Appendix C
An Added Note to Chapter 4 on the Intercepts in the Pooled Estimates

If one wishes to interpret the intercept terms for each year in our pooled time-series cross-section estimates, one should take into account how much the dollar price level rose over 1970-92 (a factor of 3.45 for US prices) and how much real gross world product rose (a factor of 2.002).[1] The theory presented in chapter 7 suggested that national dollar GNPs in each year should be deflated by dollar gross world product. We have not bothered to do so in the cross-section context because it is not necessary. But here we should add 1.9 to the intercept on the 1992 cross-section[2] to see if there has been a secular increase in real worldwide trade, relative to 1970, beyond what can be attributed to inflation and growth. As an illustrative example, the estimated intercept term in 1990 is about 1.3 (table 5.2 or 5.3; Frankel and Wei 1995d, tables 6.1 through 6.3, or Frankel, Stein, and Wei 1996). Thus the increase in real trade, adjusted for GNP and the other factors (population is the other variable that changes over

1. The log of the dollar price level increased by 1.24, or .056 at an annual rate, while the log of real income increased by .694, or .032 at an annual rate.

2. That is, 1.93 = 1.24 + .69 (see preceding footnote). If one takes first differences of the gravity equation estimated, sets the GNP coefficients to 1, and assumes no change in the other variables, then the estimated equation looks like this:

growth in nominal trade = estimated time trend + 2(nominal GNP growth).

The true equation is

growth in real trade = true time trend + 2(real growth) - real world growth.

Thus,

true time trend = estimated time trend + real world growth + inflation.

time) is −1.3 + 1.9, or 0.6. Expressing the trend on an annual basis, trade has increased at about 3 percent per year. This increase could be attributed to declining transport costs or to worldwide liberalization of trade policy.[3]

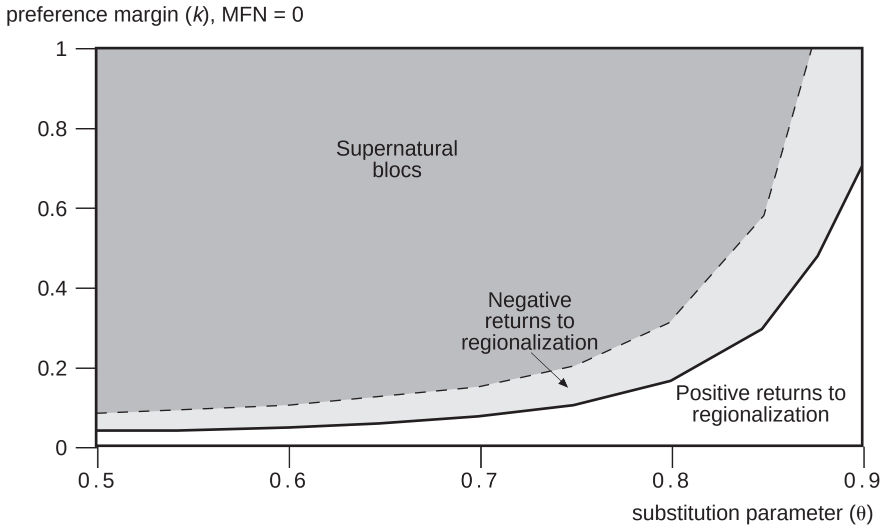
3. The reported intercept term for 1992 is not comparable to the others. It needs to be increased by the log of 1,000 to be comparable with the earlier numbers (because the trade and income data for that year differed from earlier years by a factor of 10^6 and 10^3, respectively). Perhaps the most reliable estimate would be the sum of the three intercept terms in the estimates based on changes in trade (Wei and Frankel 1995). It is 1.24. Adjusted for inflation, the estimate is 1.24 − (.25 + .38)1.24 = .46, a trend increase in trade of 2.1 percent per year.

