FUTURE DIRECTIONS

IN GLOBAL TRADE ANALYSIS

by

Thomas W. Hertel

Staff Paper #99-8

August 1999

Dept of Agricultural Economics

Purdue University

GLOBAL TRADE ANALYSIS IN THE YEAR 2010: A GLIMPSE OF THE FUTURE

by
Thomas W. Hertel
Department of Agricultural Economics, Purdue University
West Lafayette, Indiana 47907-1145
hertel@agecon.purdue.edu
Staff Paper #99-8
August 1999

Abstract

This paper discusses future directions in global trade analysis from the perspective of the Global Trade Analysis Project (GTAP) network. The first section offers a projection of where the GTAP network might be in the year 2010. This is followed by an analysis of the basic drivers of change in global trade analysis. These include: network externalities and the push for greater openness in both modeling and database work. The second half of the paper revisits John Whalley's "Hidden Challenges" for applied general equilibrium analysis, discussing how well we have fared with respect to these challenges, first posed in 1986. The paper closes with some additional challenges for global trade analysis in the coming decade.

Keywords: Global economic analysis, international trade, trade negotiations, network externalities, general equilibrium analysis.

GLOBAL TRADE ANALYSIS IN THE YEAR 2010: A GLIMPSE OF THE FUTURE

by
Thomas W. Hertel

The time is 2010. The location is Santiago, Chile, and we are attending the 13th Annual Conference in Global Economic Analysis. There are 500 participants -- a record number and a far cry from the 100 at the First Annual Conference held at Purdue University in 1998. The agenda is full, with sessions on modeling, software development, teaching and policy analysis. The purpose of this invited address is to review the progress that we have made in the decade since the Second Annual Conference held in Denmark in June of 1999.

Some would say that the growth of the global research network, loosely termed "GTAP" has been nothing short of remarkable. There are now 40 consortium members supporting core activities. Centers for Global Trade Analysis now exist on almost every continent. They work in concert with the original Center at Purdue University to coordinate regional database efforts, run short courses and organize conferences. The network of database users and contributors now numbers in the thousands.

After a decade of proprietary status, the GTAP consortium fully embraced the "open source" standard for the database in 2003. This dramatically accelerated database development work. Indeed, from our present perspective in 2010, it hardly seems possible that there was a time (less than ten years ago) when virtually all of the GTAP database modules were developed in the Center for Global Trade Analysis on the campus of Purdue University! As was the case at the end of the last century with the IBM-PC, the open architecture approach (vs. Apple's proprietary approach) has permitted the GTAP database to tap into the enormous talents of economists, statisticians and computer programmers around the world. The comprehensive data bases on domestic taxes, and environmental endowments and pollution, which we now take for granted, would not have been possible without the concentrated efforts of individuals in more than a dozen countries around the world.

The key feature in fostering a common standard, to which these diverse researchers can work, has been establishment of the GTAP Database Short Course. This now rivals the modeling short course in popularity. At this course, individuals learn how to construct the GTAP database from scratch. Having done so, they are in a position to modify the inputs and assumptions and produce a new database, perhaps with a few additional regions or sectors. Because the GTAP open access database license is "infectious", that is products based on the open access version of the database must also be made freely available, there has been no incentive to splinter the database. Improvements have been fed back to the Center for Global Trade Analysis where they have often been incorporated into the next version of the database. The privilege of having one's work formally included in the formal database release has also proven to be a strong incentive for sharing of software and data.

Open-sourcing of the GTAP database also has had a tremendous impact on global economic modeling and associated analyses. Only a few of those in the audience today in Santiago will remember the pre-GTAP era, when replication of someone else's applied GE study was viewed as

a major accomplishment! Open sourcing of models based on the GTAP database ushered in a new era in which replication became routine. Indeed, this was the essence of the early GTAP courses – replicate, and then extend, an existing study. However, the proprietary nature of the GTAP database posed a fundamental problem for the scientific community at the turn of the century. As authors began conducting studies at a highly disaggregated level, those interested in replication required a database license. Furthermore, enterprising authors began undertaking the inevitable modifications to the database, and these were performed on an *ad hoc* basis, without reference to specific standards. This served to confound efforts to replicate their work.

By removing these barriers to effective replication, the open-sourcing approach has helped to give birth to the present "golden era" of global, applied general equilibrium analysis. AGE modelers are now the envy of other empirical economists. In contrast to the early 1990's, when it was very difficult to publish applied GE work in the leading journals, editors are now very receptive to such submissions. This enthusiasm is the result of three factors. First of all, the GTAP network provides an excellent source of well-informed reviewers who can quickly discern high quality work from research of lesser value. Secondly, unlike many other empirical studies, editors can now require that GTAP-based AGE studies be independently replicated. This removes all doubt about the scientific integrity of the work.

The final and most important factor, explaining journal editor's great enthusiasm for this work is the fact that others actually use it after it is published! Gone is the day when AGE-based studies languished on the library shelf. Each electronic journal article is now accompanied by links to the web site where the complete set of inputs to the study can be downloaded and replicated. The publication of an article on a controversial topic is now eagerly awaited by readers, who quickly replicate the study's findings. They then test the robustness of the authors' conclusions to key assumptions about the theory, database and parameters. The resulting dialogue has reinvigorated the field of applied general equilibrium analysis, and it has left other fields of empirical economics scrambling to define similar standards for their databases and software.

