CeGE-Discussion Paper

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Assessing General and Partial Equilibrium Simulations of Doha Round Outcomes using Meta-Analysis

Center for Globalization and Europeanization of the Economy

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

August 2007

ISSN 1439-2305

Assessing General and Partial Equilibrium Simulations of Doha Round Outcomes using Meta-Analysis

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Abstract:

Applied general and partial equilibrium models are widely used tools for ex ante analysis of trade policy changes. However, simulation results seem to exhibit significant variation across publications, and the often criticised 'black box' character of applied trade models makes meaningful comparisons of simulation results very difficult. As a potential remedy, this paper presents a meta-analysis of simulation-based Doha round publications. The meta-regression explains simulated welfare changes as a function of model characteristics, base-data and policy experiments. Regression results show that a major share of the variation within the dependent variable is explained by the covariates, and estimated coefficients show plausible signs and magnitudes. However, results also reveal that many model-based studies lack systematic documentation of their experimental settings.

JEL classification: C00; C23; C68; F10

Keywords: Meta-analysis, Partial equilibrium, General equilibrium, Trade liberalisation, WTO, Doha

This Paper has been presented at the CeGE Research Workshop on July 5th, 2007 in Göttingen.

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The authors are grateful to Yves Surry, Bernhard Brümmer, Martin Banse, and Frank van Tongeren for many useful suggestions, and to Tinoush Jamali and Inken K¨ohler for valuable research assistance. This project has been supported by the German Research Council (DFG). Sebastian Hess has partly been supported by the Friedrich-Naumann-Foundation, and Stephan von Cramon gratefully acknowledges support from the Fulbright Commission.

Introduction

Empirical estimates of the gains and losses that would accrue to specific interest groups, countries and regions are perhaps the most important contribution made by economists to debates about trade liberalisation. Economists employ applied trade models to provide such estimates, which have become an important part of the political decision making process (Devarajan and Robinson, 2002). Over the last decade, quantitative model-based predictions of significant gains from trade liberalisation, not only for developed but also for developing and least developed countries, are often cited to highlight the benefits of a successful conclusion to the Doha Development Round (DDR) of WTO negotiations (e.g. Anderson et al., 2000; World Bank 2000; Anderson et al., 2005)

However, applied trade models are frequently criticised as having weak empirical foundations (Alston et al., 1990; Alston et al., 1995; McKitrick, 1998; Anderson and Wincoop, 2001) and as being insufficiently transparent (Ackerman, 2005; Piermartini and Teh, 2005). Furthermore, different models often produce trade simulation results that "… differ quite widely even across similar experiments" (Charlton and Stiglitz, 2005), and convincing explanations for these differences are, due to the complexity of most models, difficult to provide.

For example, Figure 1 presents a set of simulated welfare gains from agricultural liberalisation under the DDR. Simulated global gains range from under 50 to over 350 billion US$, and do not appear to be systematically related to the magnitude of the assumed liberalisation step. Experienced modellers who are acquainted with the literature can propose many explanations for the variation displayed in Figure 1. These explanations are largely partial and often quite technical, however, and only a select group of specialists will have anything approaching a comprehensive overview of the factors that drive different simulation results. For many members of the large and heterogeneous group of users of trade model simulations, variation such as that displayed in Figure 1 is bewildering, and most proposed explanations are inaccessible.

Figure 1: Simulated welfare gains from agricultural liberalisation, selected studies

Source: UNCTAD (2003).

These problems complicate an already controversial debate on trade liberalisation, and they are water on the mills of critics who question the benefits of liberalisation and the ability of economists to measure them objectively. They are especially difficult for policy makers and other stakeholders in least developed countries, which often cannot afford to maintain sophisticated own modelling capacities and dedicate highly trained personnel to interpreting and assessing the many different modelling results that are in circulation. Although the current stalemate in the DDR is certainly not primarily due to difficulties with applied trade models, it does provide an opportunity to pause and assess the input that economists have provided, and to consider whether and how this input and its communication might be made more effective.

In this paper we present a meta-analysis of partial and general equilibrium simulations of possible outcomes of the DDR of WTO negotiations. The aim of this analysis is to identify model characteristics (e.g. partial vs. general equilibrium specification, level of product or regional disaggregation) and other factors (e.g. the database employed, the size of the simulated liberalisation step) that influence simulation results in a systematic manner, and to derive quantitative estimates of these influences. Our aim is not to assess the validity or appropriateness of specific modelling frameworks or model features, but rather to increase transparency about their impacts on simulation results.

The results of our analysis demonstrate that it is possible to explain a sizeable proportion of the variation in simulated liberalisation outcomes using information on key model characteristics and other factors. These results can contribute to reducing the impression of arbitrariness that comparisons of model-based simulations such as Figure 1 above engender. They can also inform the users of simulations such as policy makers and trade negotiators. Finally, these results can add to modellers' understanding of the key factors that drive their simulation results. As an important by-product, our analysis shows that many simulation studies do not provide sufficient documentation on these key, driving factors, thus making it impossible for users to assess or reproduce their results.

The paper is structured as follows: Section 2 discusses different methods of comparing and assessing the results of trade model simulations and introduces the meta-analytical approach employed here. Section 3 outlines the data and econometric specification used in our meta-analysis of simulated DDR outcomes. Results are presented in Section 4, and Section 5 concludes.

2. Comparison and assessment of trade model simulations – past approaches and meta-analysis

What factors underlie the variation in the results of trade model simulations depicted in comparisons such as Figure 1 above? Based on previous assessments of trade models (e.g. Shoven and Whalley, 1984; Francois and Reinert, 1997; Ginzburg and Keyzer, 1997; Hertel, 1999; van Tongeren et al., 2001; Harrison et al., 2003; Bouët, 2006) we propose the following classification of possible factors into five categories.[2] First, different studies measure different outcomes (e.g. changes in welfare, output, trade flows, etc.). Second, different studies simulate the impact of different liberalisation steps (i.e. different percentage reductions in tariffs). Third, different studies are based on different model specifications (e.g. partial vs. general equilibrium, constant vs. increasing returns to scale,

[2] We discuss these categories in a general manner here; details of specification and measurement are discussed below in Section 3 when we turn to the empirical application.

level of product or regional disaggregation, etc.). Fourth, otherwise identical studies might be based on different datasets (e.g. GTAP 4 vs. GTAP 6)[3]. Finally, what might be termed a study's 'research context' can also play a role. By this we mean factors such as the affiliation of the authors (university, NGO, international institution, etc.) whether a study has been published and, if so, whether it was subject to peer review, the year of publication, etc.

The results of any trade model simulation will be a multivariate function of the many factors in these five categories, and of interactions between them. This complexity will bedevil attempts to compare and assess the quality of different simulation results. Two main approaches to carrying out such comparisons and assessments can be identified in the literature so far.