Appendix D
Sensitivity Analysis

We attempted in chapter 8 to shed some light on the type of symmetrical trade arrangements that would result in a second-best outcome when multilateral free trade is not feasible. Throughout the simulations, we worked with the same "benchmark" set of parameter values: $a = 0$, $\theta = 0.75$, and $t = 0.3$. In the case of intercontinental transportation costs, b, we allowed it to vary in several simulations to see the effects of different values of b on welfare. When we had to focus on a single value, we adopted 0.2, which is not very far from our estimation based on the bilateral trade data. For these parameter values, and a stylized world of four continents formed by 16 countries each, the second-best entails the formation of continentwide preferential trade arrangements (PTAs) with levels of intrabloc preference on the order of 27 percent. Furthermore, we have determined that the level of preferences beyond which welfare falls below the level associated with the most-favored nation (MFN) rule is 51.5 percent.

The purpose of this appendix is to study how sensitive these results are to changes in parameters θ, t, and a and to changes in the configuration of the world. We have undertaken several simulations regarding the effect of different values of θ on the optimal level of intrabloc preferences and on the level beyond which blocs enter the "supernatural" region. In the first of these simulations, θ is allowed to vary, while a, b, and t remain at their benchmark level. The results can be seen in figure D.1: for any value of θ below 0.85, the qualitative results do not change much. The optimal degree of regionalization occurs for intrabloc preference levels on the order of 20 to 40 percent (increasing gradually as a function of

Figure D.1 Optimal degree of regionalization of continental PTAs as function of θ ($a=0$; $b=0$; $t=0.3$; $N=16$; $C=4$)



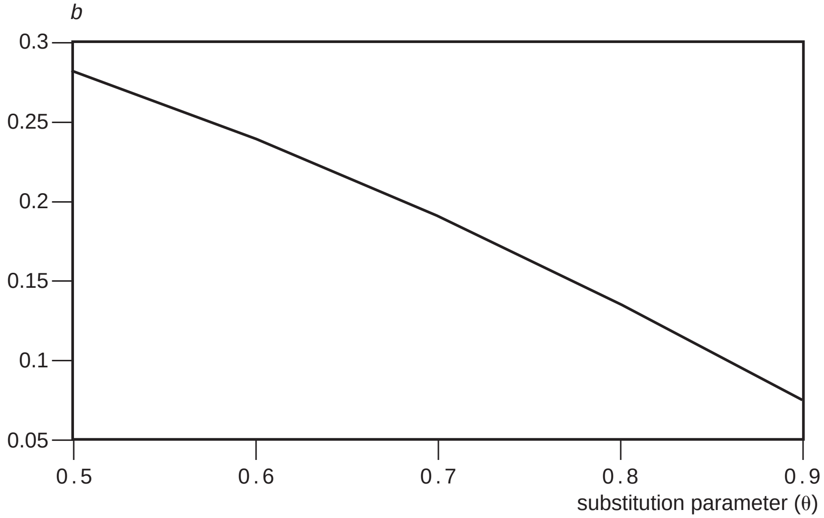
the substitution parameter θ), and supernatural blocs remain a distinct possibility. It is only for values of θ greater than 0.85 that the optimal level of *k* starts to increase rapidly, and the possibility of supernatural blocs becomes highly unlikely. However, these high values of the parameter θ would be associated with elasticities of substitution larger than 6.66—remember that the elasticity of substitution is $1/(1 - \theta)$—which seems too high to be plausible.[1]

The reason the optimal level of preferences and the level at which we enter the supernatural region increase with θ is the following: as θ increases, the preference for variety falls, and a given difference in relative prices due to natural barriers (such as transport costs) or artificial barriers (such as tariffs) has a larger effect. Thus, increasing θ implies that geography becomes more important, and therefore natural trading blocs such as the ones considered here are more likely to improve welfare, even at higher levels of intrabloc preference.

The difference between the second simulation and the first one is that now the inferred estimate of intercontinental transport costs, *b*, is made to depend on θ, as in chapter 9's preferred estimate of *b*. Figure D.2 shows how transport costs between continents depend on the value of θ we

1. For this level of elasticity of substitution, it would mean that if two varieties enter symmetrically into the utility function but the price of one of them is 15 percent higher than that of the other one, the lower-price variety will be consumed about three times as much as the higher price variety