The final area that I would like to touch on in this review of the past decade is that of teaching. Here two developments stand out. The first one relates to the methods for training new individuals in the field of AGE analysis. Prior to the 1990's, almost all of this training occurred in apprenticeships, whereby bright young graduate students spent a number of years at the feet of a master AGE modeler, and gradually picked up the basket of tools required to succeed in this field of work. While this approach to learning has proven successful over the centuries, it is extremely intensive in skilled labor, and it therefore limits the spread of expertise. As the 20th century came to an end, short courses in AGE analysis became more widespread. However, graduate course offerings in this rather specialized area of research remained relatively inaccessible to most students of economics, and such courses were unavailable to professional economists outside the university arena.

The short courses, such as those offered by the Center for Global Trade Analysis, were effective at teaching the mechanics of AGE analysis, but one still had to learn the "art-form" and advanced topics on one's own (or at the feet of a master). However, with the advent of distance learning, formal training in AGE analysis has further evolved. For example, an individual interested in using a GTAP-based model to examine the implications of trade liberalization for environmental

quality would now start by enrolling in the GTAP-online preparatory course, following this up with the intensive GTAP short course. At this point, she could choose from a variety of specialized modules aimed at specific topics of interest. These are taught by experts in each sub-field, and they are built around technical papers showing how the standard model can be extended to accommodate the problem at hand. In this case, the student might choose modules on trade and the environment, dynamics, and imperfect competition. The final product of each module is a full-scale application of the new methods to a problem of interest to the student. Having completed these advanced modules, she is now ready to embark on her own research – hopefully with some continued mentoring from one of the experts in the network. This research may involve extending the state-of-the-art if she is in academia or alternatively, an in-depth policy application if she is in the public arena.

The second striking development in the educational arena is the widespread use of AGE analysis in undergraduate and graduate courses on international trade, development, public economics, and resources and the environment. The availability of easy to use, self-contained modules on a variety of topics, ranging from simple descriptive analyses of linkages in the global economy, to sophisticated, inter-temporal modeling of global environmental issues, have made it easy for instructors to supplement their course content with AGE-based material.

In summary, the last decade has been an exciting one for those involved in global economic analysis. Who knows what the next decade will bring?

Drivers of Change in Global Trade Analysis

Network Externalities

As with any "projections" scenario, the main value in developing the preceding vision of 2010 rests in the process of constructing an internally consistent story, identifying the main drivers of change, and examining their likely consequences. In the case of global trade analysis, it is clear that the main driver of change in the coming decade will be that of *network externalities*. The more individuals who become involved in the virtual network of GTAP data base users and contributors, the more widely the network will be valued by individual participants. In their discussion of this type of "positive feedback", Shapiro and Varian refer to "Metcalfe's Law" which states that the value of a network rises with the square of the number of participants. Looking at the GTAP network over the 1998-99 year, it is plausible to assert say that, as the size of the network has doubled (from roughly 200 to about 400), the value of the network has probably more than doubled, and a four-fold increase is not out of the question.

There are a variety of reasons why the GTAP network is characterized by positive feedback. First of all, GTAP is a language, and the attractiveness of any language increases as the fluent population grows. The fact that the Japanese representatives on the APEC Economic Committee were able to get agreement on the use of GTAP to analyze various APEC trade liberalization scenarios, is a sign of the increasing fluency in GTAP (Kawasaki, 1997). Most of the member nations in APEC now have some capacity for conducting global trade analysis with GTAP, so we see positive feedback at work on the political level as well. Each new country that is represented in

the data base and in the virtual network of users makes GTAP more attractive for use in international political arenas.

From an academic perspective, I have also seen positive feedback at work in global trade analysis. As the network of individuals doing work in this area expands, it has become much easier to obtain quality reviews for journal articles and grants. Rather than spending most of one's time responding to questions about the data base, and explaining what an AGE model is, I have found myself spending much more time responding to substantive questions about the analysis and the extensions to existing work. This is more challenging, and infinitely more satisfying. The evidence is also clear. A quick search of the research applications data base on the GTAP web site (currently numbering 227) reveals many more journal articles using applied general equilibrium analysis than existed prior to the creation of this network.

Another source of network externalities in global trade analysis derives from the increased demand for software. With each new addition to the network of individuals using the GTAP database for global trade analysis, the market for the associated data base and modeling software expands. Owing to GTAP's strong ties to Australia, and the IMPACT Project in particular, it is hardly surprising that it has developed around the GEMPACK modeling software suite which was developed at IMPACT and is now maintained in the Centre of Policy Studies at Monash University (Harrison and Pearson, 1996). The demand for GEMPACK software by GTAP users has helped to spur further development of this software. Indeed, in response to the widespread use of the standard GTAP model by non-modelers, Mark Horridge has developed an entirely new interface to the GEMPACK software, nick-named RunGTAP. Early success with RunGTAP has led Ken Pearson to extend this tool to other GEMPACK-based models (RunGEM).

The positive feedback from this rapidly growing global economic analysis network to software development has recently been extended to the community of individuals using the GAMS software package. Thomas Rutherford has made available a package dubbed GTAPinGAMS that builds on Rutherford's powerful GAMS/MPS GE modeling software (Rutherford, 1998, 1999). Clearly as the group of GTAP data base users grows, it will be better served by software developers, and this in turn will fuel the productivity of those conducting global economic analysis. This kind of virtuous circle is the driving force behind the explosive growth one sees in industries characterized by network externalities (Shapiro and Varian, 1998).

The Tension between Openness and Control

Implications for Modeling: In their discussion of networks, Shapiro and Varian identify a fundamental tension between openness and control. Open networks are extremely attractive, as they maximize the potential for participation and new contributions. We have observed this with the GTAP network which offers a variety of levels of participation ranging from visits to the web site, an open discussion list, free distribution of the standard model (Hertel, 1997) and its extensions, along with short courses. The idea of a publicly available AGE model is not new -- the ORANI model of the Australian economy has been widely used by individuals in academia and government agencies in that country (Dixon et al., 1982; Powell and Snape, 1993). However, the global coverage of GTAP, coupled with the opportunities for costless dissemination via the Worldwide Web, have taken this idea to a new – and some would say dangerous – level.

