Applied General Equilibrium Modeling in Spain and Mexico

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My history at the Autònoma

I first came to Barcelona in December 1984. I had met Andreu Mas-Colell, then a professor at the University of California, Berkeley, in 1978 when I was working on my Ph.D. thesis, which used differential topology to study the properties of general economic equilibrium models.[1] Andreu provided me with a tremendous amount of help and guidance, and we became friends. I introduced Andreu to my good friend and collaborator from graduate school at Yale, Jaime Serra-Puche, a Mexican who was the son of Catalan refugees from the Spanish Civil War. In fact, Jaime's grandfather, Jaume Serra i Hunter, had been the Rector of the Universitat de Barcelona and the President del Parliament de Catalunya for a time during the Republic. Andreu arranged for first Jaime, and then Jaime and me, to visit Barcelona. Jaime and I showed the economists at the Autònoma how we had developed applied general equilibrium models to analyze the impact of tax reforms in Mexico.[2] At the Autònoma, Xavier Calsamiglia and Joan Maria Esteban helped us obtain support from the Ministerio de Economía and to assemble a team of young economists to build an applied general equilibrium model to analyze the 1986 entry of Spain into what was then the European Community. Besides Jaime and me, the researchers on this team were three economists from the Autònoma, Antonio Manresa, Clemente Polo, and Ferran Sancho, and a Mexican economist, Pedro Noyola. Cristina Echevarria and Walter Garcia Fontes were the first research assistants. The Autònoma, with its masters program, was the center for modern economic research and education in Spain the 1980s, and it was an exciting place to be. Jaime Serra-Puche and Pedro Noyola had to give up working on the Spanish project when they entered the Mexican government in 1986, but I continued. I have spent some part of every year since 1984 in Spain, mostly in Barcelona but also in Alicante, Vigo, and Madrid, doing research and teaching. In Barcelona, I have been a

visiting professor at the Universitat de Barcelona and at the Universitat Pompeu Fabra, but I have mostly spent my time at the Autònoma.

Applied general equilibrium and the Spanish model

A general economic equilibrium model describes how the interaction of consumers, producers, and the government determines the prices, consumption levels, and production levels in an economy.[3] During the summers of 1985 and 1986, our team built an applied general equilibrium model of the Spanish economy by assembling am extensive data set — which we subsequently published as the first social accounting matrix developed for Spain[4] — and using it to specify the behavior of consumers, producers, and the government in a computer model. In the model that we implemented on the computer, these agents acted in accordance to economic theory — the consumers worked, consumed, and saved to maximize their utility, the producers hired factors of production, purchased intermediate inputs, and produced to maximize their profits, and the government taxed, spent, and made transfers to follow specified policy rules. In equilibrium, the markets for goods and services cleared, and we specified a rule for how unemployment in labor markets — we had two labor markets, one for skilled workers and the other for unskilled workers — changed in response to economic conditions. Using our data set, we were able to specify the behavior of our agents so that they replicated the actions of their counterparts in Spain in 1985.

One of the two most useful features of applied general equilibrium analysis is that we can use the model to conduct policy experiments. The principle policy experiment that we conducted was to change Spanish indirect taxes to a value added tax as required by Spain's accession treaty to the European Community.[5] We also changed Spain's trade barriers with the Community-member countries, but these changes were small compared to the tax changes. The other useful feature of applied general equilibrium analysis is that, after policy changes have been enacted in the economy, we can compare our predictions with what actually occurred. I do this in the first table, which compares the changes in the prices of the major components of the consumer price index in Spain that occurred in 1986 after the value added tax reform with the changes in prices that we predicted.

