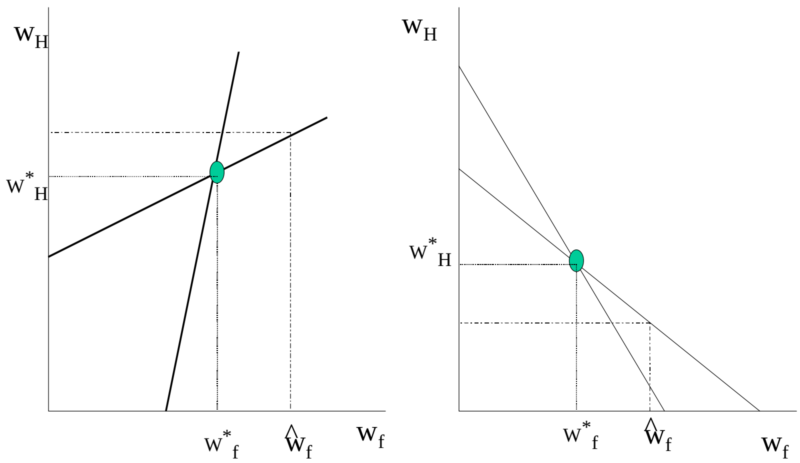
where, ζ_H and ζ_F are parameters which depend on the αparameters in utility and the production parameters p_H or p_F, respectively (see Equations 27 and 28 in the Appendix). This type of actor interaction is commonly referred to as Cournot or Nash interaction. Equation (7) is the best response of the home country to the weapons stock of the foreign country. Similarly, Equation (8) is the best response of the foreign country. When the two countries are rivals (β_H, $\beta_F < 0$), (7) and (8) show that they are engaged in an arms race. Specifically, if one country decides to increase its weapons stock (because of some shock in a parameter of the model, representing international or domestic stimulations), the other country reacts by increasing its own weapons stock.

The equilibrium weapons stocks are found by the intersection of the weapons stock reaction (or best

27. See Blanchard and Fischer (1989: chapter 2). If this condition fails to hold, the actor is not optimizing. To see this, assume that marginal product of capital, $f'(k_H)$, exceeds the discount rate ρ. In this case, a unit of capital consumed today would generate more utility than saving that unit for future use. The actor would then put capital into production of consumption goods.

28. In models of the role of weapons in wars, countries may interact in other ways. These models` results, however, depend on the assumed order of moves and information structure. See, for instance, Brito and Intriligator (1985), Powell (1993), and Andrew et al. (1993). We abstract from such considerations since we are focusing on the impact of trade on arms races and not wars.

response) functions of the home and foreign countries, as illustrated in Figure 1. The home and foreign countries` reaction functions are denoted as $w_H(w_F)$ and $w_F(w_H)$, respectively. In Panel A the countries consider each other to be rivals. In this case the reaction functions are upward sloping, indicating that the weapons stocks are strategic complements. In response to an increase in foreign country weapons stocks (from say w_F^* to $\hat{w}_F$), the home country will increase its weapons stocks <u>ceteris</u> <u>paribus</u> (from w_H^* to $\hat{w}_H$).[29] The opposite is true in the Panel B. Here the two countries consider each other allies. An increase in the foreign country`s weapons stock will cause the home country, <u>ceteris</u> <u>paribus</u>, to reduce its weapons stock. This is so because the home country gains national security from the foreign country`s stock. The mathematical solution of the equilibrium weapons stocks in autarky is given in the Appendix.



Panel A: Rivals Panel B: Allies

Figure 1.

As we show in the Appendix, the equilibrium weapons stocks depend on the relative prices of consumption goods (via ζ_H and ζ_F). Actors are aware that a unit of capital devoted to defense bears the opportunity cost of less capital devoted for consumption. An increase in p_H raises the marginal cost of capital devoted to defense in terms of foregone consumption. The preference parameters that affect the marginal utility of national security, however, remain unaffected by a rise in p_H. Consequently, a reallocation of resources occurs when p_H changes. The direction of this reallocation depends on preference parameters, as we discuss next.

29. We do not imply that $\hat{w}_H$ and $\hat{w}_F$ are the equilibrium values. The later are solved next.

6. The Impact of Trade

There are two questions regarding the impact of trade. The first is, what will happen to the capital stock? The second is, how will each country allocate resources among the alternative uses? In particular, what will happen to the stocks of weapons in each country? These questions are at the center of this section. Once again, we focus on the home country`s optimization problem.

Trade has two direct effects. First, trade raises the relative price of x in the home country (p_H to p) and lowers it in the foreign country (p_F to p). Second, trade changes the spillover parameters from capital stock to weapons production (h_H and h_F) to h_{HX} and h_{FY} respectively. Utility maximization dictates that in trade both countries specialize in production according to their comparative advantage. We assume that the relative price of x in terms of y under trade is p such that $p_H<p<p_F$. Under this condition, trade is desirable for both countries.[30] The home country will completely specialize in producing x, and the foreign country will completely specialize in producing y.