There is clearly great scope for abuse of any model and GTAP is no exception. Early on in the project there were calls for more quality control – with some even suggesting that all GTAP applications should be screened by staff at Purdue! However, we resisted that, arguing that it is instead up to the consumers of model results to discriminate between abuses and high quality applications of the model. As the novelty of being able to generate thousands of numbers about the global economy has worn off, I believe that we are settling down into a state of affairs where more is being expected of the economists using the GTAP data base to conduct global economic analysis. In short, I think we have passed through the most dangerous period of this experiment in "open-modeling".

Just as the dangers of this open source approach to global GE modeling appear to be receding, the benefits are becoming more evident. The GTAP technical paper series offers a vehicle for capturing innovations generated by members of the GTAP network – ranging from methods for incorporating scale economies and imperfect competition (Francois, 1998), to an approach to accounting for trade-related technology spillovers (van Meijl and van Tongeren, 1999). The open-source approach to modeling has also greatly facilitated replication of studies by third parties. Indeed, it is now very easy to use these studies in the classroom, where students can replicate and extend an existing study. In short, it appears that the open-source approach to economic modeling is here to stay.

Implications for Database Development and Distribution: The GTAP approach to the database has been quite different from the approach to the modeling network. Here, the Consortium has opted for a much greater degree of control. There are several reasons for this. The first is a very practical consideration. If we were to make the database available at the marginal cost of web-based distribution (zero), there would be no resources available to produce the next version. But the most important feature of the GTAP database is its continuity. Knowing that there will be a version 2, 3, 4, 5, etc. permits individuals and agencies to structure their work program around this data base. A second reason for control is the very complexity of the task of producing a global database. It is easy to make mistakes, and we have found that the only way to "get it right" is through repetition. Quality has increased substantially with each new version.

In light of the fact that GTAP needs to be a self-sustaining effort, we have had to experiment with alternative pricing schemes for the database. It has been clear from the start that a one-price-fits-all approach would not cover the cost of data base development. The market for analytical databases of the global economy is rather small. There simply aren't enough people in this business to support GTAP data base development at $100/copy. Yet, this is all one can reasonably expect students and other impoverished academics to pay for such a database. Furthermore, since the alternative to buying such a database is to develop a poor substitute in-house at a cost of hundreds of thousands of dollars, there is considerable scope for charging a higher price for agencies formally mandated to conduct global trade analysis.

The GTAP database pricing structure has evolved over time towards a combination of different versions and different pricing for different groups. The three way split between government and private sector users, multiple-user academics and individual academics has been a useful one. However, the key distinction has been that of consortium vs. non-consortium users. Consortium members get early access to the data base and help to set the direction of the overall project. We have

managed to recruit into the Consortium those agencies/institutions for whom this work is essential and who might well be doing the work in-house in the absence of this project. Their annual contributions cover the majority of the core budget. In addition, this consortium has provided a natural clientele for the Project, assuring that it will continue to remain policy relevant. This has worked very well to date, with the consortium growing rapidly and then stabilizing at its current level of 18 members.

Of course, this "proprietary" approach to the database has some significant drawbacks, as identified in the opening section of this paper. The next major challenge for GTAP will be to figure out whether there is a way to open-up the database construction process without weakening standards and eroding support for ongoing development work. Rather than speculate further on this topic, I would now like to shift gears and move from the institutional infrastructure for global trade analysis to a discussion of the research challenges that we face in this field.

Hidden Challenges Revisited

This is perhaps an appropriate time to revisit John Whalley's 1986 paper titled "Hidden Challenges to Applied General Equilibrium Analysis". While this was written nearly 15 years ago, many of the challenges posed by Whalley remain relevant today – although hopefully they are no longer quite so "hidden". I will address these points below. However, before doing so, let me note one area where considerable progress has been made.

Challenges Met

The team approach: One of the most important points made by Whalley in 1986 was the need for teams of researchers working in this area:

"Modellers often complain about the necessity of being a jack of all trades. When involved in modelling activity in the applied general equilibrium area, one has to be able to program (or at least communicate with programmers), to be familiar with data and be able to manipulate and convert it into a model admissible form, to be conversant with literature estimates of key parameters (including elasticities), to have a clear sense of policy issues and institutional structure, and to be able to interpret results. With repeated modelling activity, one also has to be something of a librarian to be able to archive and file away results. When confronted with this range of activities it is perhaps not surprising that it becomes difficult for graduate students and others to enter this area."

He goes on to propose research teams along the lines used in the natural sciences. This is indeed what has happened in many places. Programmers and mathematical economists now frequently team up with data experts and policy economists to produce timely, high quality analyses of contemporary issues. This specialization has been further strengthened by the availability of refined software for AGE modeling such as GAMS/MPS (Rutherford, 1999) and GEMPACK (Harrison and Pearson, 1996). The user no longer needs to be an expert in programming. Indeed, with the recently developed RunGTAP interface (Horridge, 1999), users willing to work within a standard model structure can conduct AGE analysis without any programming whatsoever. A similar pattern is now emerging on the data base side, where the availability of a standard data base for AGE modeling (McDougall, et al., 1999) has alleviated the need for a data expert on smaller-scale

research projects. Indeed, by plugging into the emerging global network of AGE modelers the need for large teams of researchers has been somewhat diminished – even as the scope of the modeling exercises has been increasing. However, it is still the case that collaborative projects remain the most effective means of conducting research in this field.