Changes in consumer prices in the Spanish model
(percent)

sector	data 1985-1986	model policy only	model shocks only	model policy & shocks
food and nonalcoholic beverages	1.8	−2.3	4.0	1.7
tobacco and alcoholic beverages	3.9	2.5	3.1	5.8
clothing	2.1	5.6	0.9	6.6
housing	−3.3	−2.2	−2.7	−4.8
household articles	0.1	2.2	0.7	2.9
medical services	−0.7	−4.8	0.6	−4.2
transportation	−4.0	2.6	−8.8	−6.2
recreation	−1.4	−1.3	1.5	0.1
other services	2.9	1.1	1.7	2.8
weighted correlation with data		−0.08	0.87	0.94
regression coefficient *a*		0.00	0.00	0.00
regression coefficient *b*		−0.08	0.54	0.67

The first column labeled model presents our raw prediction. The numbers at the bottom report two measures of the accuracy of the prediction. The first measure is the simple correlation coefficient between the prediction and the data weighted the importance of the different components. A value close to one indicates that the prediction was accurate. The second measure are the coefficients of a regression of the data on what occurred on the predicted values of the variables:

$$z_i^{data} = a + bz_i^{model} + e_i .$$

Here the coefficient *a*, which is the regression constant, indicates how well the model did in matching average change; a value of *a* close to zero indicates that the prediction was accurate. The coefficient *b*, which is the coefficient on the prediction, indicates how well the model did in matching the signs and magnitudes of the changes; a value of *b* close to one indicates that the prediction was accurate. Notice that our raw predictions of changes in relative prices were not very accurate. In 1990, when Clemente, Ferran, and I were comparing our predictions with the 1986 data, we realized that much of the discrepancy could be accounted for by major shocks

that hit the Spanish economy in 1986.[6] In particular, oil prices fell by half and there was a major drought that sharply reduced productivity in the agricultural sector. It was easy to incorporate these shocks into our model, and, when we did, we found that the model was capable of capturing the changes that had occurred in relative prices in Spain in 1986, although we were no longer justified calling the model output a prediction because it relied on knowledge of the other two major shocks that occurred in 1986.

Public finances in the Spanish model
(percent GDP)

variable	data 1985-1986	model policy only	model shocks only	model policy & shocks
indirect taxes and subsidies	2.38	3.32	−0.38	2.98
tariffs	−0.58	−0.82	−0.04	−0.83
social security payments	0.04	−0.19	−0.03	−0.22
direct taxes and transfers	−0.84	−0.66	0.93	0.26
government capital income	−0.13	−0.06	0.02	−0.04
correlation with data		0.99	−0.70	0.92
regression coefficient *a*		−0.06	0.35	−0.17
regression coefficient *b*		0.74	−1.82	0.80

It was in analyzing the predictions on relative prices that Clemente, Ferran, and I realized the importance of taking into account other shocks that had occurred in 1986. We found that, for many other variables, however, the raw predictions, which did not take these shocks into account, were much more accurate and incorporating the oil price shock and the agricultural productivity shock did little to improve the model's predictions. This was especially true of the most important prediction of the model, that the 1986 value added tax reform was, in fact, a major tax increase. The officials in the Ministerio de Economía who were supporting our research were not happy with this prediction since they were on record as claiming that the tax reform would make collection more efficient but would be revenue neutral. In fact, they utilized a clause in their contract with us to prohibit us from publishing our results in Castilian at least before or immediately after the tax reform. We circumvented this prohibition by

publishing a paper in Catalan in the *Revista Econòmica de Catalunya* in 1986.[7] The second table compares our predictions on the changes in different components of government revenue with what actually occurred in 1986. We predicted that revenues from indirect taxes, which included the value added tax, would double from being about three percent of GDP to being about six percent of GDP. Our predicted increase was only slightly larger than what actually occurred. In subsequent research, Clemente and Ferran identified much of the difference between our predicted increase in tax revenues and actual increases as being tax evasion.