The first of these is sensitivity analysis, which traces the changes in simulation results that are caused by chosen variations in selected parameters and model specifications (Hertel et al., 2003). Sensitivity analysis can provide important insights into the robustness of specific simulation results with respect to parameters and specifications. However, a potential shortcoming is that modellers may be disinclined to report findings that indicate that their simulation results are highly sensitive to certain model characteristics, as recent literature on publication bias in economics suggests (Stanley 2005). Instead, there will be a natural inclination to demonstrate that simulation results are robust. Moreover, sensitivity analysis cannot be readily applied to compare results from models and experiments which differ from one another in many respects simultaneously. Hence, sensitivity analysis is usually confined to a specific modelling framework. An example of sensitivity analysis and its strengths and limitations as a tool for comparing and validating model results is provided by Gohin and Moschini (2005), who use the GTAP model to compare general equilibrium with partial equilibrium closures.[4]

The second approach used to compare and assess the results of trade model simulations is the qualitative review (Robinson, 1989; Scollay and Gilbert, 2000; Laird et al., 2003; Charlton and Stiglitz, 2005; Piermartini and Teh, 2005). In such reviews, tables and graphs are typically used to compare results from different models grouped according to selected model characteristics ('dynamic vs. static', 'increasing vs. constant returns to scale', etc.). The major shortcoming of this approach is that such bivariate comparisons are potentially misleading as they cannot control for simultaneous multivariate variation in the many factors outlined above (Harrison et al., 1997).

Meta-analysis is a comparatively recent inductive empirical approach that seeks to identify similarities and explain differences between scientific findings on similar research questions across studies (Stanley 2001). Meta-analysis has three objectives:

Combining evidence: This was the primary goal when meta-analysis was established in the fields of medicine and psychology. Since experiments with human beings are often of necessity based on

[3] GTAP is the Global Trade Analysis Project (see www.gtap.org).

[4] The development of model response surfaces, which is common for agent-based models (Kleijnen et al., 2006), can be seen as an extension of sensitivity analysis. However, this has not yet been widely applied to trade models.

small samples, combining different experiments to create a larger meta-sample can lead to more precise estimation of the relationship between a treatment and its effect.

'Separating wheat from chaff': In some applications, experts devise weighting schemes for the scientific quality of publications within the meta-sample. If the studies in such a sample report widely differing results, it is important to identify those that deserve a higher weighting because they are deemed to be more reliable.

Evaluating methods (Stanley, 2001; Florax et al., 2002): This approach has evolved especially in economics and related disciplines in which reproducible measurements are often hard to obtain and quantitative results are known to depend heavily on the methods that have been applied. Meta-analysis can quantify the share of variance within a given set of estimates that is due to different methodologies, assumptions and other factors.

Each meta-analysis also faces at least three major methodological threats that can lead to meaningless or biased results:

'Comparing apples and oranges' (Eysenck, 1995): This occurs when the studies being analysed utilize approaches that are so fundamentally different that no common evidence can be identified.

Publication bias (Stanley, 2005): Meta-analysis hinges on the selection of a representative literature sample, and its results will be biased if some strands of the literature are under- or overrepresented in the sample. This can result from an inadequate literature search strategy. It can also result from any bias that might exist in the publication process (e.g. against publishing results that point to insignificant impacts), from the fact that an important sub-set of the available evidence might be published in obscure, non-English journals, or the fact that some relevant studies might be confidential and thus unavailable.

'Junk in junk out' (Wachter, 1988): If standards in a field of research are, for whatever reason, poor in the first place, a meta-analysis cannot be expected to yield evidence that is of any greater value.

If these pitfalls can be avoided, meta-analysis has the potential to add to the insights provided by sensitivity analysis and qualitative reviews by permitting quantitative comparison of trade model simulations that controls for simultaneous variations in measured effects, model characteristics, liberalisation steps, databases and research context across a large and heterogeneous set of studies.

The meta-analysis in this paper is therefore based on the following general model:

$$I = f(MC, LE, DB, RC, u), \qquad (1)$$

where I is the (suitably standardised) simulated impact of a trade liberalisation experiment, MC is a vector of model characteristics (e.g. partial or general equilibrium, depiction of returns to scale), LE describes the liberalisation experiment (e.g. the magnitude of the simulated tariff reduction), DB is the database underlying the simulation (e.g. GTAP 5 or 6), RC is a vector of research context variables (e.g. affiliation of the authors, whether the study has been published) and u is an error term. In the following section we explain the empirical application of this model to the literature on simulated DDR liberalisation outcomes.

3. An empirical application to simulated Doha Development Round liberalisation outcomes

3.1 Sample collection

Collecting an encompassing and representative sample of DDR liberalisation simulations is a complex task that involves delineating the intersection of two vast literatures, one dealing with the DDR and the other dealing with quantitative trade modelling. To generate the sample employed here, the following strategy was pursued. From a recent review of quantitative trade models (van Tongeren et al., 2001) a vector of keywords that describe the type of applied models in question was derived. This was combined with a second vector of keywords taken from §13 of the Doha Ministerial Declaration, which addresses important trade-related DDR issues. The combination of these vectors yields a matrix of search words that was applied to the most important literature databases in economics (e.g. Econlit, Repec, etc.)[5] using an automated procedure programmed in VisualBasic®. In addition, the internet was searched using the same search word matrix to sample 'grey' literature that might not be listed in scientific databases. While it is conceivable that some relevant studies will not include any of our search words in their titles, abstracts or keyword lists (and will thus have been overlooked), we are confident that this search strategy is reasonably comprehensive and exhaustive.

The result is a raw dataset comprising over 1200 studies.[6] Many of these studies do not present original simulations but rather draw on the results of earlier simulation studies to analyse specific DDR impacts (e.g. on poverty). We set aside such studies, and eliminate redundancies (sometimes the same simulation results appear in a working paper, a conference paper and, later, a journal publication). Furthermore, we omit studies that provide no information on the model used to produce a simulation (for example, some studies only make reference to 'World Bank estimates' or 'GTAP'), and those that do not report results in numerical form (some studies only present graphs). This leaves roughly 400 studies that i) present original, own simulation results; ii) report results in numerical form; and iii) provide at least some information on the underlying model. Retaining only those studies that report welfare changes (and not, for example, changes in trade flows or production volumes) results in a further reduction to 230 studies from the years 1994 to 2006. At this point we note that the 'apples and oranges' critique of some meta-analyses can safely be disregarded here. All

[5] The keyword matrix and the literature databases employed are listed in Appendix 1.
[6] We refer to 'studies' rather than 'publications' to highlight that not all of the DDR simulations in our literature sample have been published in the conventional sense of the word.

of the 230 studies in the literature sample purport to provide quantitative estimates of the impacts of trade liberalisation on some measure of welfare, and there is no reason why they should not be amenable to comparison.

Of these 230 studies, 110 are included in the final sample that provides observations for the econometric meta-analysis.[7] Roughly 60 studies are omitted because, on closer examination, they are found to focus not on DDR trade liberalisation but rather on related but distinct topics such as regional free trade agreements, global technology adoption, country-specific aspects of WTO accession, and the poverty-alleviating effects of trade liberalization at the individual household level. A further 60 studies are not included in the final sample due to incomplete documentation. While studies that have been subject to a scientific review process tend to be more transparent and thoroughly documented than others, in many instances documentation of even very fundamental characteristics of a liberalisation experiment and/or the model characteristics used to produce simulation results is missing.[8] Admittedly, it can be difficult for modellers to provide detailed documentation even if they wish to; limits on the length of journal articles, book chapters and conference papers sometimes preclude full documentation of the data, parameters and assumptions behind a simulation exercise.[9] Nevertheless, considering both those studies that are dropped from the original 1200 because they provide essentially no information about the underlying model, and those that are omitted later on because the information that they do provide is found to be lacking in some key respect, the inescapable conclusion is that incomplete documentation is very common in the trade modelling literature. This is grounds for concern because without sufficient documentation users cannot interpret and replicate simulation results.