Explicit modeling of policies: A second challenge posed by John Whalley, which has also been met with some degree of success, involves the improved modeling of public policies. This is nowhere more important than in agriculture, where the value of policy transfers can sometimes exceed the gross domestic value of production (USDA, 1988). In addition to involving large outlays, many agricultural policies are not easily amenable to "ad valorem equivalent" modeling (Gohin et al., 1998, Frandsen et al., 1998 Kilkenny and Robinson, 1988; Veenendaal, 1998; Whalley and Wigle, 1990; Rutherford, Whalley and Wigle, 1991).

One of the more vexing problems in agricultural policy modeling has involved the search for an appropriate framework with which to model voluntary farm programs. For example, in an effort to stem surplus production in the United States, it has been common to require to idle a certain proportion of their base acreage in order to qualify for a variety of program benefits including payments on output. The most common approach to modeling these programs was to derive an average "incentive price" which, when combined with the supply shift due to idled acreage, would have induced the observed market supply of the crop in question (Gardner, 1989). However, such efforts ignored the impact that changing program parameters have on important components of the problem such as variable costs per acre, optimal yields, and the nature of the supply shift. In reality, this is a complex, highly nonlinear problem.

Whalley and Wigle (1990) proposed an alternate approach to modeling participation in the U.S. grains programs. They specify an explicit distribution of farms that reflects differences in their underlying cost structure such that the incentive to participate varies across five broad classes of farms. As program parameters or market conditions change, the participation rate varies endogenously. Hertel, et al. (1990) extended this framework to incorporate a continuous distribution of land capacities, while Shoemaker (1992) examines steady-state effects of voluntary farm programs in an aggregated AGE model. All of this work highlights the differential incidence of farm programs on participants, non-participants, and those who are roughly indifferent to participation.

Similar levels of creativity will be required to come to grips with some of the new agricultural policies frustrating the free flow of food around the world. The introduction of tariff rate quotas (TRQs) under the Uruguay Round Agreement on Agriculture has created enormous new opportunities for rent-seeking and redistribution of the benefits of protection. Boughner and DeGorter's recent analysis of TRQs in world agricultural trade illustrates the difficulties in modeling this new institution. Rather than one regime change, as with a quota, there are now two regime changes – the first as imports increase and one moves from the (low) in-quota tariff to the binding quota -- and the second after quota rents build to the level of the out-of-quota tariff so that imports once again increase. With the TRQ it is also necessary to track both the tariff revenues and the quota rents. The distribution of the latter is uncertain, since the quota allocation rules vary widely and are sometimes altogether unclear (Boughner and DeGorter).

Unmet Challenges

Parameter Specification: Two of Whalley's challenge areas that continue to loom large today are parameter specification and model preselection. In his paper he laments the predominance of hypothesis testing in econometrics – at the expense of parameter estimation. Indeed, he notes that the most recent survey of price elasticities, which he could find, was published in 1951! If one looks hard enough it is now possible to find exceptions to this generalization – for example, Peterson's 1988 survey of international agricultural supply elasticities, and Clements and Chen's 1996 paper on international demand elasticities. However, such papers are more nearly the exception that proves the rule. The fact is that we still have terribly little to go on when it comes to specifying the parameters for applied general equilibrium modeling.

There are some exceptional instances where authors have estimated parameters explicitly for their model. A recent example is offered by McKitrick (1998). Such estimates can be extremely important for the performance of AGE models. Coyle et al., draw on Cranfield et al.'s econometric estimates of the AIDADS non-homothetic demand system in their global AGE analysis of the changing structure of world food trade. They find that this demand system is the single most important determinant of the dramatic shift in the composition of world food trade over the past two decades – proving even more important than supply side factors, changes in transport costs, and border policies.

The relative paucity of such econometric work in support of AGE modeling is hardly surprising. The fact is that such research is very time-consuming, with uncertain payoffs. At the margin, researchers have found that development of new theoretical features, or the application of an existing model to a new problem, yields a higher payoff. However, the fact is, that without serious attention to the problem of parameter specification and – ultimately to model validation – applied general equilibrium models will never graduate to the next level of maturity.

There are several reasons for optimism that the next decade will bring more progress than the last. The first of these derives from new developments on the software, modeling and database fronts. Because it is now possible to pull a ready-made model and database off the shelf, more time is being made available for other activities. Furthermore, with many individuals using a common database and similar model structures, more attention will be paid to parameters as a means of differentiating any given piece of research. As we all know, many of the key findings in AGE studies are determined by a combination of the database and the parameters. While the database was being pinned down, there was perhaps some justification for neglecting the parameters. However, now their importance will loom larger in our analyses.

A second reason for my belief that the next decade will see more attention paid to parameter specification in AGE models is the fact that it is now becoming routine to conduct systematic sensitivity analysis (SSA) on these parameters. We have come a long way since the pioneering work of Pagan and Shannon (1987), Harrison and Vinod (1992), and, Harrison *et al.* (1993). Recent advances in the application of Gaussian Quadrature to SSA (DeVuyst and Preckel, 1997) permit users to generate reasonably accurate confidence intervals on their results with only a modest number of simulations. Furthermore, this technology has now been automated in a manner which leaves users no excuse leaving it out (Arndt and Pearson, 1996; Pearson, 1999). Once it is clear that the

expected impact of a key policy recommendation hinges critically on the value of a particular substitution elasticity, the willingness of government agencies to invest in econometric research will increase considerably.