Once trade opens, the home country`s production of x is still given by $x_H = k_x$. A portion of the production of good x (x_{CH}) will be allocated toward domestic consumption, and the remainder (x_{TH}) will be traded with the foreign country for good y. The foreign country will do the same for y. That is, the foreign country produces y_F, consumes domestically y_{CF}, and trades y_{TF} with the home country for x_{TH}. The distribution of domestic production in each country to consumption and export is shown below.

$$x_H = x_{CH} + x_{TH} \text{ and } y_F = y_{CF} + y_{TF} . \tag{9}$$

The terms of trade are given by $p = y_{TF} / x_{TH}$. In addition, the following trade balance identities must hold: $y_{CH} = y_{TF}$ and $x_{CF} = x_{TH}$. That is, home country consumption of the good y must equal the volume of y exported by the foreign country, and the same must hold for the foreign country consumption of good x. Using the terms of trade, the trade balance identities, and the production technologies, we may rewrite Equation (3) for trade.

$$f(k_H(t)) = x_{HC} + \frac{y_{HC}}{p} + d_H + \frac{dk_H(t)}{dt}. \tag{10}$$

Because trade involves specialization, we include an exogenous change in the weapons dynamics (Equation (5)) under trade. Specifically, the parameter h_H changes to h_{HX}, and h_F changes to h_{FY}. Assuming, for instance, x is the higher technology, higher spillover good, the home country specialization in x will cause h_H to rise to h_{HX}, and the foreign country specialization will cause h_F to fall to h_{FY}. In this example, these

30. Assume that the home country consumes the same amount of x and spends the same amount on defense, both pre- and post-trade. Pre-trade, a unit of capital yields p_H units of y. Post-trade, the home country specializes in x, exports it to the foreign country, and receives p units of y for each unit of x. As $p>p_H$, trade enhances the efficiency of producing y (via trade) for the home country. For the foreign country, trade enhances the efficiency of producing x (via trade).

changes imply that it is the production of the x and y goods that generates spillovers to national security, not the consumption of the two goods.[31] Using the new spillover parameters, we rewrite (5) for the home country weapons dynamics (and its foreign country counterpart).

With all these changes in place and using Equation (10), the home country optimization problem under trade is:

$$\max_{x_{HC}, y_{HC}, d_H} \int_0^\infty [\, x_{HC}^{a_x} \; y_{HC}^{a_y} + (g_H w_H - b_H w_F)^{t_H} \,] \, e^{-rt} \, dt$$

$$s.t. \quad \frac{dk_H}{dt} = f(k_H) - x_{HC} - \frac{y_{HC}}{p} - d_H \qquad (11)$$

$$\frac{dw_H}{dt} = h_{HX} \, k_H + g_H d_H - f_H w_H .$$

The foreign country faces a similar problem. Comparing the optimization problems for autarky (Expression 6) and for free trade (Expression 11), we see that only the relative prices of consumption goods (p) and the technological spillover parameter (h_{HX}) have changed. Hence, the home country`s trade problem may be solved in the same manner as it was under autarky. Hence, we may use the autarky expressions, with the appropriate parameter changes, to trace the impact of trade.

We first focus on the impact of trade-induced production specialization on the optimal equilibrium level of the capital stock. Assume for the moment that the spillover parameters (h_H and h_F) do not change. In this case the autarkic equilibrium level of the capital stock is unaffected by trade, as in the Golden Rule case. This occurs in the model because the specialization and trade allow a more efficient translation of capital into consumption (through trade) but do not affect the underlying national production function f.

Next assume that trade, via specialization, alters h_H and h_F. If the home country specializes in producing a high technology good, while the foreign country may specialize in producing a lower technology good, then h_H will rise and h_F will fall. In this case, as we show in Appendix, the trade equilibrium capital stock will rise, ceteris paribus, relative to autarky for the home country. Similarly, the trade equilibrium capital stock will fall relative to autarky for the foreign country.

We now answer the question of how the countries will allocate their capital stocks after trade liberalization. In particular, what will be the effect of trade on the stock of weapons? To answer this question we need to trace the impact of the trade-induced relative price change (for the home country from p_H to p and for the foreign country from p_F to p). We show in the Appendix that the first impact is to increase the consumption of good y relative to the consumption of good x, for the home country. The opposite will be true for the foreign country. This relative change in consumption, however, does not tell us how capital will

31. In the trade equilibrium, both countries may consume more of x and y.

be allocated among consumption and defense. This question can only be answered by first solving for the Nash equilibrium weapons stocks in the trade equilibrium.