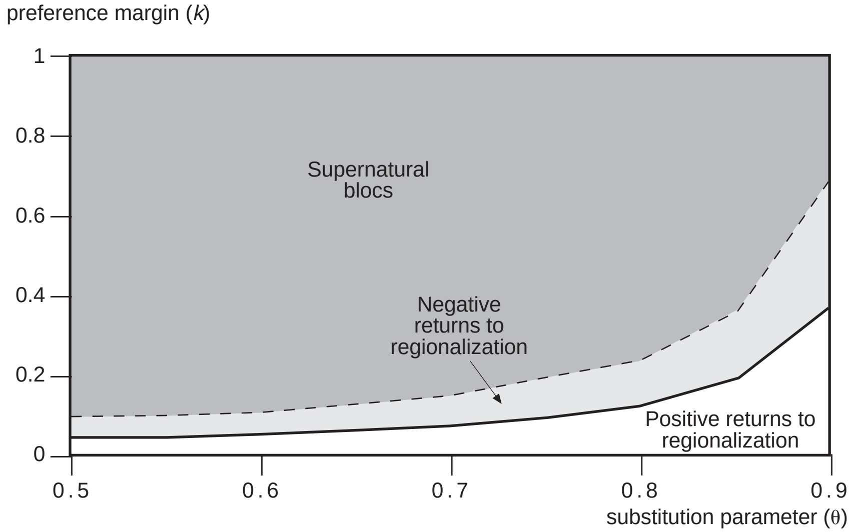
Figure D.2 Preferred estimate of intercontinental transport costs (*b*) as a function of θ



assume. Intuitive logic for this dependence is possible. The distance estimates of the gravity equation (together with the average distances between two countries in the same continent and two countries in different continents) tell us how much more on average a country is likely to trade with members of its own continent compared with trade with nonmembers. There are two factors making trade with neighbors higher; one is intercontinental transport costs, which introduce a price differential between varieties from neighbors and nonneighbors. The other reason is related to the elasticity of substitution. A given level of intercontinental transport costs will have a much larger effect on trade the higher the elasticity of substitution between varieties. Our gravity estimates tell us that, on average, two countries on the same continent will trade approximately twice as much as two countries on different continents, other things being equal. If the value of θ is very high, and so is the elasticity of substitution, a small value of intercontinental transport costs (with the corresponding small effect on relative prices of neighbor and nonneighbor varieties) will be enough to ensure that, on average, countries on the same continent will trade twice as much among themselves as with countries on different continents. On the other hand, for low values of θ and correspondingly low values of the elasticity of substitution, a much higher level of intercontinental transport costs will be necessary to bring about this pattern of trade. This explains the negative relationship between *b* and θ shown in the figure.

In our second simulation, then, we allow θ to vary, and *b* is determined by the relationship given in figure D.2. (The other parameters, *a* and *t*,

Figure D.3 Optimal degree of regionalization of continental PTAs as function of θ ($a = 0$; $b = b(\theta)$; $t = 0.3$; $N = 16$; $C = 4$)



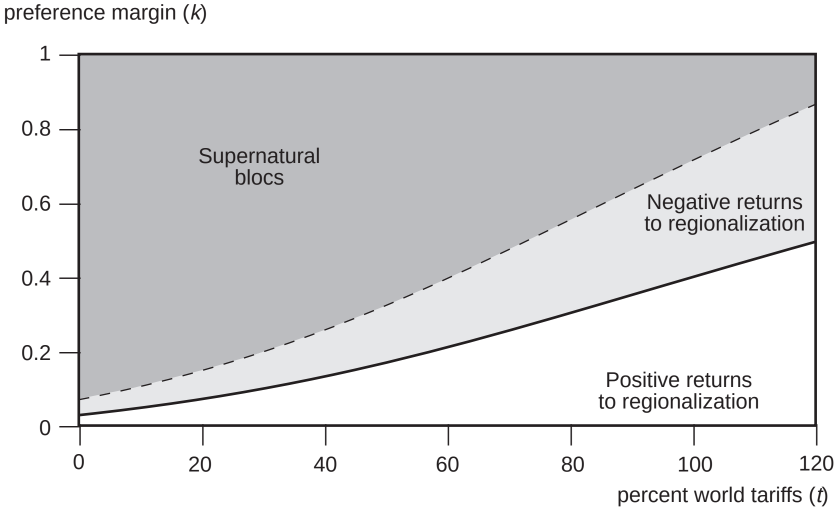
remain at their benchmark levels.) The results of this simulation can be seen in figure D.3. In this case, our basic conclusions remain intact, even at higher levels of the elasticity of substitution. Throughout the range of θ allowed, the optimal level of preferences remains under 40 percent.[2]