Applying general equilibrium models to North American economic liberalization

As I mentioned, my friend Jaime Serra-Puche had to give up working on the Spanish project when he joined the Mexican Government as Subsecretario de Ingresos in the Secretaria de Hacienda y Crédito Público in 1986. In 1988, he was appointed Secretario de Comercio y Fomento Industrial. In 1990, Jaime asked me to serve as his Special Economic Advisor when he was negotiating the North American Free Trade Agreement with Canada and the United States. Given our success with applied general equilibrium models in analyzing tax reforms in Mexico and Spain, we decided to rely heavily on these sorts of models to evaluate alternative policy changes. We also tried to incorporate the impact of the liberation of trade and foreign investment on economic growth. In doing this, we were influenced the endogenous growth theories that were popular at the time. Our team used these models to forecast that NAFTA would result in a substantial increase in economic growth in Mexico.[8] NAFTA resulted in a substantial increase in North American trade, in fact, more than our models had predicted, but the increases in trade by sector were uncorrelated with our forecasts, and the economic growth rate of Mexico did not increase significantly. Much of my research over the past twenty years has been dedicated to understanding where and how we went wrong.

Using the new products margin to predict expansion of trade at the industry level

The models that we used to evaluate the potential impact of NAFTA typically had a large number of industrial sectors, something like twenty to forty. In this sort of model, countries traded goods and services because they had comparative advantages in different industries driven by differences in production technologies or by differences in endowments of such

factors of production as skilled labor, unskilled labor, and physical capital. To generate the volumes of trade observed in the data, modelers also assumed that the outputs of the same industries in different countries were close, but imperfect, substitutes. This assumption, named for the economist at the IMF who first employed it in the 1960s, Paul Armington, was useful in allowing modelers to match any trade pattern they observed in the data, especially the large volume of cross hauling, where, for example, not only does the United States export large quantities of automobiles to Mexico but Mexico also exports large quantities of automobiles to the United States. This hybrid mixture of classic comparative advantage and country specific differentiation of outputs also embodied a general approach to modeling what drives trade and changes in trade patterns: A country's comparative advantage is revealed by trade patterns before trade liberalization. That is, if a country is exporting the output of a given industry before trade is liberalized, it will export even more after trade is liberalized, and the largest increases in trade volumes will occur in those industries where trade barriers like tariffs are reduced the most. The models that Jaime Serra-Puche and I had used in the 1980s to analyze policy reforms in Mexico and Spain, had perfect competition in all sectors. The models that we used in the early 1990s to analyze NAFTA had increasing returns and imperfect competition in some sectors, but the implementation of these models and the general approach to modeling the drivers of trade and changes in trade patterns remained the same.

Unfortunately, when I repeated the same sort of ex post performance evaluation exercise that we had done on the Spanish model for the models that we used to analyze the impact of NAFTA, the results were discouraging.[9] I compared the predictions of three of the most prominent models of the NAFTA with the changes in trade patterns that actually occurred, and I could find no consistently positive correlation between the predictions and subsequent changes. The next table presents results typical of those that I found. It compares the predictions of the model developed by Drusila Brown, Alan Deardorff, and Robert Stern with the changes in trade patterns between Canada and the United States that occurred following the implementation of the U.S.-Canada FTA in 1989 and NAFTA in 1994. Notice that the correlation coefficient between predictions and outcomes is positive for U.S. exports to Canada but negative for Canadian exports to the United States. Furthermore, Alan Fox, in his 2000

Ph.D. thesis at the University of Michigan could not find any exogenous shocks that he could introduce into the model to improve the comparison.