The final cause for optimism about the potential for improvements in parameter specification stems from an emerging body of work under the broad heading of Maximum Entropy (ME) econometrics (Golan, Judge and Miller, 1996). This work offers an ideal tool for fitting AGE models to historical data. The first application of the ME approach to AGE analysis was presented at last year's conference by Arndt and Robinson (1998) for a model of the Mozambique economy. They combine the problems of parameter estimation and (in-sample) model validation by searching for a combination of parameters which enables the model to track recent economic history in Mozambique. Work is currently underway at Purdue to apply this technique to the GTAP model, in an effort to "estimate" (i.e., adjust) the trade elasticities so that they better fit historical experience. If successful, the approach can readily be extended to other parameters in the model as well. This is really just an extension of previous work aimed a model validation via historical simulation (Gehlhar, 1997; Fox, 1998; Kehoe, Polo and Sancho, 1991). This is the kind of research that is essential if our work is to establish credibility with decision-makers. It will also generate demand for more economy-wide time series data. While the GTAP effort has moved in that direction by providing time series bilateral trade data with version 4, much more information could potentially be marshaled.

Model Preselection: A second challenge from John Whalley that remains salient today is the problem of model preselection. By this he refers to the consequences of modeling decisions that are made -- even before data are collected and parameters are specified. Are markets imperfectly competitive or not? If so, what form of competition applies? Shall we fix the trade balance? What about international factor mobility? What are the consequences of employing alternative terminal conditions in a dynamic analysis? Does the use of a nested CES specification in production predetermine the incidence of a given policy? In some cases theorists could be very helpful in shedding light on the implications of alternative closure rules and functional forms. However, their tendency is to seek greater generality as opposed to examining the implications of specific restrictions on individual behavior or institutional relationships. Addressing the problem of model preselection will require more diverse efforts than that of parameter specification, but it is no less important.

Further Challenges and Future Directions

Rigorous Analysis: There is a natural progression to be observed with consumers of AGE results. Initially they are happy to simply "get the numbers": How much is the Uruguay Round worth to the global economy? How much will enlargement of the European Union cost developing countries? And so on. Armed with new databases and software, AGE modelers have been increasingly effective at delivering such numbers. However, after awhile, intelligent decision-makers begin to ask for some *analysis*. Here we have not been as universally capable – particularly with very large and complex global economic models.

A fundamental problem facing many AGE analysts is lack of time. In the past, when the model had to be built from scratch, data collected, and programming errors uncovered, there simply

wasn't much time left over for analysis. Now that some of these preparatory tasks have been lightened, our list of excuses for the frequent lack of solid analysis has become quite a bit shorter. Often it simply comes down to the fact that rigorous analysis of AGE results can be very difficult. The large number of simultaneous interactions often leaves the user wondering where to jump in and start the analysis! However, given the relatively standard structure of AGE models, it is possible to come up with general approaches and techniques for facilitating analysis of model outcomes. This is a direction that deserves more serious attention.

One such technique standard technique for analysis was introduced by Wouter Keller (1980) to shed light on the sources of efficiency changes from marginal perturbations in a one region, AGE model. This technique was extended to a global model and adapted to cover other sources of comparative static welfare changes (technology, endowments, terms of trade) by Huff and Hertel (1996). Their technique also incorporates numerical integration methods from GEMPACK, thereby coming to grips with non-local shocks to the model. This welfare decomposition tool has now become a standard tool of analysis for those using the GTAP model. However, there is nothing to stop this from being used with any well-specified applied GE model.

Being able to decompose the sources of welfare change in an AGE model into (e.g.) quantity changes interacting with price distortions is a very useful thing. However, it does not explain why the quantity changes themselves have come about. This is a far more difficult task. One approach that is helpful in understanding the consequences of individual perturbations of the model is to analyze the outcome in terms of the so-called "general equilibrium" elasticities of supply and demand (Hertel *et al.*, 1997). However, when there are many simultaneous shocks to the model, it is more difficult to understand what is going on. Until recently, the only sensible approach to this problem was to administer the shocks one-at-a-time, or in groups (e.g., Harrison, Rutherford and Tarr, 1996). Of course, this approach always leaves some "interaction" term, which cannot be explained. The more numerous and the larger the shocks, the larger this interaction term is likely to be and the more dissatisfying this approach to analysis. For this reason, I am particularly pleased to see on the program for this conference a paper by Harrison, Horridge and Pearson (1999), that offers an analytical approach to decomposing the effect of individual components of a composite set of shocks. This is a very important development, and just the kind of thing that will help us move further down the path of establishing a broad base of solid analysis in AGE modeling.

Distributional consequences of changes in the global economy: When we were designing the GTAP model, we were keenly aware of the difficulty of obtaining disaggregated data on individual household groups in each of the countries in the database. For this reason, we chose to focus instead on questions of *inter-regional incidence*. This brought the database burden down to a manageable level. However, it also makes it difficult to respond to the increasing interest in the *intra-regional incidence* of changes in the global economy. There are two approaches to tackling this problem. The first is to develop procedures for linking GTAP results to national models which themselves have more household detail. This has been successfully employed for the Monash model by Adams *et al.* (1997). The second approach is to add sufficient information about household expenditure and revenue patterns to permit a detailed incidence analysis using prices from a GTAP-based model directly. This avenue has not yet been vigorously pursued, but it offers considerable promise as well. Ultimately, most policy makers are interested in a greater level of resolution than is offered by

models built on the GTAP database. Standard procedures for eliciting the distributional consequences of changes in the global economy are very much needed.

Improving user interfaces: One fundamental premise of the GTAP effort has been that global, applied general equilibrium analysis is far too valuable a tool to be reserved for use by AGE modelers alone. Economists of all sorts can benefit from the insights and economy-wide perspective offered by this tool. However, until recently, the software interface to the databases and models has been a very big barrier to new entrants. Requiring users to have a working knowledge of GAMS or GEMPACK means that many potential beneficiaries simply will not try it out.