In our third simulation, we allow the level of external tariff, t, to vary. The outcome can be seen in figure D.4. The lower curve, which represents the optimal degree of intrabloc tariffs at each level of t, can be interpreted as the optimal path toward trade liberalization in a world in which regional blocs are formed but multilateral negotiations through the World Trade Organization continue to lower the external level of tariffs, t. The more successful multilateral trade negotiations are in lowering t, the lower the optimal level of intrabloc preferences, so trade policy becomes less and less discriminatory. Obviously, when external tariffs becomes 0, it does not make sense any more to talk about levels of intrabloc preferences.

To understand the positive slope of the curves, imagine the extreme case in which tariffs are set at a prohibitively high level (the far right of figure D.4). In this case, countries would not trade outside their bloc regardless of the preference level, and therefore the formation of free

2. This appendix treats tariffs as levied on c.i.f. prices. Sensitivity for the case where tariffs are levied on f.o.b. prices is explored in Stein (1994, appendix) or Frankel, Stein, and Wei (1994). There, the optimal k is seen to be U-shaped with respect to θ. It remains within the range of 23 to 37 percent. Supernatural blocs kick in at levels of preference between 43 and 70 percent.

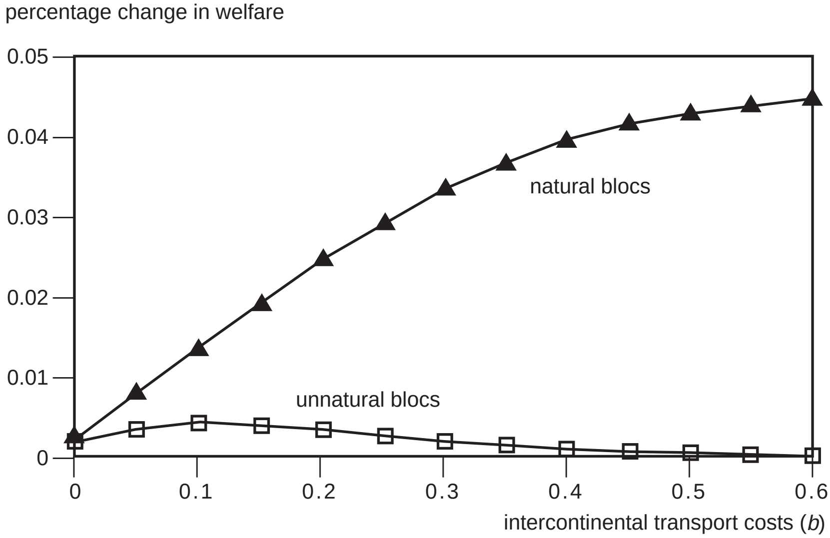
Figure D.4 Optimal degree of regionalization of continental PTAs as function of world tariffs ($\theta = 0.75$; $a = 0$; $b = 0$; $N = 16$; $C = 4$)



trade areas (FTAs) does not involve any trade diversion. In this extreme situation, 100 percent preferences would be optimal, which is analogous to the formation of natural FTAs when intercontinental transport costs, b, are infinite.

The simulations illustrated in this appendix adopt a strategy of seeing what happens when one parameter at a time is perturbed, keeping the others at their base levels. But we have also explored more widely. One result requires special mention. If *both* the global tariff rate, t, *and* the substitution parameter, θ, are raised above their base levels, then the benefit of forming regional trading blocs rises sharply. The supernatural zone may not exist, even for low levels of intercontinental transport costs. For example, if $t = 0.35$ and $\theta = 0.85$, FTAs are welfare-improving (relative to MFN) even when $b = 0$. This simulation is illustrated in Figure D.5 (taken from Stein and Frankel 1994, figure 3). The intuitive explanation is that, under these parameters, residents consume so much of the domestic good that it is a net gain to realign correctly the relative price of a neighbor's good in terms of the domestic good, even though this distorts the relative price of the neighbor's good in terms of all goods produced elsewhere in the world. This example just confirms what was already acknowledged by Krugman (1991a): the claim that the consolidation of six blocs into three is probably bad, in the absence of transport costs, depends on the values of t and θ. In addition, the higher the values of t and θ, the higher the optimal preference level, k, for every level of transport cost, b, which implies a smaller zone in which there are negative returns