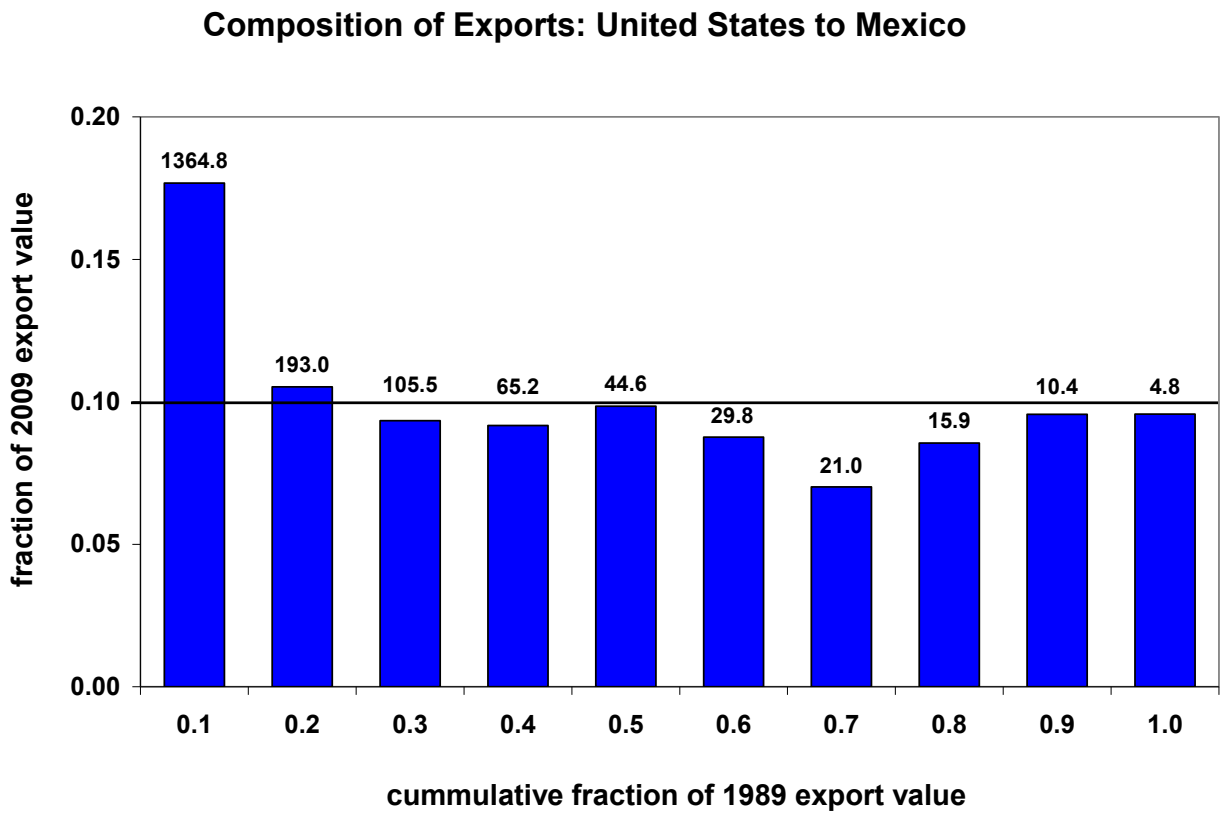
Changes in Canada-U.S. trade relative to exporter's GDP (percent)

	Canada to U.S.		U.S. to Canada	
industry	**1989–2009 data**	**BDS model**	**1989–2009 data**	**BDS model**
agriculture	12.5	3.4	−6.4	5.1
mining and quarrying	237.6	0.4	51.3	1.0
food	101.2	8.9	124.1	12.7
textiles	42.4	15.3	−35.9	44.0
clothing	50.2	45.3	−3.0	56.7
leather products	−67.7	11.3	−64.0	7.9
footwear	−49.9	28.3	−67.2	45.7
wood products	−54.5	0.1	−30.6	6.7
furniture and fixtures	−46.6	12.5	22.5	35.6
paper products	−65.9	−1.8	13.7	18.9
printing and publishing	0.7	−1.6	−19.6	3.9
rubber products	45.8	9.5	30.2	19.1
chemicals	99.6	−3.1	50.2	21.8
petroleum products	−79.8	0.5	−43.1	0.8
glass products	−45.7	30.4	−20.0	4.4
nonmetal mineral products	−0.4	1.2	−1.9	11.9
iron and steel	−12.7	12.9	53.5	11.6
nonferrous metals	−20.9	18.5	−20.8	−6.7
metal products	17.7	15.2	−5.3	18.2
nonelectrical machinery	−8.4	3.3	−38.9	9.9
electrical machinery	−16.4	14.5	−42.6	14.9
transportation equipment	−44.3	10.7	−37.8	−4.6
misc. manufactures	56.1	−2.1	−19.2	11.5
weighted correlation with data		−0.28		0.39
regression coefficient *a*		21.82		−26.62
regression coefficient *b*		−3.33		1.34

One reaction to the poor performance of models of NAFTA in predicting the sectoral impact of trade reform would be to give up on industry as a unit of analysis. Indeed, much of the research in international trade over the past fifteen years has focused on the characteristics of firms that exports but ignores the industries in which they operate and the products that

they produce. I think that this is an unfortunate trend because policy makers think of trade policy at the industry level. Furthermore, we can trace the impact of changes in trade pattern through the economy using input-output linkages if we can identify the industries in which these changes take place.