For our meta-analysis, heterogeneous documentation creates a trade-off between i) the number of studies included in the final sample, and ii) the number of independent variables that can be quantified and included in estimation of equation (1). As the number of variables to be included in the estimation increases, the set of studies that include sufficient information on all variables shrinks. For example, Harrison et al. (1997) suggest that the effects of increasing returns to scale in the model used in studies by Francois (e.g. Francois et al., 2003) are largely attributable to increased elasticities of substitution between primary and intermediate inputs in this model. However, while both authors provide information on these substitution elasticities in their own models, most other

[7] A complete list of the 230 (110) studies in the initial (final) literature sample is provided in Appendix 2.

[8] An internet questionnaire is being used to collect missing information from the authors of studies in our sample, but the response rate has been low. A common problem is that not all authors were directly involved in the hands-on modelling underlying their studies. If the actual 'modellers' (e.g. research assistants and graduate students) have moved on and are no longer available in such a case, there may be no way of reconstructing how a simulation was carried out.

[9] With the advent of the internet, however, these limits are not longer binding.

authors do not. Therefore, it would not be possible to test the influence of these elasticities without drastically reducing the size of the final sample.[10]

Since the aim of this meta-analysis is to identify model characteristics and other factors that influence simulation results in a systematic manner, and to derive quantitative estimates of these influences, our first priority is to identify a sample of studies that document as many of these model characteristics and other factors as thoroughly as possible. As is explained in the following section, the average study contributes 50 observations to the dataset used to estimate equation (1). Hence, degrees of freedom are not a limiting factor. We are thus at some liberty to emphasise coverage of key explanatory variables, and to sacrifice studies that do not provide clear information on these variables, while maintaining a large final sample.

This final sample will not be representative (the 'publication bias' threat to meta-analysis) if there is any correlation between the variables in equation (1) and the thoroughness with which authors document their simulation models (for example, if partial equilibrium modellers tend to document more thoroughly than general equilibrium modellers, or if modellers who document poorly tend to produce larger simulated welfare gains from trade liberalisation). While such correlations cannot be ruled out, we see no compelling reason for their existence and are confident that the final sample of 110 studies is representative of the literature on simulated DDR outcomes.

Figure 2 presents information on the number of studies per year in the initial sample of 230 studies as well as in the final sample of 110 studies that is used in the econometric meta-analysis. It also shows the average welfare gain per liberalisation experiment over all 110 studies in the final sample for each year from 1994 to 2006.

Figure 2: Number of studies/year in the initial and final literature samples, and average reported welfare gains in the final sample (1994 – November 2006)

Source: Own calculations based on literature search.

In both the initial (n = 230) and final (n = 110) samples, the number of studies peaks three times, in conjunction with the Doha, Cancun and Hong Kong ministerial meetings. Some authors refer to the "shrinking gains from Doha" (Achterbosch et al., 2004, p. 53; Ackermann, 2005), pointing out that the simulated benefits of trade liberalisation appear to have declined over time. Our literature sample seems to support this view, at least up to the Cancun ministerial meetings (Figure 2). However, this trend must be interpreted with caution. It reflects changes in the magnitude of the liberalisation steps that were being considered in different phases of the DDR negotiations, and changes in the other

[10] In some cases one might assume that if a study makes no mention of a specific characteristic (i.e. a closure rule), then this characteristic is not present in that study. Responses to the internet survey mentioned above indicate that this is not always a safe assumption, however, and this can lead to attenuation bias in the estimation of equation (1).

factors discussed above (e.g. changes in the databases employed over time), and not the evolution of an expert consensus on the benefits of liberalisation *per se*.

3.2 Defining what constitutes an individual observation

We begin by defining what constitutes an individual observation in the meta-analysis. Each study in the literature sample presents the results of one or more liberalisation experiments (often labelled ‘scenarios’). Each liberalisation experiment simulates welfare changes in one or more countries or aggregated geographical regions. In the meta-analysis here, each individual country or region for which the impact of a liberalisation experiment is reported is considered a single observation. Hence, a study that reports the results of two simulations (e.g. a 25% and a 50% reduction in tariffs) from a model that depicts 20 different countries/regions produces 40 observations. A more disaggregated view might consider each individual sector within a country or region for which the impact of a liberalisation experiment is reported as an observation. Since only few studies report sectoral results, however, (most report only aggregated results at the country/region level) this approach would lead to a greatly reduced sample.

Our definition of an observation has two important implications. First, since the average study simulates more than one liberalisation experiment, and since the average model depicts more than one country/region (and some PE models consider more than 100 countries), a literature sample that includes 110 studies will generate far more than 110 observations for the meta-dataset used to estimate equation (1). Table 1 classifies the studies in the final literature sample according to the modelling framework[11] that they are based on, the number of observations that each contributes to the meta-dataset, and other descriptive characteristics. Table 1 reveals that on average, each of the 110 studies in the final literature sample produces just over 53 observations, for a total of 5835 observations in the meta-analysis.

Table 1: Description of modelling frameworks and studies in the final literature sample, and their contributions to the meta-dataset

Source: Own calculations based on literature sample.

[11] The assignment of studies to modelling frameworks in Table 1 is based on information in the individual studies. It provides some orientation to those who are familiar with the applied trade modelling literature, but no definitive classification into distinct categories. It is not always clear where one modelling framework begins and another ends; frameworks often evolve from common antecedents and share elements such as databases or elasticities. Furthermore, frameworks are generally quite flexible, leaving modellers considerable discretion to ‘customise’ by choosing specifications, parameter values etc. (see Hertel’s (1999) discussion of ‘model pre-selection’). Hence, a simulation produced in framework *A* might more closely resemble one produced in framework *B* than another from framework *A*.

Second, Table 1 reveals that while some studies produce many observations, others produce as few as one (if they report on only one liberalisation experiment for one country/region). As a result, studies will have different weights in the meta-dataset, and hence different influences on the econometric estimation of equation (1). This poses the danger that studies that might be particularly informative for the meta-analysis because they embody unique characteristics, but that generate few observations, might get 'swamped' by others that generate many more observations.

For this reason, both an unweighted and a weighted version of equation (1) are estimated. In the weighted version, each observation is divided by the number of observations produced by the underlying study. This weighting scheme gives each of the 110 studies in the final literature sample an equal weight. Weighting schemes of this nature are commonly employed in meta-analysis (e.g. Weichselbaumer and Winter-Ebmer, 2005; Knell and Stix, 2005; Stanley, 1998).

3.3 Variable definitions: The dependent variable

To estimate equation (1), the dependent variable *I* (impact) and independent variables that span key dimensions of *MC* (model characteristics), *LE* (liberalisation experiment), *DB* (database) and *RC* (research context) must be defined, and then measured for each observation. The dependent and independent variables employed in the estimation are described in this and the next section, respectively. Table 2 presents corresponding descriptive statistics.