Figure D.5 Welfare effects of free trade areas with high tariffs and elasticity ($\theta = 0.85$; $a = 0$; $t = 0.35$; $N = 2$; $C = 3$)

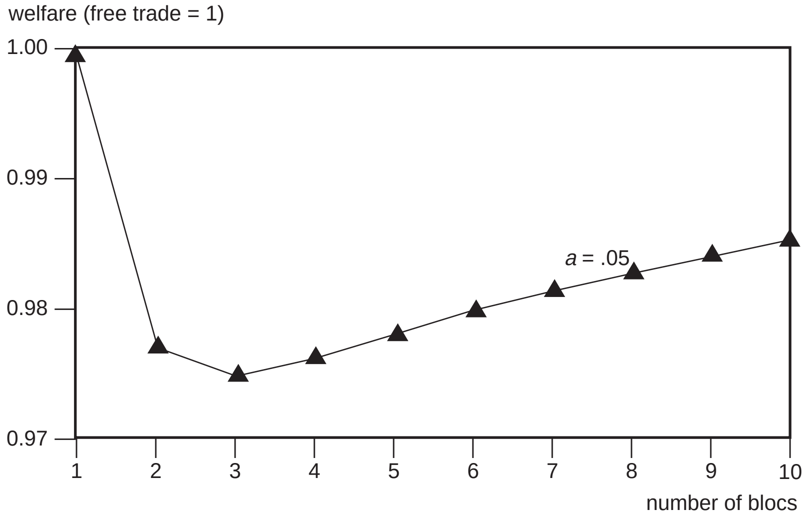


Source: Stein and Frankel (1994, figure 3).

to regionalization. In other words, all the contours shown in figure 8.7 shift upward.

Next, we allow within-continent transport costs, *a*, to vary. In the text, we constrained this parameter to zero, for convenience and in order to be able to focus on the key parameter, intercontinental costs (*b*). But it is important to relax this constraint. The imperfect substitutes model seems to give tremendous importance to the relative prices of goods imported from various foreign countries and to treat domestic producers as just one more source. Yet we know that domestic goods play a disproportionately large role in each country's consumption. This was adduced in chapter 3 as evidence that international integration is still far from complete. One natural way to make our simulation results consistent with the observed home-country bias in consumption is to recognize the costs to doing business with all firms located in other countries, not just those located on other continents. In other words, we must let *a* be greater than zero. Some readers have felt that our results regarding natural and supernatural blocs are attributable to the fact that Krugman's model gives too much weight to substitution among foreign varieties and not enough to substitution in domestic versus foreign goods. Specifically, Nitsch (1995) has suggested that both the results in Krugman (1991a) and in Frankel, Stein, and Wei (1993), as well as our results in this book, are very sensitive to the value of *a*. He claims that if *a* is allowed to be even

Figure D.6 Effects of intracontinental transportation costs (*a*) on welfare with change in bloc size ($C = 1$; $N = 60$; $\theta = .75$; $t = .3$)



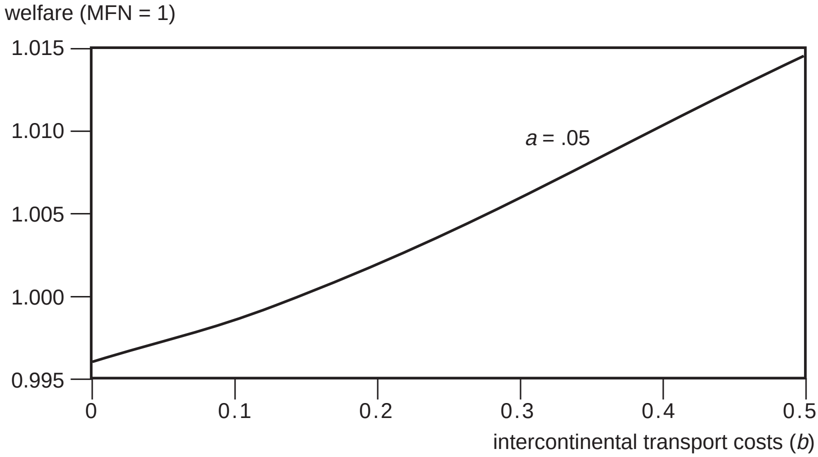
as small as .05, Krugman's result—that a move from six blocs to three large blocs (in the absence of intercontinental costs) lowers welfare—disappears. He further claims that our result that three large blocs lower welfare if intercontinental transport costs are sufficiently low also disappears—in other words, that when $a = 0.5$, welfare is improved no matter how low b is.