The equilibrium weapons stock under trade are analyzed in the Appendix. The expression is similar to that in autarky, but includes parameter changes as we have explained above. The trade-induced relative price change will shift each country`s weapons reaction function. Using the weapons stock reaction function (7), we can find the shift in the home country`s reaction function because of a change in the relative price p. This shift is given by the partial derivative of the weapons stock reaction function with respect to p and is presented in the Appendix (see Equations 34 and 35).

As we show, the effect of trade on the weapons reaction function depends on the sign of (τ_H -1). In the spirit of the liberal paradigm, if the home country exhibits diminishing returns to national security (τ_H < 1), it would desire a lower stock of weapons for any given foreign weapons stock under free trade than under autarky. If, on the other hand, τ_H >1, the home country will increase its weapons stock under trade relative to autarky for a given foreign weapons stock, contrary to the spirit of the liberal paradigm.

Why is this so? In free trade the home country specializes in the production of x. The resulting excess production of x is traded for y. Free trade (when combined with specialization) raises the consumption possibilities and the utility of the home country relative to autarky, ceteris paribus. The home country, however, also derives utility from national security (and weapons stock). Of course, capital devoted to defense means less capital available for producing x. In equilibrium, capital devoted to defense must bear a marginal (opportunity) cost equal to the marginal benefit of capital devoted to the production of x. Whether more or less capital is reallocated from consumption to defense depends, ceteris paribus, on whether the home country exhibits increasing or decreasing marginal utility of national security.

Let us revisit the question we posed in the introduction. Russia is now a country which needs to invest heavily in its infrastructure. It could do so under autarky by building the equipment it requires to make these improvements (i.e. earth movers, trucks etc.). Under free trade however Russia could purchase this equipment from the West at a lower (quality adjusted) cost than building it internally. This frees up resources in Russia. Will it devote these resources to the production of consumption goods, military buildup, or for a combination of both? The answer depends on the relative utility Russia derives from these options.

The analysis above is conducted for a given foreign weapons stock. Trade, however, impacts both countries. Hence, we need to examine changes in both countries` weapons stock reaction functions, in order to determine the equilibrium weapons stocks under trade. The impact of trade on the foreign country`s best response function in the model is also shown in the Appendix. As in the case of the home country, this impact depends on the sign of (τ_F - 1).

Using (7), the impact of trade on the optimal equilibrium weapons stocks of each country depends not only on the shifts in the two countries` reaction functions, but also on the slopes of those reaction functions. That is, it depends on whether the countries are rivals (β_H, β_F > 0) or allies (β_H, β_F < 0). Focusing on the case of rivals, Table 2 summarizes the possible combinations of changes in the equilibrium weapons stocks for different τ_H and τ_F parameters.

Table 2. Equilibrium Changes in Weapons Stocks Due to Free Trade Between Rivals

	National	Changes in weapons stocks relative to autarky
Case 1	$_H <1$, $_F <1$	$w_H<0$, $w_F <0$
Case 2	$_H >1$, $_F >1$	$w_H>0$, $w_F >0$
Case 3	$_H <1$, $_F >1$	w_H, w_F depend on parameters.
Case 4	$_H >1$, $_F <1$	w_H, w_F depend on parameters.

Note: When $_H$ and $_F$ differ in sign, one country views its trade partner as an ally, while the partner disagrees with the characterization. These cases are ruled out by assumption.

To see how the τ_H and τ_F parameters affect the equilibrium outcomes, consider first the two unambiguous cases 1 and 2 in Table 2. In case 1, we assume diminishing marginal returns to national security for both countries. This implies that, under free trade, both countries will shift out of the production of weapons. Consider the perspective of the home country. As trade opens it becomes relatively more efficient at acquiring consumption goods than weapons, compared to autarky. Since its marginal utility of national security is diminishing, optimization of capital allocation requires it to reallocate capital previously devoted to weapons toward producing for consumption. The home country will do so until the marginal utilities from weapons and consumption become equal. The foreign country would also reduce its weapons stock. Yet, as the foreign country reduces its weapons stock, national security for the home country rises. The home country will further reduce capital allocated for defense, until the marginal utilities of devoting capital to defense and consumption become equal.[32] As this also happens for the foreign country, the end result is a drop in equilibrium weapons stocks.