Although my first reaction to the failure of applied general equilibrium models to predict the sectoral impact of NAFTA was to be discouraged about international trade modeling, I later perked up. Comparing the evaluation of the NAFTA models with that of the Spanish model, I came to interpret these results as indicating that we economists understand international trade far less than we understand public finance. In spite of my 1990–1994 stint as Special Economic Advisor to the Secretary in Mexico, I am basically a professor, that is, a researcher, a teacher, and, especially, a supervisor of graduate student research. Our profession's lack of understanding of international trade presents a tremendous opportunity for me and my students.



Kim Ruhl, originally a student of mine at Minnesota, and I have found that a large share of the increase in trade following trade liberalizations like NAFTA is the result of countries exporting products that they had exported little or not at all previously. Let me be precise about my vocabulary: When I say industry, I mean something like the 23 industries in the BDS model or the 37 3-digit ISIC (International Standard Industrial Classification), revision 3, industries. When I say product, I mean something like the 1,836 5-digit SITC (Standard International Trade), revision 2, products. Notice that, on average, every BDS industry is made up of almost ninety products. Kim and I listed the 1,836 products that one country potentially exported in order of how large the exports were before liberalization. We then sorted these products into ten bins, each of which accounted for 10 percent for trade in the base year of our analysis, before liberalization. Notice that, in the figure for U.S. exports to Mexico, the 4.8 products that were exported the most accounted for 10 percent of exports in 1989 as did the 1,364.8 products that were the least traded. After trade liberalization, trade increased in all of the bins — something we do not see in the figure — but the largest increase occurred for the least traded products. Furthermore, this pattern is typical for country pairs where there is significant trade liberalization or where one of the countries is going through significant structural change, but not otherwise.[10]

Comparisons of forecasts, NAFTA
(correlations with data)

exporter	importer	BDS model	LTP model
CAN	MEX	−0.10	0.55
CAN	USA	−0.28	0.30
MEX	CAN	0.06	0.33
MEX	USA	−0.13	0.17
USA	CAN	0.39	0.54
USA	MEX	−0.06	0.47
weighted average		−0.00	0.39
pooled regression		0.06	0.24

Working with Jack Rossbach, a recent Minnesota student, Kim and I have been able to use our observation that much of the increase in trade comes from exports of least traded

products into a simple forecasting model.[11] Letting z_j be in the increase in the exports of industry *j* as a fraction of GDP, we predict that

$$z_j = a + bs_j,$$

where s_j is the fraction of exports accounted for by least traded products in the base year, 1989. We assume that *b* is positive. In other words, we simply predict that industries with many least traded products will have the largest increases in exports. We evaluate our model by "predicting" the industry-level effects of NAFTA using only data that would have been available in 1989 — before the implementation of NAFTA. We compare our predictions with the actual growth in trade that occurred from 1989 to 2009 and find that the model does well: The table shows that the weighted correlation between our predictions and the data averages 0.39 across all six NAFTA country pairs. This result is even more striking when we compare our forecasts with those from general equilibrium models actually used to forecast the effects of NAFTA, whose weighted correlation with the data averages 0.00.

I interpret the results of the exercise that Kim Ruhl, Jack Rossbach, and I have performed as giving us hope that we can develop models to provide more accurate analysis and predictions the impact of trade liberalization at the industry level. Notice that our results indicate that the previous approach, which "locked in" the pattern of comparative advantage, was wrong. In particular, the pattern of trade before liberalization does not reveal where the largest increases in trade will occur. Developing new models will be challenging, but exciting. We are working on them now.