The dependent variable (*I*) is defined as the simulated economic welfare change in a particular country/region due to a liberalisation experiment. Many public debates (e.g. does liberalisation benefit developing countries) focus on simulated welfare changes as indicators of expected gains and their distribution, and most studies report, among other findings, some measure of welfare change, making this a natural indicator of the outcome of a simulation. However, as noted earlier, some studies report only changes in prices, trade volumes or production volumes (e.g. FAPRI), and had to be omitted from the final sample. The remaining studies report one of three different welfare measures; absolute change in GDP, percentage change in GDP and change in equivalent variation (EV) (see Mas-Colell et al. (1995) for a discussion of different measures). All measures are transformed into million US$ using appropriate exchange rates and baseline GDP[12] as necessary. Dummy variables on the RHS of (1) are used to capture any systematic effects of the different measures used. The reference measure is EV: one dummy = 1 if the study reports absolute changes in GDP; another dummy = 1 if the study reports percentage change in GDP; and a third dummy = 1 if a study reports a PE sum of economic rents.

[12] Exchange rates and GDP are taken from the Penn World Table (Heston et al., 2006).

No use is made of the information that dynamic models generate about the paths taken by welfare changes over time. Instead, the welfare impact of a dynamic simulation is taken to be the reported welfare change in the last year of the simulation run or, if a study reports a sum of annual welfare gains, the average annual welfare gain over the simulation horizon. In cases in which dynamic gains are reported relative to baseline GDP, the baseline GDP in the last year of the simulation run is projected assuming an annual 2 percent rate of GDP growth.

Table 2: Definitions and descriptive statistics for the variables employed in the estimation of equation (1)

Source. Own calculations with literature sample.

3.4 Variable definitions: The independent variables

During the processing of the initial sample of 230 studies, roughly 150 different variables were either extracted from the studies or drawn from other sources (e.g. data on initial GDP and trade volumes was assembled for all observations, as outlined below). It would be beyond the scope of this paper to describe all of these variables. As might be expected, many of these variables are collinear. For example, the product and country/region aggregations underlying a simulation (dimensions of *MC*) are a function of the dataset employed (*DB*), which in turn depends in part on the year of publication (*RC*) as increasingly disaggregated datasets have become available over time. This poses the question of how to select a parsimonious and theoretically consistent set of independent variables for the estimation of equation (1). As outlined above under 'Sample collection', the size of the final literature sample is influenced by this question, because not all studies provide complete documentation on all variables. To address this question, an initial review of the literature on modelling methods and model comparison (Shoven and Whalley, 1984; Francois and Reinert, 1997; Ginzburg and Keyzer, 1997; Hertel, 1999; van Tongeren et al., 2001; Harrison et al., 2003; Bouët, 2006) was used to identify key variables and groups of variables that experts expect to have an influence on simulation outcomes. Next, exploratory analysis using stepwise regression (Draper and Smith, 1981; Darlington, 1990) and regression trees (Breiman et al., 1984; Yohannes and Hoddinott, 1999) was carried out with a preliminary set of 53 studies and roughly 1600 observations.[13] This analysis identified a core set of independent variables that account for the important model-driving effects suggested by the literature, and that have significant and consistent impacts across different estimates of equation (1) (using different weighting schemes and subsets of the meta-dataset). In the following, the categories *MC*, *LE*, *DB* and *RC* are discussed in turn.

[13] See *Authors* (2006) for the results of this preliminary analysis. Besides size, a key difference between the preliminary dataset and that employed here is that the latter includes numerous studies from 2006 that use the new GTAP-6 database.

<u>Model characteristics (*MC*)</u> is a broad category that includes the following variables:
Whether the model is partial equilibrium (PE) or general equilibrium (GE) (dummy = 1 if PE; 0 otherwise). Because they do not include 'dampening' GE-feedback effects, PE models are expected to produce larger welfare effects, *ceteris paribus*. However, a distinction must be made between PE models that report welfare changes in EV terms, and PE models that report PE measures of welfare change. A dummy variable is used to flag the latter cases (dummy = 1 if a PE measure of welfare change is reported; 0 otherwise). The coefficient on this variable is expected to be negative because PE measures address only a fraction of the income in an economy.
Whether the model uses the so-called Johansen macro-closure (dummy = 1 if yes; 0 otherwise). Closure rules resolve overdetermination – i.e. the fact that GE models contain more variables than equations – by declaring certain variables exogenous. All of the GE models in the final literature sample either assume that savings determine (endogenous) investment (the so-called 'neoclassical macro-closure'), or that investment is exogenous as in the Johansen macro-closure.[14] The literature on closure rules and their impacts on simulation results (e.g. Rattsø, 1982; Dewatripont and Michel, 1987; Lofgren et al., 2002; McDonald and van Tongeren, 2003; Robinson, 2005; Robinson and Lofgren, 2005) does not establish any generalisations about the impact of the Johansen macro-closure relative to others, so we formulate no expectations.
Whether one or more countries' trade balances are assumed to be fixed in a simulation (dummy = 1 if yes; 0 otherwise). Where this is assumed, a country essentially cannot respond to liberalisation along the lines of comparative advantage, as either exports or imports are 'forced' to change to maintain a fixed trade balance. Hence, this assumption is expected to lead to lower welfare gains.
Whether a model includes any additional restrictions on the availability or mobility of primary factors beyond the usual assumptions of a fixed stock of land and uniform labour supply (dummy = 1 if yes; 0 otherwise). Hertel (1989) emphasises the importance of different ways of modelling supply response. However, missing information in some studies and the heterogeneity of the supply-side specifications in the literature sample make it difficult to define appropriate variables. The dummy variable chosen here is a catch-all for any specifications that might be expected to restrict supply response and thus reduce the welfare benefits of liberalisation. These include assumptions of inter-sectoral factor immobility, specifications according to which a factor such as labour is divided into different qualities (e.g. skilled and unskilled) which are not perfect substitutes, and quantitative policy restrictions such as production quotas and land set-aside.
A series of ten dummy variables is employed to capture the effects of four key model characteristics and interactions between them. These four characteristics are: i) whether the observation in question is based on comparative static or dynamic modelling; ii) whether perfect competition and constant returns to scale (CRTS) or imperfect competition and increasing returns to scale (IRTS) are

[14] Other macro-closures (e.g. Keynesian, Kaldorian) are possible, but they do not occur in the literature sample.

assumed; iii) whether the capital stock is assumed fixed or allowed to accumulate; and iv) the magnitude of the assumed Armington elasticities, classified as 'low' (standard GTAP values or lower) or 'high' (greater than standard GTAP values).[15] Dynamic modelling, imperfect competition and IRTS, capital accumulation and high Armington elasticities are expected to be associated with higher simulated welfare gains. Sixteen combinations of these four binary variables are possible, but some occur only very rarely or not at all in the literature sample, so only ten combinations (see Table 2) are included in the estimation of equation (1).

For dynamic models, the length of the simulation run in years is included in linear and quadratic form. The dynamic studies in the literature sample simulate runs from a few to over 20 years in length. It is expected that longer simulation runs will lead to larger welfare gains, *ceteris paribus*, and the quadratic term is included to account for possible non-linearity in this relationship. For comparative static models this variable takes the value 0.