We begin in figure D.6 by vindicating Krugman (1991a). This shows the familiar U-shaped relationship between welfare and the number of blocs into which the world is carved (as in figure 8.2). To be sure, raising a from 0 to .05 pulls down welfare slightly when the number of blocs is large.[3] But the effect is very small. Welfare is still greater for six or ten blocs than for three. There is nothing like the monotonically falling level of welfare that Nitsch claims. The same is true even if a is as high as .15.

Next we freeze the number of blocs at three and repeat our introduction of intercontinental transport costs, b. Figure D.7 shows the same positive relationship between b and the welfare effects of three FTAs as figure 8.3 does: as intercontinental costs fall below about 0.15, welfare under FTAs falls below the MFN status quo. The introduction of within-continent transport costs, $a = 0.05$, does indeed narrow the supernatural zone—

3. Figure D.6 shows welfare measured relative to the benchmark of worldwide free trade. On an absolute scale, the introduction of deadweight transport costs reduces economic welfare substantially regardless of the bloc configuration.

Figure D.7 Effect on welfare of intra- and intercontinental transport cost with three blocs ($C = 3$; $N = 2$; $\theta = 0.75$; $t = 0.3$)

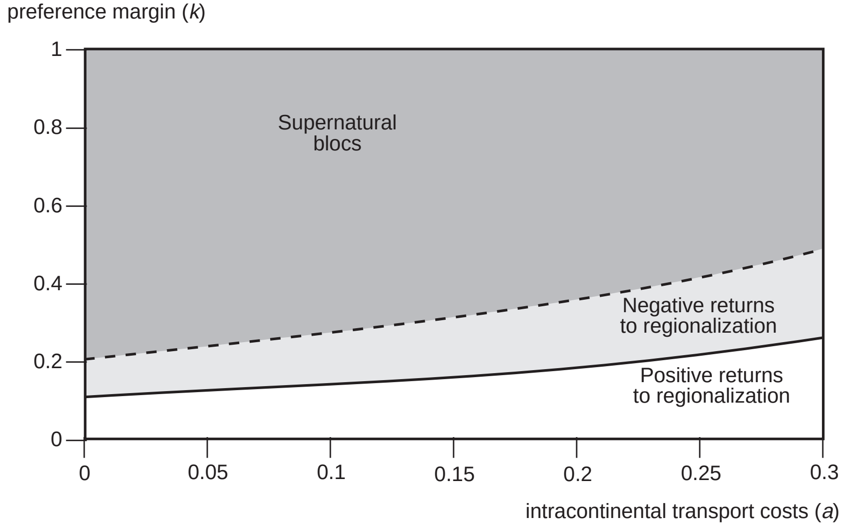


that is, to decrease the range of *b* in which FTAs are worse than MFN—but the effect is relatively small. A lower *b* now corresponds to the border between the natural zone and the supernatural zone. By no means does the supernatural zone disappear, as has been claimed.

Our third and final experiment with respect to within-continent transport costs is to see how they affect the optimal level of preferences, *k*, in a world of preferential trade arrangements. Figure D.8 shows the relationship between *a* and the optimal *k*, with *b* constrained to 0.2. Once again, the results are not very sensitive. The optimal *k* rises with *a*, but only very gradually. If *a* rises as high as 0.3, then the optimal level of preferences is as high as 34 percent, as compared with the case in which $a = 0$ and the optimal *k* is 27 percent. The effect on the level of *k* at which blocs become supernatural is not substantial either.