In case 2, both countries exhibit increasing marginal utility of national security. The effect of trade on weapons stocks is again unambiguous; this time, however, both countries increase their weapons stocks. Examine the effect of trade on the weapons stock from the perspective of the home country. As before, trade increases the marginal utility of capital devoted to consumption (since through trade, capital can be translated into more consumption). Optimization requires that capital devoted to defense also exhibits a rise in its marginal utility. In this case, however, such a rise will come about only if the home country builds up its weapons stocks since $\tau_H > 1$. The same will be true for the foreign country. However, for each unit that the foreign country increases its weapons stock, the home country must increase its own weapons stock to compensate for the decline in its national security. The result is an unambiguous increase in both weapons stocks and defense expenditures due to trade.[33]

In cases 3 and 4, the two countries` marginal utilities of national security move in opposite directions

32. The home country`s reaction to a reduction in the foreign weapons stock is a less than one for one reduction in its own stock. The same is true for the foreign country, thus ensuring a stable equilibrium.

33. This result suggests some caution in arguing for the use of trade to promote peace. For instance, the response of India and Pakistan following their recent nuclear tests seems to suggest that they have increasing marginal utility for national security. Under these conditions, trade will increase their weapons stocks and will most likely complicate their political relations.

when trade opens. The overall impact of trade on the equilibrium weapons stock is ambiguous in the model. In these cases it is the relative shift in the home and foreign country weapons stocks reaction functions that determines the ultimate impact of trade on the weapons stocks. This sign of this shift depends on the parameters τ_H and τ_F relative to 1. The size of this shift, however, is unambiguous: it declines with g_H or g_F (the efficiency of capital devoted to defense), grows with ϕ_H or ϕ_F (the resources required to keep the weapons stock) and declines with e_H and e_F (the overall ability of weapons to generate national security).[34] The equilibrium weapons stocks resulting from these shifts are illustrated next.

In Figure 2, we have assumed that the marginal utility of national security of the home country is diminishing ($\tau_H < 1$) and that of the foreign country is increasing ($\tau_F > 1$). Point A denotes the autarkic equilibrium. Using this setup, we investigate the effect of changes in g_F, e_F, and ϕ_F, ceteris paribus, on the equilibrium weapons stocks under free trade. When trade opens, the reaction function of the home country moves down in this case.

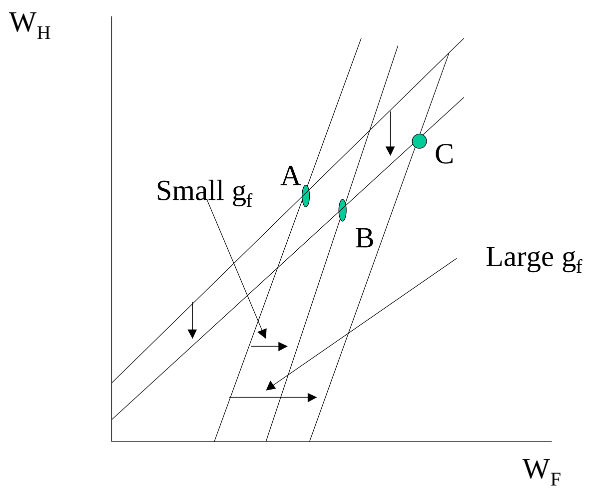


Figure 2

We first examine the effect of a change in the efficiency of capital devoted to defense in producing weapons in the foreign country, g_F. Two cases are illustrated. When g_F is small, the free trade equilibrium is at point B. The home country`s weapons stock decreases in free trade relative to autarky while that of the foreign country increases. Next, assume that $g_F$ is large. In this case the free trade equilibrium is at point C. The foreign country`s weapons stock increases while that of the home country increases less compared to the foreign country. Hence, the larger the efficiency of capital devoted to defense in producing weapons is, the smaller the effect of free trade on the weapons stock will be.

Some observers may argue that point C in Figure 2 describes the current EU-Russian equilibrium.

34. These results are derived by taking the partial derivatives of (33), or (34), both in the Appendix, with respect to these parameters.

Indeed, it is reasonable to assume that capital is more efficient in producing weapons in the EU than in Russia. Given the difference in political pressures in the EU and Russia, one may argue that the marginal utility of national security is decreasing for the EU and increasing for Russia. Under these assumptions, our model predicts that under trade Russia would increase its weapons stocks more relative to autarky than the EU would.

Next, the effect of the ability of the weapons stock to generate security, e_H and e_F, on the weapons stock in trade relative to autarky is similar to that of g_H and g_F. Using Figure 2, the larger the ability of the weapons stock to generate security is, the smaller the effect of trade on weapons stocks will be, ceteris paribus. Once more, some may argue that this fits well the case of EU-Russian trade as the weapons stock of the EU is currently more advanced than that of Russia. For Russia, then, the increase in the ability of capital to generate consumption due to trade may be translated to less consumption relative to the EU as Russia`s weapons stock is still contributing little to its national security (and utility). For the EU, however, it may be beneficial to allocate the gains from trade more toward consumption than toward weapons.