Whether a model's database is projected to a new base year prior to the commencement of a simulation run. The length of this projection, in years, is included in the estimation of equation (1). It is expected that longer projections will be associated with lower simulated welfare gains, *ceteris paribus*, as projections often imply that some liberalisation steps are assumed to take place before the liberalisation experiment in question is carried out. For example, a DDR simulation undertaken in 2000 could be based on a projected 2006 base year that anticipates implementation of the EU's 'Agenda 2000' policy changes. The more such liberalisation is anticipated, the less distortion will remain to be liberalised in the ensuing simulation.

How disaggregated the model is in terms of countries/regions and products. Two variables are included: one that equals the product of the number of countries/regions and the number of sectors depicted in a model, and one that counts the number of agricultural products depicted. Agriculture is considered specifically because it plays an important role in the DDR and is the focus of many studies in our literature sample, with some PE models in particular depicting as many as 50 agricultural products. Aggregation bias is an important issue in applied trade modelling. Martin et al. (2003) attribute aggregation bias to an averaging problem and a weighting problem. The former problem results because welfare effects are a quadratic function of price wedges. Hence, the sum of the welfare losses caused by a high and a low tariff on otherwise identical markets is greater than sum of the welfare losses caused by applying the average of these tariffs to both markets. The weighting problem results from the fact that commonly used trade-weighted averages underemphasise high tariffs (at the limit, a prohibitive tariff eliminates trade, resulting in a weight of 0; see also Anderson, 2006). Martin et al. (2003) present evidence that these problems lead to

[15] In practice, modellers who wish to assume 'higher' Armington elasticities often double the standard GTAP values. The 'high' Armington elasticities group includes models that do not make the Armington assumption thereby implicitly assume perfect substitution and infinite Armington elasticities. See Sarker and Surry (2006) for a discussion of the use of the Armington assumption in agricultural trade models.

substantial underestimation of the benefits of trade liberalisation, so we expect that increased disaggregation will lead to lead to higher simulated welfare gains.

Whether the authors of a study report making *ad hoc* modifications to elasticities that they have taken from the literature or that are a part of the modelling platform employed, captured using a dummy variable (dummy = 1 if *ad hoc* modification are reported; 0 otherwise). In a similar vein, a further dummy variable equals 1 if authors report that any of the elasticities they use are based on own econometric estimates (0 otherwise). It might be expected that authors will undertake such modifications if they are convinced that 'mainstream' elasticities produce simulated welfare gains that are either too big, or too small. Hence, the signs of the coefficients on these two variables are, *a priori*, ambiguous.

Liberalisation experiments (*LE*) are difficult to quantify consistently. Much confusion about differences in simulation results arises because important differences between what appear to be identical liberalisation experiments are overlooked. While two experiments that both simulate, for instance, a 50% cut in OECD agricultural tariffs may appear to be identical, they can differ considerably depending on the type of tariff (bound vs. applied, treatment of preferences and mixed tariffs, etc.) and the underlying aggregation of products and regions.

The domestic price of good i in region r following a reduction in import tariffs is:

$$p_{ri}^{\text{domestic}} = p_{ri}^{\text{border}} * [1 + t_{ri} (1\text{-}s)], \qquad (2)$$

where: p_{ri} = the price of good i in region r; t_{ri} = the initial *ad valorem* tariff levied on imports of i; and s = the proportional reduction in t_{ri}. Clearly, differences in t_{ri} (due for example to different treatments of tariffs and aggregations) paired with different levels of p_{ri}^{border} (due, again, to different aggregations, or the use of different base years) will lead to different impacts of a given s. This is the reflection in the modelling world of some of the market access issues that have proven so contentious in recent years of DDR agricultural negotiations, and that modellers are only beginning to explore systematically (Anderson, 2006; Bchir et al., 2006; Brockmeier and Pelikan, 2006; Martin et al., 2003).

Simulation results can therefore not be compared meaningfully without controlling for the level of protection that is reduced in liberalisation experiments, and the aggregation/economic size of the sector to which this reduction is applied. To deal with this problem, a reference database is constructed that includes information on applied and bound tariffs, production volumes and trade flows. Key sources for this reference database are GTAP-5, GTAP-6, FAO, ATPSM and MacMap.[16]

Using this reference database, LE variables are constructed as follows:

To quantify experiments that involve tariff reduction, we re-create the regional and product aggregations of each simulation experiment in the literature sample, and derive initial *ad valorem* MFN tariffs for each combination of country/region and products/product aggregates in a study.

[16] See www.gtap.org, http://faostat.fao.org, http://192.91.247.38/tab/ATPSMdwnlds.asp, and www.macmap.org.

Each *ad valorem* tariff is then multiplied with the production value of the corresponding product (in million US$) and the simulated proportional tariff reduction, and the result is summed over all products for which a country/region reduces tariffs to create a first *LE* variable (labelled 'Changes in tariffs...' in Table 2). The result is a standardised, monetary measure of the size of the liberalisation step underlying a particular simulation result.[17] Beside tariffs reductions, this variable includes changes in both export subsidies and 'yellow box' agricultural measures, also calculated in terms of the underlying production value. Negative values indicate a reduction in protection, so the corresponding regression coefficient is expected to be negative as reductions in protection lead to welfare gains. This variable is also included in quadratic form in the estimation of equation (1) to account for non-linearity in the relation between welfare effects and price wedges. Note that this variable will not fully capture the nuanced trade liberalization and domestic policy reform scenarios simulated in a few studies that use very detailed datasets (e.g. Hoekman et al., 2004, who work with data at the HS 6-digit level).

Whenever authors indicate that a liberalisation experiment includes reductions in NTBs, these reductions are proxied analogously using the formula (production value)*(twice the applied conventional *ad valorem* tariff)*(the reported proportional reduction in NTBs). This rough approximation was chosen because few studies that analyse NTB reduction provide sufficient information on how NTBs were estimated to permit more precise measurement. In the few studies that provide detailed information, reported estimates of NTBs are considerably larger than the corresponding tariffs. Furthermore, many experts believe that the importance of NTBs is underestimated, increasingly so as past GATT and WTO agreements have succeeded in reducing conventional tariffs. Hence, we assume that authors who do consider NTBs in their liberalisation experiments will tend to work with high estimates of NTBs (approximated here as twice the level of conventional tariffs). Again, negative values of this variable indicate NTB reduction, so the corresponding regression coefficient is expected to be negative as well.

Changes in blue and green box policies in agriculture are approximated as (relevant production value)*(the reported proportional change). This fails to do justice to the more detailed representation of green and blue box policies in some PE models, but it reasonably approximates the stylised manner in which these policies are depicted in most GE models (e.g. via closure modifications or by relaxing an income constraint). *Ceteris paribus*, blue box policies are welfare reducing (albeit less so than yellow box policies). Green box policies are either welfare neutral (e.g. decoupled payments) or welfare increasing (e.g. productivity enhancing investments in research and extension), although the

[17] For example, consider a study in which the impact of a 10% reduction in EU tariffs for the aggregate 'grains' is simulated. Using the reference data base, we determine the aggregated value of EU grains production and the *ad valorem* tariffs applied to EU grain imports in the appropriate year/base period. (10%)*(the production value)*(the applied *ad valorem* tariff) measures (in US$) the amount of protection for grains in the EU that is reduced in the liberalisation experiment.

distortionary effects of raising tax revenue to pay for these measures must be considered (Alston and Hurd, 1990). Hence, the coefficient on this variable could be greater or less than 0. Furthermore, there is some collinearity between this variable and the 'Changes in tariffs' variable introduced above, because blue and green box policies are often increased to compensate farmers for reductions in yellow box support.