Our last set of exercises varies the configuration of the world—the number of continents (*C*) and the number of nations on each continent (*N*). Here, the results, expressed as the levels of preferences that are optimal or that begin the supernatural zone, are more sensitive. For example, the optimal *k* is 13 percent if there are 16 countries in each of three continental blocs (assuming $b = .15$), but this rises sharply to 54 percent if there are only two units on each of the three continents (table D.1). Similarly, the level of *k* at which we first pass into the supernatural zone is only .25 if $N = 16$, but rises to .95 if $N = 2$. This sensitivity, which was noted in chapter 8, is more apparent than real. More precisely, the results *should* be sensitive to these parameters because we are asking fundamentally different questions. Given that the real world in fact has

Figure D.8 Optimal degree of regionalization of continental PTAs as function of intracontinental transport costs (*a*)
($\theta = 0.75$; $b = 0.2$; $t = 0.3$; $N = 16$; $C = 4$)



many countries, the first question ($N = 16$) can be interpreted as asking the desirable degree of regionalization on each of three continents. The second question ($N = 2$) can be interpreted as asking, if each continent has *already* divided up into two large and fully implemented customs unions, what is the desirable degree of preferences between *them*? (An example would be negotiations between the North American Free Trade Agreement and a hypothetical South American Free Trade Agreement.)

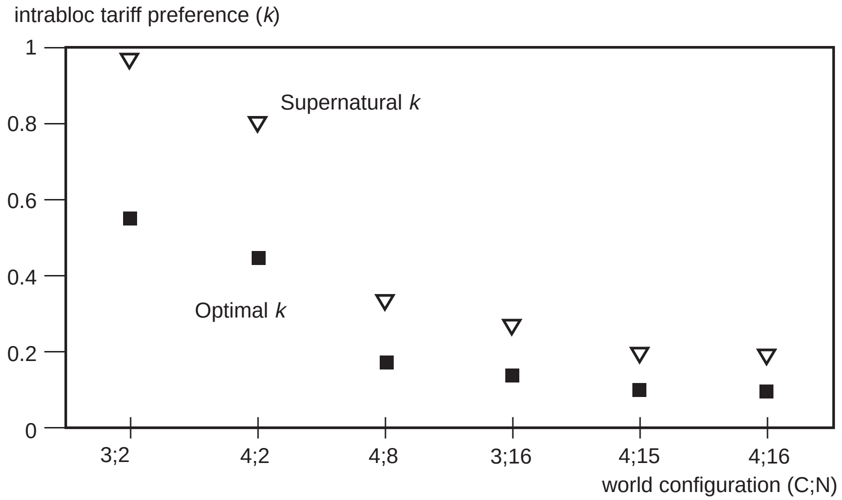
In Table D.1 we vary not just the number of countries on each continent, but the number of continents as well. It reports the critical values of k corresponding to different configurations (for $b = .164$, our preferred estimate of intercontinental transport costs). Figure D.9 shows analogous results (assuming now that $b = 0.2$). As a general rule, the k contours shift down when the total number of countries in the world goes up, whether it is N or C that goes up. If there are many countries in the world, then a high degree of regional preferences is more likely to be harmful because the distortions between members and nonmembers weigh more heavily than distortions between members and domestic producers.

Overall, the conclusion to be drawn from the sensitivity analysis is that the basic results of chapter 8 hold up rather well—namely, that a few large blocs with 100 percent preferences are worse than the status quo of MFN, but partial preferences are better than the status quo. One can push most of the parameters relatively far without altering the basic results, though the precise borderlines between the zones shift when the parameters vary.

Table D.1 Effect on optimal levels of within-bloc preferences (*k*) of different configurations of continents

Number of continents	Number of countries	Intercontinental transport cost (*b*) at edge of supernatural zone for FTAs ($k = 1$)	optimal *k*		supernatural *k*	
			$b = 0.164$	$b = 0.15$	$b = 0.164$	$b = 0.15$
4	16	0.602	0.093	0.089	0.181	0.173
4	15	0.594	0.098	0.094	0.192	0.183
3	16	0.545	0.133	0.127	0.259	0.249
4	8	0.512	0.170	0.182	0.327	0.314
4	2	0.289	0.448	0.436	0.800	0.779
3	2	0.186	0.550	0.537	0.968	0.947

Figure D.9 Optimal degree of regionalization for different world configurations ($a = 0$; $b = 0.164$; $\theta = 0.75$)



It should be repeated, however, that the entire exercise takes some things as given. In particular, relaxing the assumption that the level of worldwide tariffs is fixed would change the results more fundamentally.