Last, we investigate the effect of the resources needed to maintain the weapons stock on the weapons stock in free trade. Referring back to Figure 2, the larger ϕ is, the larger the effect of free trade on the weapons stock will be, ceteris paribus. As more resources are required to keep the weapons stock, the gains from trade are more likely to be translated to producing weapons than consumption.

In sum, we have shown that the deciding factor in whether free trade intensifies arms races or not depends on the relative marginal utilities from consumption and weapons. The empirical literature on arms races and military disputes or wars demonstrates that arms races may be linked to the escalation of military disputes and wars. Accordingly, in the concluding section we comment on the possible implications of our model to the trade and conflict debate.

7. Conclusions

We have examined the effect of free trade on an arms race between political rivals. In the spirit of the liberal paradigm, one may expect that the stocks of weapons in the two countries would decrease in trade relative to autarky. Yet, the effect of trade on arms buildups in our model is not clear cut. It is possible that rivals would increase their weapons stock in trade, relative to autarky. At the same time it is also possible that the opposite would occur.

Our results do not follow from Neo-Marxist or realist assumptions. Our model was designed to follow the liberal trade paradigm. The countries in the model do not compete over production resources, markets, world trade shares, economic supremacy, do not use trade as a tool of political influence, and do not maximize their relative trade gains. Each country in the model specializes in the good of its comparative advantage and trades it for the good of its comparative disadvantage. As predicted by neoclassical trade theory, under free trade both countries gain in terms of consumption goods. The standard story stops at the point of demonstrating the existence of these gains from trade. We go further and show that the mere existence of the gains from trade may lead to more weapons.

In many cases countries involved in arms races and disputes continue to trade. What is the likely effect of trade on the bilateral political relations in such cases? Some may argue that political disputes or wars enter utility negatively, which will reduce the desire to translate trade gains to weapons accumulation. Yet, in this case it is important to note that it is not trade itself that must limit arms buildups, but rather other social forces which were not modeled here. While these forces are worth additional investigation, our goal is to take the first theoretical step toward combining trade and arms race models. Clearly, then, we did not model the link between arms races, trade, and conflict. Nevertheless, we believe that some discussion of our results in relation to the link between trade and conflict is in order.

As we have shown, the question whether militarized disputes escalate to wars more in the presence of arms races has received much attention. While the empirical results may not be conclusive, many observers agree that arms races create an inflammable environment prone to tension and that most disputes do not escalate to wars when arms race are not present.[35]

To the extent that disputes are more likely to escalate in the presence of an arms race, if trade leads to more weapons, it may be considered a cause of conflict. If, however, trade leads to less weapons, it could be considered a cause of peace. Hence, free trade may not always generate peace. In this respect, our model also contributes to the trade and conflict debate. Whether trade brings peace or not depends on the structure of national preference. While in some cases trade may be linked with changing preferences toward consumption and away from the accumulation of arms, this does not have to be so in all cases. Historically, the rise of free trade in the late-19th and early-20th centuries was associated with intensified arms races among traders which led to World War I. The extraordinary increase in trade among some of the same countries, however, is associated with peace in the post-1945 era. Both of these observations are accounted for by our model.

Summarizing, while trade may generate peace in some cases, trade as a causal factor does not seem to be a force that will automatically bring peace in all cases. Our paper points out that if countries derive positive marginal utility from national security, and national security is adversely affected by the foreign weapons stock of potential rivals, trade may not take them out of the security dilemma. The only sure way out of the security dilemma is predicated on a change of national preferences from security to consumption. We do not preclude the possibility that this change of preferences could occur as a result of trade itself. That is, preferences themselves may change with a rise of trade volumes toward preferring consumption over weapons. Such change, indeed, seems to fit the experience of some countries. Yet, for other countries this does not seem to be the case. Hence, a change in national preferences due to trade over time seems to be debatable as a generalizable phenomenon and in any case can only be evaluated in retrospect.

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35. We do not argue, however, that all arms races escalate to wars.

Appendix

The Appendix is intended to provide the mathematical details of the model, and is consequently short on detailed explanations. It should be read with the paper. We first solve the model in Autarky. We then investigate the impacts trade will have on the behavior of the two nations. Both solutions follow optimal control theory.