The perils of financial liberalization

One of the most important features of Spain's integration into the European Community was that it opened the economy to foreign investment. Gonzalo Fernández de Cordoba and I developed a dynamic general equilibrium model to analyze the impact of the increased capital flows that occurred.[12] We found that these capital flows had a large impact on the Spanish economy, causing an increase in the relative price of nontraded goods and causing a reallocation of resources from the production of traded goods to producing nontraded goods, that is, services and construction. In fact, the impact of this increased foreign investment in

Spain was larger than the impact of the changes in tax and trade policy that our original, static model of was meant to capture. A notable feature of the capital inflows was how volatile they were. When the costs of German reunification lead the German government to raise interest rates in 1992, foreign investment in Spain dried up quickly leading to a recession.

Kim Ruhl and I, using a dynamic model similar to Gonzalo's and mine, found that volatile capital flows had an even larger impact on the Mexican economy when it opened.[13] These capital flows came to a two-year stop in 1995 and 1996 following the Mexican financial crisis of December 1994 and January 1995. In the beginning of December 1994, my friend from Yale, Ernesto Zedillo took office as President of Mexico and he asked Jaime Serra-Puche to be his Secretario de Hacienda. Once again, Jaime asked me to be his Special Economic Advisor, but within three weeks the market for government bonds in Mexico started to collapse and within four weeks Jaime had to resign.

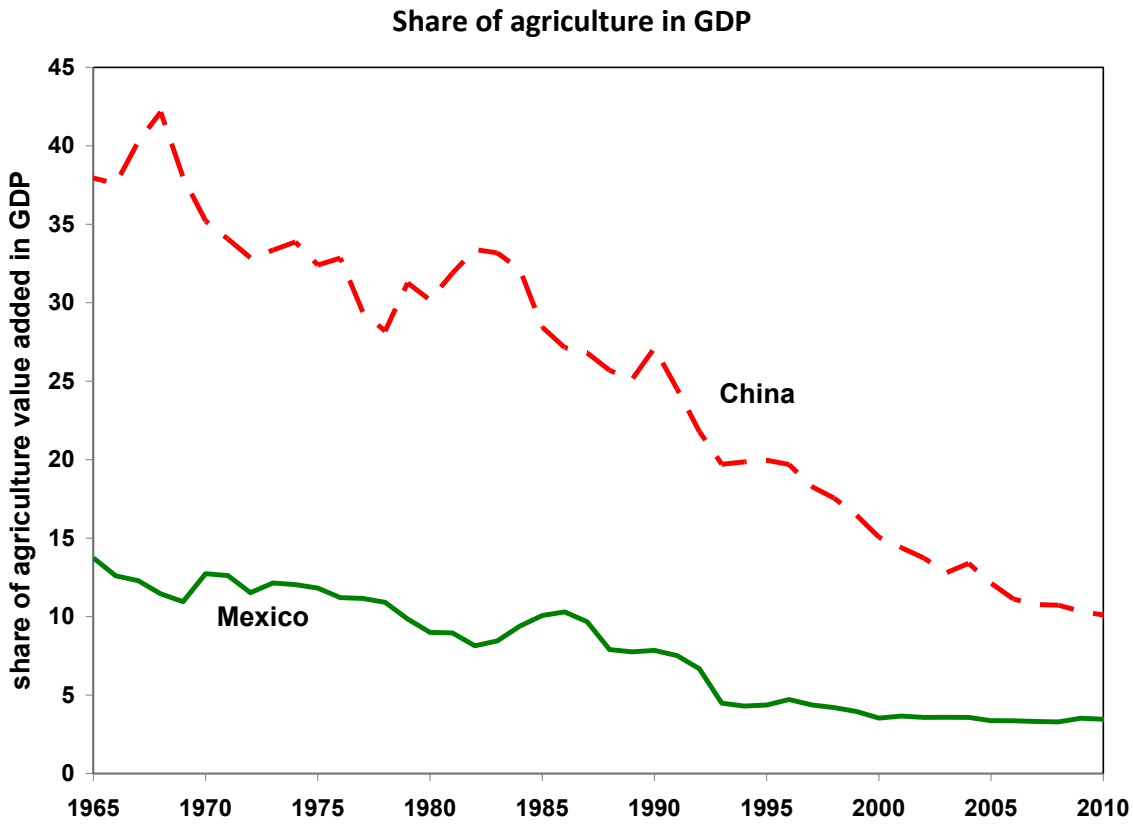
What had happened was that starting earlier in the year, the previous Secretario de Hacienda had started to covert Mexican government debt into very short-term, dollar-indexed, bonds, known as tesobonos. Although the overall level of Mexican government debt was low by international standards, its short maturity meant that the government had to roll this debt over frequently. Back in Minneapolis, I was depressed about what was going on in Mexico, but I was well informed, and I gave a couple of presentations to the local economics community. My friend, Hal Cole, then a researcher at the Federal Reserve Bank of Minneapolis, convinced me to work with him developing a dynamic, stochastic general equilibrium model in which the need to frequently sell large quantities of bonds leaves a government vulnerable to a self-fulfilling financial crisis.[14] In this sort of crisis, if investors panic and only buy bonds at a very low price — which means that the interest rate on these bonds is very high — the government is pushed towards default. If, however, the investors do not panic and buy the bonds for a higher price, there is not crisis.