In response to this potential market, there have recently been some promising steps forward. Mark Horridge, at the Centre of Policy Studies, has now developed a suite of two software packages for use with the GTAP database which facilitate easy aggregation and viewing (GTAPagg), as well as straightforward analysis with the standard model (RunGTAP) – all via a convenient Windows interface Horridge (1999a, 1999b). No knowledge of GEMPACK is required. This has proven so popular, that Kenneth Pearson has released a more general version of the modeling software (RunGEM) for use with any GEMPACK model. Thomas Rutherford reports that similar developments are underway for use with GAMS-based models. In short, this is now a fertile area for software development work. It will do a great deal to broaden the pool of users of AGE analysis.

Exploiting teaching opportunities: As was briefly foreshadowed in the 2010 introduction to this paper, I believe that there are many unexploited teaching opportunities for those conducting AGE analysis of global economic issues. Most of these opportunities will be in the context of existing courses. For example, I have recently begun offering a module on applied GE analysis in a colleague's course on International Trade Theory. Similar opportunities exist in courses on general equilibrium theory and welfare economics. In addition, the database itself – perhaps coupled with some illustrative simulation assignments -- is potentially a tremendous resource for undergraduate educators seeking to convey to students the importance of global economic linkages.

The continuing demand for the GTAP short course (now in its seventh year) also provides evidence of the breadth of demand for stand-alone courses in global, applied GE analysis. This demand is especially strong with professional economists who are already working in government, academia or the private sector. The strength of this continuing demand is perhaps surprising given the high costs of the course. While the $2500 tuition for this course is a high barrier for many, this is often exceeded by the cost of participants' travel and time away from the office. In the long run we need to find ways to offer this kind of training in a fashion which better meets the needs of a busy, geographically dispersed audience. Towards this end, we have been developing a set of "distance-learning" modules for GTAP.

We are currently offering a "preparatory short course" which is designed to permit participants to begin the process of learning about applied general equilibrium analysis over the Worldwide Web – before they arrive at the short course. In the future, we hope to extend this to a set of post-course modules. Eventually, it may be possible to offer the entire body of material over the web. (However, we have found that face-to-face interaction is essential for network-building.) In addition to saving travel time and costs, this distributed approach to learning permits us to draw

more readily on the global instructor base. I believe is not unrealistic to envision an advanced course in which each module is offered by an expert on a different continent.

Playing a role in the debate over the environment: There is no doubt that public interest in the environment and associated policy issues will continue to increase over time, as incomes and population pressures increase. Environmental interests tend to divide naturally between local issues and global issues. In the latter case, they generally cut across many sectors. Therefore, the economic implications of environmental policy are logically addressed in a global AGE framework. This is why much of the quantitative research into the economic consequences of the Kyoto Protocol to reduce atmospheric CO2, for example, has been conducted using the GTAP database. This research has, in turn, stimulated the demand for improved representation of the energy sectors in GTAP – as well as the provision of a separate energy volumes data base from which to compute CO2 emissions.

Our experience with the climate change work is likely representative of what will be required for other environment-related applications of global AGE analysis. In each case, some kind of satellite data base will be needed to capture the physical relationships involved in the degradation of the environment – and attempts to mitigate such damage. Such special projects offer great potential for enriching the GTAP database. However, if they are to be more than "one-off" efforts, we will need to find ways of institutionalizing regular updates.

Getting developing countries off the sidelines: A final challenge which I would like to pose for the next decade involves getting developing countries off the sidelines of the international trade negotiations and onto center stage. The Uruguay Round Agreement (URA) offers an excellent case study of this problem. It is striking that quantitative analyses of the likely impact of this agreement on the developing countries were dominated by individuals from OECD countries (see the volume edited by Martin and Winters, 1996). Perhaps it is not surprising then that, outside of East Asia, developing country commitments under the UR were very timid (Hertel, *et al.,* Table 1, (1996). If developing countries aren't in a position to independently evaluate the impact of the negotiations on their own economy, how can we expect them to be bold in their commitments?

This absence of analytical capacity is again looming large in the upcoming WTO negotiations – dubbed the "Millennium Round". There for the first time manufactures have been left off the built-in agenda, with agriculture and services taking center stage. Perhaps this makes sense from the point of view of the OECD nations, where manufacturing tariffs are already very low and services trade is increasingly important. Also, if one thinks of developing countries' exports as being dominated by primary products, it makes sense to see agriculture on the agenda. However, when one takes a closer look at the facts, the omission of manufactures turns out to be much more serious for developing countries. Examination of the version 4 GTAP database shows that the share of manufactures in developing countries' total merchandise exports has tripled since the early 1960's when they accounted for less than one-fourth of developing country exports. Most of this growth has occurred recently – in the last 15 years. Hertel and Martin (1999) note that nearly three-quarters of developing country merchandise exports are now made up of manufactures. Those authors go on to evaluate the distribution of gains from further reductions in manufactures tariffs, and they find that 95% of these gains accrue to developing countries! Thus the omission of manufactures from the Millennium Round's built-in agenda is serious -- and one more indication that developing countries need to get more involved in shaping the international trade policy agenda.

It strikes me that the network of researchers and policy analysts represented at this conference offers an excellent vehicle for getting the developing countries off the sidelines and into the fray of international trade policy analysis. The combination of conferences, short courses, database and model development which we are nurturing can offer the necessary support for economists from developing countries seeking to increase their capacity for trade policy analysis. All that is lacking is a bit of funding at the margin to cover scholarships, travel, and database development so that these researchers can realize their potential. I hope that we can all commit to furthering this goal, so that developing country participants are in the majority at the 13th Annual Conference in Global Economic Analysis – in the year 2010.