Autarky

We translate the problem specified in (6) into the following current value Hamiltonian.

$$H = e^{-rt}\,[\, x_H^{a_x} y_H^{a_y} + (g_H w_H - b_H w_F)^{t_H} + \lambda_{H1}(f(k_H) - x_H - y_H / p_H - d_H) + \lambda_{H2}(h_H k_H + g_H d_H - f_H w_H)] \quad (12)$$

In (12), λ_{H1} is the co-state variable (shadow price) of capital and λ_{H2} is the co-state variable of weapons. The variables k_x and k_y in (12) were replaced by the appropriate terms as dictated by the technology of production (see Equation 6). Optimizing (12) yields the following first order conditions.

good x:

$$\frac{\partial H}{\partial x_H} = 0: \quad a_x x_H^{a_x - 1} y_H^{a_y} = \lambda_{H1} \quad (13)$$

good y:

$$\frac{\partial H}{\partial y_H} = 0: \quad a_y x_H^{a_x} y_H^{a_y - 1} = \frac{\lambda_{H1}}{p_H} \quad (14)$$

defense expenditures:

$$\frac{\partial H}{\partial d_H} = 0: \quad \lambda_{H1} = g_H \lambda_{H2} \quad (15)$$

shadow price of capital:

$$\frac{d(e^{-rt}\lambda_{H1})}{dt} = -\frac{\partial H}{\partial k_H}: \quad \frac{d\lambda_{H1}}{dt} = \lambda_{H1}(r - f'(k_H)) - \lambda_{H2}\eta_H \tag{16}$$

shadow price of weapons:

$$\frac{d(e^{-rt}\lambda_{H2})}{dt} = -\frac{\partial H}{\partial w_H}: \quad \frac{d\lambda_{H2}}{dt} = \lambda_{H2}(r + \phi_H) - \tau_H(\gamma_H w_H - \beta_H w_F)^{\tau_H - 1} \tag{17}$$

Next, we discuss equations (13) to (17). At each time, the home country chooses x and y such that the marginal utility from an extra unit of x or y (U_x and U_y, respectively) equals its marginal cost. In (13), a unit of x has a marginal cost of λ_{H1} because a unit of capital which has a cost of λ_{H1} (its shadow price) produces one unit of x. In (14), a unit of y has a marginal cost of λ_{H1}/p_H because a unit of capital produces p_H units of y. In (15), the cost of the marginal unit of capital devoted to defense, is $g_H\lambda_{H2}$, since this unit contributes g_H units to the weapons stock (which has a price of λ_{H2}).

If relations (13)-(15) do not hold, the allocation of capital is not optimal. Along the optimal path, the marginal values from allocating capital to x, y, defense, and accumulating more capital are equal. To see this, note that the marginal unit of capital allocated for x generates one unit of x and has a value U_X. That same unit of capital allocated for y generates p_H units of y and has a value $p_H U_Y$. From (13) and (14), these values are given by λ_{H1} (the value of that unit of capital, or shadow price of capital). From (15), the allocation of this unit of capital to defense has the same value. At optimality, the value of allocating an extra unit of capital to defense must equal its marginal cost. Yet, the marginal cost of capital allocated for defense is $g_H\lambda_{H2}$ which, from (15), equals λ_{H1} and therefore equals the marginal value of x and y. Hence, along the optimal path, the values the nation derives from allocating the marginal unit of capital to one the four alternatives are equal.

Equations (16) and (17) define the dynamic path of the capital and the weapons stocks` shadow prices. In (16), the shadow price of the capital stock rises when the discounted value of the capital stock is larger than the sum of the value of the capital stock to weapons production (through spillover) and the value of one more unit of capital (when consumed today instead of reinvested to accumulate more capital). In (17), the shadow price of the weapons stock rises when the discounted and depreciated value of the weapons stock (the first term on the right hand side of 17) is larger than the marginal utility of national security (the second term on the right hand side of 17).

Equilibrium requires that all the variables are stationary. Hence, the following familiar conditions must hold:

$$\frac{d\,l_{H1}}{dt} = \frac{d\,l_{H2}}{dt} = \frac{dk}{dt} = \frac{dw}{dt} = 0. \tag{18}$$

These expressions are sometimes referred to as the steady state conditions. For the case of δ=1, they hold at all times in the model, not just in the steady state. Using (18), (17) illustrates that in equilibrium the home country chooses a level of defense expenditures such that the marginal utility of national security equals the discounted and depreciated value of the weapons stock. Similarly, (16) demonstrates that the home country chooses a level of the capital stock such that the discounted value of capital stock equals the sum of the value of the capital stock to weapons production and the value of one more unit of capital stock to consumption.

Using the first order conditions (13) through (17) and the equilibrium conditions (18) we may solve for the equilibrium levels of the capital and weapons stocks and the actor`s resource allocation to consumption and defense expenditures. Division of condition (13) by condition (14) illustrates that the x and y goods are consumed in fixed proportion. Dividing expression (13) by (14), we get:

$$y_H = p_H x_H \left(\frac{a_x}{a_y}\right). \tag{19}$$

Substituting expression (19) back into expression (13) yields the shadow price of capital:

$$l_{H1} = z_H = A(p_H^{1-a_x}); \quad A = a_x^{a_x}(1 - a_x)^{1-a_x}. \tag{20}$$