I became identified as an expert on sovereign debt crises, which was identified as specialty associated mostly with Latin America. In 2011, I spent most of the year here on sabbatical at the Autònoma, and, as sovereign debt crises rolled through Greece, Ireland, and Portugal, towards Spain and Italy, Juan Carlos Conesa suggested that we extend the Cole-Kehoe

sovereign debt model to analyze the European debt crises.[15] We found that Spain, like Mexico, had a low level of debt by international standards. In the case of Spain, it was the high level of the deficit that made it necessary for the government to sell large quantities of bonds. Furthermore, the severe recession in Spain made it difficult for the government to cut spending and raise taxes to eliminate this deficit.

The stages of economic growth

When Mexico opened to foreign trade and investment in the late 1980s and early 1990s, it was the first large less developed country to do so, followed soon after by China. In spite of my optimistic predictions about increased growth in Mexico, Mexican growth performance has been disappointing, while Chinese growth performance has been spectacular. Kim Ruhl and I argue that Mexico has had poor growth performance since the 1980s because of problems in its financial system, immobility in labor markets, and lack of rule of law.[16] We point out that these sorts of barriers to growth are also present in China, and are perhaps even worse there. We propose a theory in which the barriers that slowed growth in Mexico have not yet slowed China because China has not reached the stage of growth where these barriers are binding. Instead, China is still benefiting from the massive movement of the population from rural areas to urban areas, accompanied by expansion of basic education and the movement of workers from agriculture to manufacturing. These are exactly the forces that made Mexico one of the fastest growing countries in the world during the period 1950–1980. As the figure shows, China is still has a larger agricultural sector than does Mexico, and it is still behind Mexico on a large number of development indices. When we published our paper in 2010, Kim and I hypothesized that, as China continued to develop, the problems in its financial system, immobility in labor markets, and lack of rule of law would start to bind and Chinese growth would slow sharply, perhaps before China reached the level of development of Mexico. It seems that this may be happening now.



Working with a number of current and former students, I recently have been working on expanding our comparison of Mexico and China into a theory of stages of economic growth inspired by Walt Rostow's seminal 1960 work.[17] Felipe Meza and I, in our modern economic history of Mexico, hypothesize that Mexico would be currently doing much better, if it had opened to foreign trade and investment earlier. Jose, Asturias, Sewon Hur, Kim Ruhl, and I develop a dynamic model in which growth in driven by entry and exit of heterogeneous firms.[18] We argue that, if a country is going to open to foreign trade, it is better that it do so early in its development process so that it has builds up a distribution of firms suited to international competition. There is obviously more work to be done developing a theory of stages of growth, but I am excited about the potential of our approach.

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