References

Adams, P., K. M. Huff, R. McDougall, K. R. Pearson, and A. A. Powell (1997). "Medium- and Long-Run Consequences for Australia of an APEC Free-Trade Area: CGE Analysis Using the GTAP and Monash Models," *Asia-Pacific Economic Review* 3, (1):19-42.

Arndt, C., and K.R. Pearson (1996) "How to Carry Out Systematic Sensitivity Analysis via Gaussian Quadrature and GEMPACK," GTAP Technical Paper No. 3, Center for Global Trade Analysis, Purdue University, West Lafayette, IN. *http://www.agecon.purdue.edu/gtap/techpapr*.

Arndt, C., and S. Robinson (1998) "Estimating Computable General Equilibrium Model Parameters: A Maximum Entropy Approach," paper presented at the First Annual Conference on Global Economic Analysis, June 8 - 10, Purdue University, West Lafayette, IN.

Boughner, Devry and H. DeGorter (1999) "The Economics of 2-tier Tariff-Rate Import Quotas and the Agreement on Agriculture in the WTO," revised version of that presented at the International Trade Research Consortium Annual Meetings in St. Petersburg, Florida in December 1998.

Clements, K.W., and D. Chen (1996) "Fundamental Similarities in Consumer Behaviour," *Applied Economic*s 28: 747-757.

Coyle, W., M. Gehlhar, T.W. Hertel, Z. Wang and W. Yu (1998) "Understanding the Determinants of Structural Change in World Food Markets," *American Journal of Agricultural Economics* 80(5): 1051-1061.

Cranfield, J.A.L., T.W. Hertel, J.S. Eales and P.V. Preckel (1998) "Changes in the Structure of Global Food Demand," *American Journal of Agricultural Economics* 80(5): 1042-1050.

DeVuyst, E.A. and P.V. Preckel (1997) "Sensitivity Analysis Revisited: A Quadrature-Based Approach," *Journal of Policy Modeling* 19(2):175-85.

Dixon, P.B., B.R. Parmenter, J. Sutton and D.P. Vincent (1982) *Orani: A Multisectoral Model of the Australian Economy*. Amsterdam: North-Holland.

Fox, A.K. (1998) "Evaluating the Success of a CGE Model of the US-Canada Free Trade Agreement," paper presented at the First Annual Conference on Global Economic Analysis, June 8 - 10, Purdue University, West Lafayette, IN.

Francois, J.F. (1998) "Scale Economies and Imperfect Competition in the GTAP Model," GTAP Technical Paper no. 14, Center for Global Trade Analysis, Purdue University, West Lafayette, IN, *http://www.agecon.purdue.edu/gtap/techpapr*.

Frandsen, E.F., C.F. Bach and P. Stephensen (1998) "European Integration and the Common Agricultural Policy: A CGE Multiregional Analysis," In: M. Brockmeier, J.F. Francois, T.W. Hertel and P.M. Schmitz, (eds.), *Economic Transition and the Greening of Policies: Modeling New Challenges for Agriculture and Agribusiness in Europe*. Kiel: Vauk.

Gardner, B.L. (1989) "Gains and Losses from the U.S. Wheat Program," unpublished paper, *Department of Agricultural Economics and Resource*, University of Maryland.

Gehlhar, M. (1997) "Historical Analysis of Growth and Trade Patterns in the Pacific Rim: An Evaluation of the GTAP Framework," chapter 14 In T.W. Hertel, (ed.), *Global Trade Analysis: Modeling and Applications*. New York: Cambridge Univ. Press.

Gohin, A. H. Guyomard, N. Herrard, Y. Le Roux, and T. Trochet (1998) "Modelling Agricultural Policy Instruments in a Single Country, Multi-Sector General Equilibrium Framework: Application to France," In: M. Brockmeier, J.F. Francois, T.W. Hertel and P.M. Schmitz (eds.), *Economic Transition and the Greening of Policies: Modeling New Challenges for Agriculture and Agribusiness in Europe*. Kiel: Vauk.

Golan, A., G. Judge and D. Miller (1996) "Maximum Entropy Econometrics: Robust Estimation with Limited Data," Chichester, Wiley.

Harrison, G.W. and H.D. Vinod (1992) "The Sensitivity Analysis of General Equilibrium Models: Completely Randomized Factorial Sampling Designs," *Review of Economics and Statistics* 74:357-362.

Harrison, W.J., J.M. Horridge and K.R. Pearson (1999) "Decomposing Simulation Results with Respect to Exogenous Shocks," paper presented at the Second Annual Conference in Global Economic Analysis, Denmark, June 20-22

Harrison, W.J. and K.R. Pearson (1996) "Computing Solutions for Large General Equilibrium Models Using GEMPACK," *Computational Economics* 9:82-127.

Harrison, G.W., R. Jones, L.J. Kimbell, and R. Wigle (1993) "How Robust Is Applied General Equilibrium Analysis?", *Journal of Policy Modeling* 15(1): 99-115.

Harrison, G.W., T.F. Rutherford, and D. Tarr (1996) "Quantifying the Uruguay Round." In Will Martin and L. Alan Winters, (eds.), *The Uruguay Round and the Developing Countries*, pages 216-252. Cambridge University Press.

Hertel, T.W., (1997) *Global Trade Analysis: Modeling and Applications*. New York: Cambridge University Press.

Hertel, T. W., B. Dimaranan, W. Martin, and K. Yanagishima (1996) "Liberalizing Manufactures Trade in a Changing World Economy", chapter 4 In Will Martin and Alan Winters (eds.), *The Uruguay Round and the Developing Economies*, Cambridge University Press.