An additional *LE* variable measures whether a simulation assumes an exogenous shock to technology or any related parameter that influences productivity in a model. This shock is measured as the proportional change in technology (e.g. a 2% productivity boost due to adoption of GMO varieties in a country's cotton sector) multiplied by the production value of the affected products. Such shocks, where included, are expected to lead to increased welfare gains.

Finally, the total volume of trade of the country/region underlying an observation for all goods and services depicted in the model (not just those subject to liberalisation) is included in the estimation of equation (1). This variable captures potential spillover benefits that can accrue in sectors other than that in which the simulated liberalisation takes place. Furthermore, increasing volumes of overall trade could be related to market power in international trade, and perhaps negotiating power in trade negotiations that enables bigger traders to secure better terms, so that the liberalisation scenarios considered might tend to favour large countries.

Databases (*DB*) are incorporated in the estimation of equation (1) by use of four dummy variables. GTAP-3, with base year 1992, is the reference database relative to which the impacts of all others are measured. Dummy variables are included for GTAP-4, GTAP-5 and GTAP-6, as well as for 'all other databases' (such as national account data for single country CGEs, or agricultural production and trade statistics for most PE models). In each case the dummy = 1 if the database in question is used; 0 otherwise. Dimaranan et al. (various years), provide background information (such as base years, measurement of tariffs, etc.) on the GTAP databases. With time, newer databases incorporate progressive reductions in protection worldwide, and more accurate depictions of tariffs (bound vs. applied, preferences). Hence, newer databases are expected to be associated with progressively lower welfare gains, *ceteris paribus*, compared with GTAP-3.

To capture elements of the research context (*RC*), meta-analyses commonly use descriptive bibliographic information about a study (year of publication, number of authors) as well as information about the setting in which it was produced (institution of origin, subject to peer review, etc.). In the case at hand, many of these variables cannot be quantified reliably. For instance, the 25 authors who appear most frequently in the literature sample are involved in 176 (76%) of 230 publications.[18] This highlights the strength of networks in the trade modelling community; it also makes it difficult to code, for example, 'institution of origin', as the same Professor may contribute

[18] In total, 288 individual authors contribute to the 230 studies in the literature sample.

to university working papers, refereed journal articles, and studies for national and international institutions as well as NGOs.

As it turns out, the *RC* variables that could be quantified (year of publication, number of authors, subject to peer review) have no significant impact on the estimation of equation (1). In the case of 'year of publication', this is likely due to collinearity with the database (*DB*) variables. More fundamentally, it is likely that *RC* influences will be largely captured by *MC* variables. If, for example, authors who work for a particular institution did feel 'encouraged' to produce larger (or smaller) estimates of welfare gains from liberalisation, this would probably be reflected in a tendency to choose model characteristics that are expected to generate such estimates.

An author's years of modelling experience might be included in the *RC* category, as inexperience may be responsible for a number of outliers in the dataset that perhaps reflect the results of numerically unstable simulation solutions.[19] Unfortunately, there is no way of gleaning this information from the studies in our sample, and even if it were available, most studies have more than one author so that some arbitrary measure (mean, median, etc.) would have to be selected.

In summary, 34 explanatory variables are selected that describe key model characteristics, important dimensions of typical DDR liberalisation experiments, and the databases commonly used in quantitative trade policy modelling. The returns to adding further explanatory variables are diminishing due to collinearity and to incomplete documentation in many studies which leads to sample attrition. Many of the chosen explanatory variables are of necessity approximations, and a number of complex model characteristics in particular can only be depicted, if at all, as dummy variables. The analysis could be restricted to those studies that provide sufficient information to permit a more sophisticated depiction of these model characteristics, but this would greatly reduce the number of usable studies and the size of the final sample. The following section shows that these concerns notwithstanding, the chosen set of explanatory variables produces plausible and informative estimates of equation (1).

4. Results

Results of the OLS estimation of equation (1) are presented in Table 3. Four sets of regression results are presented, one for each combination of the two weighting schemes (unweighted, and with each observation weighted by the reciprocal of the number of observations generated by the underlying study) with two samples. These samples are i) the final literature sample of 110 studies, and ii) a smaller sample of 107 studies that omits three papers (that produce 408 observations) based on the Michigan Model of Production and Trade (Brown et al., 2002, 2003 and 2005), as well as 32

[19] We are grateful to Yves Surry for this suggestion.

observations generated by two of the twelve experiments presented by Lodefalk and Kinnman (2006). In the following, these samples are referred to as respectively 'with' and 'without B+L' (for Brown and Lodefalk).[20]

The observations that are not included in the 'without B+L' sample report simulated global welfare gains from liberalisation that are up to four times as large as any others reported in the literature sample (859 as opposed to 203 billion US$ – see Table 2) and they simulate tariff reductions measured in terms of production value that are over five times as large (12,790 as opposed to 2,506 billion US$). Brown et al. (2002, 2003 and 2005) are based on a *sui generis* model characterised by a unique combination of features (e.g. IRTS and imperfect competition together with a fixed capital stock and high Armington elasticities[21], own estimates of NTBs and endogenous flows of foreign direct investment). The two experiments in Lodefalk and Kinnman (2006) that are omitted in the 'without B+L' sample (labelled "dynamic full" and "dynamic more") are based on an approach to modelling monopolistic competition in GTAP that, according to Hertel et al. (2006, p. 10), makes the model "less stable". As can be seen in Table 3, including the 440 B+L observations reduces the regressions' goodness of fit considerably. This effect is weaker in the weighted regressions, which reduce the weight of the B+L observations from roughly 7.5% (440/5836 observations) to 2.7% (3/110 studies). Hence, the B+L observations appear to include many outliers, and we estimate equation (1) with and without these observations to permit comparison.

Independent of the weighting scheme and the inclusion of the B+L observations, the results in Table 3 are robust. In the weighted regressions with and without B+L observations, most of the estimated coefficients are statistically significant and have both the expected signs and similar, plausible magnitudes. The signs, significance and magnitudes of the coefficients in the unweighted regressions generally agree with those in the weighted regressions. However, in the unweighted regressions less coefficients are significant (or are significant at lower levels), and results with and without B+L observations are less homogeneous in terms of sign, magnitude and significance. These comparisons confirm that the B+L observations have a strong influence on the estimation of equation (1), and that the weighting scheme reduces this influence.

The coefficient of determination (R^2) of the unweighted regression suggests that roughly 40% (20% if the B+L observations are included) of the variation in simulated welfare gains across observations can be explained using the chosen explanatory variables (R^2 in the weighted regressions pertains to a transformed dependent variable and cannot be interpreted in this manner). In view of the

[20] This is not entirely accurate, as observations based on the other ten experiments in Lodefalk and Kinnman (2006) are retained in the 'without B+K' sample. Their inclusion/exclusion has little impact on the estimation of equation (1).