Equation (20) shows that a change in the relative price of good x (p_H) alters the shadow price of capital devoted to consumption goods, l_{H1}. If the home country becomes more efficient at producing good x, it is more costly to forego production of it. Substituting l_{H1} from (20) into the first order condition for d_H (15), the shadow price of defense is affected by p_H in a similar manner to l_{H1}:

$$l_{H2} = \frac{z_H}{g_H}. \tag{21}$$

Since the shadow prices are functions of time-invariant parameters, the time derivatives of the shadow prices in the model always equal zero. From (20) and (21) we find that the optimal allocation of capital between goods production and defense must ensure that the shadow prices of capital devoted to these activities must move together, ceteris paribus. From (21) we find that along the optimal path, the price of capital devoted to the accumulation of more capital equals the value of capital devoted to defense.

Using (16) for the capital costate variable, and (20) and (21) for the solved shadow prices of capital and weapons, we find the optimal equilibrium level of capital. In equilibrium, the time derivative of l_{H1} must equal zero. Thus, the optimal level of capital is given by:

$$f'(k_H) = r - \left(\frac{l_{H}1}{l_{H}2}\right)h_H = r - \frac{h_H}{g_H}. \tag{22}$$

This is a modified Golden Rule result. The greater is the spillover parameter (h_H) the greater will be the steady state capital stock (as the marginal product of capital, $f'(k_H)$, is diminishing with k_H). Similarly, the more efficient are the defense expenditures in producing weapons (g_H is higher), the smaller will be the steady state capital stock in equilibrium as more capital will be devoted to defense (again, $f'(k_H)$ is diminishing with k_H).

Using (20) and (21) and the first order condition (17) we obtain the level of the home country weapons stock in equilibrium, for a given level of the foreign country weapons:

$$w_H = \frac{1}{g_H}\left(\left[\frac{z_H(r + f_H)}{g_H t_H g_H}\right]^{\frac{1}{t_H - 1}} + b_{Hw_F}\right), \tag{23}$$

Equation (23) is the home country`s weapons stock best response to the foreign country`s weapons stock. A similar response exists for the foreign country for a given level of the home country weapons. Note that (23) holds at all times since the shadow price of weapons was found to depend only on the model`s parameters. If any of the relevant parameters of the model jump to a new level, the weapons stock jumps to the new equilibrium instantaneously. This simple transition path follows from the assumption $\delta=1$ in Equation (5). Equation (23) illustrates that the optimal weapons stock is affected by a change in p_H (via ζ_H, see 20).

Next, we address the allocation between consumption and defense. Using the Ricardian (linear) technology relation, and applying the equilibrium conditions (20) for the capital and weapons stocks to (3) and (5), respectively, we obtain the optimal equilibrium defense expenditures,

$$d_H = \left(\frac{1}{g_H}\right)[f_H w_H - h_H k_H], \tag{24}$$

and a relationship between consumption, capital, and defense expenditures,

$$f(k_H) = x_H + y_H / p_H + d_H . \tag{25}$$

Equation (24) determines the equilibrium allocation of capital toward defense for given capital and weapons stocks (from 22 and 23, respectively). Given d_H from Equation (24), Equations (25), (19) and (20) can be used to determine the allocation of capital towards production of the x and y goods. Thus the optimal equilibrium of the model is fully given by Equations (23) through (25) and Relations (19) and (20).

To solve for the equilibrium of the model we first solve for the intersection of the weapons stocks response function (23), and its foreign country counterpart. Doing so we find

$$w_H^* = \frac{\gamma_F C_H + \beta_H C_F}{\gamma_H \gamma_F - \beta_H \beta_F} \quad and \quad w_F^* = \frac{\gamma_H C_F + \beta_F C_H}{\gamma_H \gamma_F - \beta_H \beta_F}. \tag{26}$$

In (26), the variables C_H and C_F are given by

$$C_H = \left(\frac{\zeta_H (r + \phi_H)}{\gamma_H \tau_H}\right)^{\frac{1}{\tau_H - 1}} \quad and \quad C_F = \left(\frac{\zeta_F (r + \phi_F)}{\gamma_F \tau_F}\right)^{\frac{1}{\tau_F - 1}}, \tag{27}$$

where ζ_H is given in (20) and its foreign counter part ζ_F is given by:

$$\zeta_F = B\, p_F^{\alpha_y - 1}; \quad B = \alpha_y^{\alpha_y} (1 - \alpha_y)^{\alpha_y - 1}. \tag{28}$$

Notice that the equilibrium weapons stocks (and in turn the equilibrium goods production levels and defense expenditures) are affected by changes in the relative price of x (and y), via ζ_H and ζ_F. The main impact of trade is to change these relative prices for the two nations. The impact of the changes in these prices is investigated next.