Hertel, T.W., D.K. Lanclos, K.R. Pearson and P.V. Swaminathan (1997) "Aggregation and Computation of Equilibrium Elasticities," chapter 5 In: T.W. Hertel, (ed.), *Global Trade Analysis: Modeling and Applications*, New York: Cambridge Univ. Press.

Hertel, T.W., M.E. Tsigas, and P.V. Preckel (1990) "An Economic Analysis of the Freeze on Program Payment Yields," ERS/USDA Staff Report No. 9066.

Hertel T.W. and W. Martin (1999) "Developing Country Interests in Liberalizing Manufactures Trade," paper presented at the CEPR workshop on "New Issues in the World Trading System", London, United Kingdom, Feb. 19-20.

Horridge, J.M. (1999a) RunGTAP Software Suite, published by the Center for Global Trade Analysis, Purdue University, West Lafayette, IN.

Horridge, J.M. (1999b) RunGTAP Software Suite, published by the Center for Global Trade Analysis, Purdue University, West Lafayette, IN.

Huff, K.M. and T.W. Hertel (1996) "Decomposition of Welfare Effects in the GTAP Model," GTAP technical paper no. 5, Center for Global Trade Analysis, Purdue University, West Lafayette, IN. *http://www.agecon.purdue.edu/gtap/techpapr*.

Kawasaki, Ken (1997) "Economic Effects of the Manila Action Plan - Preliminary CGE Model Simulation", paper submitted to the Expert Seminar on "Impact of Trade Liberalization", conducted by the APEC Economic Committee, Trade Liberalization Task Force members, Tokyo, Japan.

Kehoe, T.J., C. Polo and F. Sancho (1991) "An Evaluation of the performance of an Applied General Equilibrium Model of the Spanish Economy," Working Paper No. 480, Federal Reserve Bank of Minneapolis, Minneapolis, MN.

Keller, W.J. (1980) *Tax Incidence: A General Equilibrium Approach* Amsterdam: North Holland.

Kilkenny, M. and S. Robinson (1988) "Modeling the Removal of Production Incentive Distortions in the U.S. Agricultural Sector," invited paper, XX International Conference of Agricultural Economists, Buenos Aires, Argentina, August 24-31.

Martin, W. and L.A. Winters (1996) *The Uruguay Round and the Developing Countries*. Cambridge University Press.

McDougall, R.A., A. Elbehri and Truong P. Truong (1999) "Global Trade Assistance and Protection: The GTAP4 Database," Center for Global Trade Analysis, Purdue University, West Lafayette, IN.

McKitrick, R.R. (1998) "The Econometric Critique of Computable General Equilibrium Modelling," *The Role of Functional Forms, Economic Modelling*, vol. 15: pp. 543-573.

Pagan, A.R. and J. Shannon (1987) "How Reliable are ORANI Conclusions?" *Economic Record* 1:33-45.

Pearson, K.R. (1999) "Help file on Systematic Sensitivity Analysis", RunGTAP software suite, published by the Center for Global Trade Analysis, Purdue University, West Lafayette, IN.

Peterson, W. (1988) "International Supply Response", *Agricultural Economics*, vol 2, pp. 365-374.

Powell, A.A., and R.H. Snape (1993) "The Contribution of Applied General Equilibrium Analysis to Policy Reform in Australia," *Journal of Policy Modeling* 15(4):393-414.

Rutherford, T.F. (1998) The GTAPinGAMS software package, published at the University of Colorado, Boulder, CO. *http://robles.colorado.edu/~tomruth/gtapingams*

Rutherford, T.F. (1999) "Applied General Equilibrium Modeling with MPSGE as a GAMS Subsystem: An Overview of the Modeling Framework and Syntax," *Computational Economics* (forthcoming).

Rutherford, T. F., J. Whalley, and R. Wigle. (1991) "Capitalization, conditionality and dilution: Land prices and the U.S. wheat program." *Journal of Policy Modelling*.

Shapiro, C. and H.R. Varian (1998) *Information Rules.* Cambridge, Mass.: Harvard Business School Press.

Shoemaker, R.A. (1992) "The Incentive Effects of Agricultural Support Programs: A Dynamic Analysis of U.S. Agricultural Policy," *Unpublished Ph.D. dissertation*, George Washington University.

U.S. Department of Agriculture, Economic Research Service. (1988) "Estimates of Producer and Consumer Subsidy Equivalents: Government Intervention in Agriculture, 1982-86," Staff Report No. AGES880127, Washington, D.C.

Van Meijl, H. and F. van Tongeren. (1999) "Endogenous International Technology Spillovers and Biased Technical Change In The GTAP Model," GTAP Technical Paper no. 15, Center for Global Trade Analysis, Purdue University, West Lafayette, IN. *http://www.agecon.purdue.edu/gtap/techpapr*.

Veenendaal, P.J.J. (1998) "EU Agricultural Policy Implementation Using Complementarity Conditions," paper presented at the First Annual Conference on Global Economic Analysis, June 8 - 10, Purdue University, West Lafayette, IN.

Whalley, J. (1986) "Hidden Challenges in Recent Applied General Equilibrium Exercises," In: Piggott and Whalley, (eds.), *New Developments in Applied General Equilibrium Analysis*. New York: Cambridge University Press.

Whalley, J. and R. Wigle (1990) *Terms of Trade Effects, Agricultural Liberalization, and Developing Countries*, In: O. Knudsen and I. Golden, (eds.), *Agricultural Trade Liberalization: Implications for Developing Countries*, Washington, D.C.: The World Bank.