[21] Brown et al. (2002, 2003 and 2005) are the only studies in the literature sample that are based on this combination of RTS, competition, capital stock and Armington assumptions. Hence, the dummy variable that captures this constellation is only included in the estimation of equation (1) with B+L observations.

approximate nature of many of the explanatory variables employed in the estimation, we find this a surprisingly high proportion.

Table 3: OLS regression results for the estimation of equation (1), dependent variable is welfare change in million US$

Source. Own calculations with literature sample.

In the following we discuss the estimated coefficients for individual explanatory variables, referring, unless stated otherwise, to the 'weighted by [1/(observations in study)]' and 'without B+L' regression in the third set of columns in Table 3. To ease the interpretation of individual coefficients, note that the average welfare gains across all observations in the samples with and without B+L observations are 5.0 and 3.5 billion US$, respectively (Table 2).

Liberalisation experiment (*LE*): Results for the 'Changes in tariffs...' variables indicate that the relation between reduction in tariffs and welfare gains is non-linear. Calculations with the coefficients in Table 3 show that over the relevant range of tariff reductions expressed in terms of production value (see Table 2), estimated welfare changes range from a loss of 2.3 billion US$ (corresponding to roughly -0.9% of the largest considered tariff increase of roughly 250 billion US$) to a gain of almost 200 billion US$ (corresponding to roughly -8% of the largest considered tariff reduction of 2,500 billion US$). Over this range, welfare gains grow more rapidly than reductions in tariffs, and this convexity is in keeping with the fact that welfare losses are a quadratic function of price wedges. The results of the weighted regression including B+L observations are counterintuitive in this respect. As mentioned above, the B+L observations span a much larger range of tariff reductions (as high as 12,790 billion US$ in simulations of global liberalisation – see Table 2). Over this range, welfare gains estimated using the coefficients in Table 3 first increase until tariff reductions expressed in terms of production value reach roughly 7,500 billion US$, and then decrease. For tariff reductions of between roughly 0 and 1,500 billion US$ – which is where most of the observations in both the with and without B+L samples are located – welfare gains estimated using the coefficients in Table 3 are of a similar order of magnitude regardless of whether the with or without B+L results are used. The B+L studies include a number of experiments with much larger tariff reductions than this, however, and since the simulated welfare gains corresponding to these large tariff reductions are comparatively small, the estimated relation between tariff reductions and welfare gains becomes concave when these studies are included.

Reductions in NTBs also have negative impacts, but these are smaller and less (or not) significant, perhaps because of the very rough manner in which the NTB variable is defined. Increases in blue and green box policies lead uniformly to small welfare gains (5,000 US$ for every 1 million US$ increase) that are significant in three of four specifications in Table 3. Collinearity between this variable and the ‘Changes in tariffs...’ variable implies that the effects of these two variables may be confounded. Exogenous technical change or productivity shocks have a uniformly significant and positive impact on welfare gains, with a shock that boosts production by 1 million US$ resulting in a gain of 86,000 US$. Simulated welfare gains are significantly higher for countries with larger trade volumes, with each additional 1 million US$ of trade leading to a 9,000 US$ increase in gains, *ceteris paribus*.

Databases (*DB*): As expected, the coefficients on the database dummy variables are negative. Most are also significant. The lower significance of the ‘other database’ coefficients may be due to the heterogeneity of this ‘catch-all’ for non-GTAP databases. Use of the GTAP-4 (GTAP-5, GTAP-6) database leads to a reduction in simulated welfare gains of -8.2 (-8.2, -10.7) billion US$ with respect to the GTAP-3 database, and this pattern of decreasing welfare gains over subsequent GTAP databases is consistent across specifications in Table 3.

Model characteristics (*MC*): Measuring welfare changes in terms of GDP (percent or absolute change) as opposed to equivalent variation leads to higher gains (7.2 and 0.9 billion US$, respectively, with only former being significant). While the effect using percent changes in GDP is consistently significant and positive across specifications in Table 3, the effect of using absolute GDP changes is not. The impact of using a PE welfare measure is, as expected, negative (-2.2 billion US$, all other things being equal), and this effect is negative and significant in all specifications.

PE models produce larger simulated welfare gains than GE models according to the results in Table 3 (2.3 billion US$), but this effect is only significant in the weighted specification without B+L observations. The Johansen closure leads to higher simulated welfare gains (2.1 billion US$), and this effect is significant in three of four specifications in Table 3. The estimated coefficients of the ten dummy variables that depict different combinations of dynamic/static, returns to scale and competition, treatment of capital and Armington elasticities display several regularities. Of 22 estimated coefficients for combinations that involve ‘high’ Armington elasticities in Table 3, 18 are positive as expected and significant, and only two are negative (but not significant). The combination that is unique to the B+L observations (IRTS and imperfect competition together with a fixed capital stock and high Armington elasticities) is associated with large and significant coefficients, capturing part of the large simulated welfare gains in these observations.

Added restrictions on factor mobility or supply result in significantly lower welfare gains (-2.3 billion US$). Longer pre-simulation projections of the database are associated with lower welfare gains (-14.6 million US$ per year of projection) as expected, but this effect is not significant in all specifications. With increasing length of dynamic simulation runs, welfare gains first fall and then increase; in the weighted regressions the latter effect dominates for simulation runs of more than roughly 13 years. As expected, fixing trade balances in a model reduces simulated welfare gains by

roughly -2.7 billion US$, although a significant positive impact is estimated in one of the unweighted regressions.
Greater disaggregation reduces simulated welfare gains significantly. The incremental effects of adding a country/region or an agricultural product/aggregate are small (-6 and -73.2 million US$, respectively), but over the ranges of these variables (for example, the number of agricultural products ranges from 1 to 158 in the sample – see Table 2) these effects can produce large differences. This consistently negative impact of disaggregation on welfare gains is not in line with the expectations formulated above according to which disaggregation should reduce the underestimation of welfare effects caused by the ‘averaging’ and ‘weighting’ problems.
Where authors report making *ad hoc* modifications to the elasticities in a model, significantly larger welfare gains (3.1 billion US$) are reported. Where authors use own econometric estimates of elasticities, significantly smaller welfare gains (-2.9 billion US$) result. One might see this as evidence that *ad hoc* modifications to elasticities tend to be undertaken by those who feel that conventional values (and econometric estimates) produce underestimates of welfare gains, but this is speculative as underlying motivations are not observable.