Trade

In the trade equilibrium both countries specialize in production according to their comparative advantage. We assume that the relative price of good x in terms of y under trade is p such that $p_H < p < p_F$. The home country specializes in x, and the foreign country in y. Consequently the “trade” counterpart to

Equation (3) is

$$f(k_H(t)) \;=\; k_x + d_H + \frac{dk_H(t)}{dt} \tag{29}$$

Using the terms of trade, the trade balance conditions (discussed in section 6 of the paper), and the production technology equations from (6), we rewrite Equation (3) as

$$f(k_H(t)) \;=\; x_{HC} + \frac{y_{HC}}{p} \;+\; d_H \;+\; \frac{dk_H(t)}{dt}. \tag{3}$$

The home country specialization in x will cause h_H to change to h_{HX}, and the foreign country specialization will cause the parameter h_F to change to h_{FY}. Hence, we may rewrite Equation (5), and its foreign country counterpart, as:

$$\begin{aligned} \frac{dw_H}{dt} \;&=\; h_{HX}\,k_H - g_H\,d_H - f_H\,w_H\,, \\ &\quad and \\ \frac{dw_F}{dt} \;&=\; h_{FY}\,k_F - g_F\,d_F - f_F\,w_F\,. \end{aligned} \tag{30}$$

Using equations (30), we can write the home country optimization problem under trade as:

$$\begin{aligned} &\max_{x_{HC},y_{HC},d_H} \int_0^\infty [\, x_{HC}^{a_x}\;\; y_{HC}^{a_y} + \;(g_H\,w_H - b_H w_F)^{t_H}\,]\, e^{-rt}\,dt \\ &\qquad s.t.\;\; \frac{d\,k_H}{dt} \;=\; f(k_H) - x_{HC} - \frac{y_{HC}}{p} - d_H \\ &\qquad\quad \frac{d\,w_H}{dt} \;=\; h_{HX}\,k_H + g_H\,d_H - f_H\,w_H\,. \end{aligned} \tag{31}$$

The foreign country faces a similar problem. Comparing the optimization problems for autarky (Equation 6) and free trade (Equation 31), the impacts of trade are to raise p_H (to p) for the home country, lower p_F (to p) for the foreign country, and change the spillover parameters h_H and h_F (to h_{HX} and h_{FY}, respectively). Thus, the impact of trade on the optimal equilibrium can be determined in the same manner as in autarky. The Hamiltonian from Equation (31) looks similar to (12) and is written here for completeness.

$$H = e^{-rt}\,[\, x_{HC}^{a_x}\, y_{HC}^{a_y} + (g_H\,w_H - b_H\,w_F)^{t_H} + l_{H1}(f(k_H) - x_{HC} - y_{HC}/p - d_H) + l_{H2}(h_{HX}\,k_H + g_H\,d_H - f_H\,w_H)] \tag{32}$$

Assume that the home country specializes in a high technology good and the foreign in a low technology good. In this case, h_H rises and h_F falls. From (22), we can see that the home country trade equilibrium capital stock rises relative to autarky since f=(k) is diminishing with k. Similarly, the foreign country counterpart (22) will show that the trade equilibrium capital stock for the foreign country will fall relative to autarky.

The trade-induced relative price changes shift each country=s weapons reaction function. Using (23) this shift for the home country p is given by

$$\frac{\partial w_H}{\partial p}\Big|_{w_F=constant} = \frac{1}{g_H(t_H - 1)}\left(\frac{r + f_H}{g_H t_H \Phi_H}\right)^{\frac{1}{t_H - 1}} z_H^{\frac{2-t_H}{t_H - 1}} \frac{dV_H}{dp}. \tag{33}$$

The sign of this derivative depends on the sign of (τ_H -1). The impact of trade on the shift of the foreign country=s best response function in the model is shown next.

$$\frac{\partial w_F}{\partial p}\Big|_{w_H=constant} = \frac{1}{g_F(t_F - 1)}\left(\frac{r + f_F}{g_F t_F \Phi_F}\right)^{\frac{1}{t_F - 1}} z_F^{\frac{2-t_F}{t_F - 1}} \frac{dV_F}{dp}, \tag{34}$$

which in turn, depends on the sign of (T_F - 1).[36] Our analysis of the importance of these changes on the trade equilibrium is given in Section 6 of the paper.

36. The transition from the autarky to the trade equilibrium occurs in the model instantaneously. Non-instantaneousness transitions arise for $\delta \neq 1$, but do not qualitatively affect the steady state. Equation (15) holds in all times and implies that λ_{H1} jumps to its trade value. The assumed constant returns to scale weapons production (δ=1) implies, through (15), that λ_{H2} directly moves with λ_{H1}. Thus, λ_{H2} and λ_{F2} also jump to their trade value. Hence, changes in the weapons or capital stocks in the model are instantaneous.

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