5. Conclusions

The results presented above indicate that a simple meta-regression using variables that describe the liberalisation experiment, the characteristics of the model used, and the database employed can explain an important share of the variation in simulated welfare changes in a sample of Doha Development Round trade liberalisation studies. The results provide quantitative estimates of impacts that have hitherto only been considered qualitatively and without accounting for simultaneous variation in numerous factors across modelling frameworks and studies. These quantitative estimates are for the most part significant and have plausible signs and magnitudes, and they are robust to changes in the specification of the meta-regression.
By adding to our understanding of how model characteristics, liberalisation experiments and databases influence trade policy simulations, these results can contribute to reducing the impression of arbitrariness that arises when economists produce what appear to be very different estimates of liberalisation benefits. The quantitative estimates of individual impacts reported here can be used by both modellers and model users to compare, assess and at least partially reconcile divergent simulation results. Exercises of this nature can be especially beneficial for least developed countries, which often cannot afford to maintain sophisticated own modelling capacities and dedicate highly trained personnel to the comparison and assessment of different and often conflicting model results.
The fact that so many potentially informative studies had to be omitted from the final meta-regression highlights the importance of clearly communicating exactly how a simulation has been

carried out. Too many studies do not document even the admittedly abbreviated and approximate information used to carry out the quantitative analysis presented here. We expect that if documentation was more detailed and complete, a considerably larger proportion of the variation in simulated welfare changes in our sample could be explained. More importantly, thorough documentation would facilitate communication both among modellers and between modellers and users.

In closing we emphasise that the results presented here do not shed any light on what is the 'right' model. While the meta-analysis presented here indicates that use of the Johansen as opposed to the neoclassical closure leads to systematically higher simulated welfare effects, it does not provide any basis for deciding which of these two closures – if any – should be used. More generally, our analysis can be seen as an attempt to estimate a sort of meta-model response surface using a dataset extracted from published and otherwise disseminated studies. Extensive and methodical sensitivity analysis with a range of available models could conceivably be used to expand this dataset and permit a much more sophisticated and precise estimation of the meta-model response surface. If the resulting response surface were sufficiently accurate and parsimonious, it might even provide a low-cost alternative to actual modelling in some applications, at least to a first order of approximation. However, practitioners would still have to make many choices to use this response surface, such as which closure rule to use, whether to assume constant or increasing returns to scale, etc.

Moreover, the meta-analysis presented here sheds light on factors that drive simulation results that were generated using current, received modelling practices. The meta-model response surface hypothesised above would also reflect these practices. Sceptics might argue that meta-analysis based on these practices suffers from 'junk in, junk out' as a consequence: it provides insights into how commonly used models work, but this is of limited interest if one is not convinced that these models provide adequate representations of important economic phenomena (for example speculative capital flows, intra-industry trade, the exercise of market power, preferences for variety, etc.). Continued advances in trade theory and progress in bridging the gap between theory and applied trade models are needed to address these concerns and formulate increasingly 'right' models.

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Table 1: Description of modelling frameworks and studies in the final literature sample, and their contributions to the meta-dataset

Modelling framework	**Type of model***	**Assumptions about competition and returns to scale**	**Comparative static or dynamic****	**Armington assumption**	**Number of studies**	**Observations contributed to the meta-dataset**
ATPSM	PE	perfect, CRTS	comp.static	No	4	38
ATPSM	PE	perfect, CRTS	comp.static	Yes	3	495
BDS	GE	imperfect, IRTS	comp.static	Yes	3	408
CAPRI	PE	perfect, CRTS	dynamic	Yes	1	3
CAPSIM	PE	perfect, CRTS	comp.static	No	1	2
China WTO	GE	perfect, CRTS	comp.static	Yes	2	52
DRC Council Beijing	GE	perfect, CRTS	dynamic	Yes	1	5
Exter	GE	perfect, CRTS	comp.static	Yes	1	4
Francois	GE	perfect, CRTS	comp.static	Yes	1	45
Francois	GE	imperfect, IRTS	comp.static	Yes	7	462
FSM	PE	perfect, CRTS	comp.static	No	1	3
FTAP	GE	imperfect, IRTS	dynamic	Yes	1	18
GROUNDNUT	PE	perfect, CRTS	comp.static	No	3	115
GTAP	GE	perfect, CRTS	comp.static	Yes	44	2340
GTAP	GE	imperfect, IRTS	comp.static	Yes	2	99
GTAP-Agr	GE	perfect, CRTS	comp.static	Yes	1	51
GTAP-dyn	GE	perfect, CRTS	dynamic	Yes	1	38
GTEM	GE	perfect, CRTS	dynamic	Yes	1	48
HRTmr	GE	perfect, CRTS	comp.static	Yes	2	222
HRTmr	GE	imperfect, IRTS	dynamic	Yes	1	15
LINKAGE	GE	perfect, CRTS	dynamic	Yes	7	450
LINKAGEoecd	GE	perfect, CRTS	dynamic	Yes	1	15
LTEM	PE	perfect, CRTS	dynamic	No	1	8
MEGABARE	GE	perfect, CRTS	comp.static	Yes	1	13
MIRAGE	GE	perfect, CRTS	comp.static	Yes	1	187
MIRAGE	GE	perfect, CRTS	dynamic	Yes	1	24
MIRAGE	GE	imperfect, IRTS	comp.static	Yes	1	5
MIRAGE	GE	imperfect, IRTS	dynamic	Yes	1	150
MRT-SS	GE	perfect, CRTS	dynamic	Yes	1	117
ORANImodified	GE	perfect, CRTS	comp.static	No	1	1
Hoekman et al.	PE	perfect, CRTS	comp.static	No	1	242
Tumbarello	PE	perfect, CRTS	comp.static	Yes	1	14
Hosoe et al.	GE	perfect, CRTS	comp.static	Yes	3	24
Shantong-Zhai et al.	GE	perfect, CRTS	dynamic	Yes	3	28
PerroniWhalley	GE	perfect, CRTS	comp.static	Yes	1	1
PRCGEM	GE	perfect, CRTS	comp.static	Yes	1	2
PRCGEM	GE	perfect, CRTS	dynamic	Yes	1	2
RATSIM	PE	perfect, CRTS	comp.static	Yes	1	4
Rutherford	GE	perfect, CRTS	dynamic	Yes	1	70
Sum					**110**	**5835**

Source: Own calculations based on literature sample.

*Note: * PE = partial equilibrium; GE = general equilibrium. ** Labelled dynamic are all dynamic specifications except those based on the Baldwin closure under comparative statics (which some authors also consider dynamic).*

Table 2: Descriptive statistics for the variables employed in the estimation of equation (1)

Cate-gory	Variable	Units	Sample without B+L[a] (107 studies, n=5395)				Sample with B+L[a] (110 studies, n=5835)			
			Min.	Max.	Mean	Std. dev.	Min.	Max.	Mean	Std. dev.
I	Simulated welfare change	million US$	-43930	203400	3472	10914	-43930	859400	5007	25967
MC	Dependent variable is percent change in GDP	dummy	0	1	0.045	-	0	1	0.040	-
MC	Dependent variable is absolute change in GDP	dummy	0	1	0.086	-	0	1	0.080	-
MC	Dependent variable is PE welfare	dummy	0	1	0.122	-	0	1	0.110	-
MC	Model is partial equilibrium	dummy	0	1	0.171	-	0	1	0.158	-
MC	Model uses Johansen Macro closure	dummy	0	1	0.010	-	0	1	0.079	-
MC	Dynamic, CRTS, perf. comp., capital stock fixed, AE high	dummy	0	1	0.014	-	0	1	0.013	-
MC	Dynamic, CRTS, perf. comp., capital stock accumulates, AE low	dummy	0	1	0.080	-	0	1	0.057	-
MC	Dynamic, CRTS, perf. comp., capital stock accumulates, AE high	dummy	0	1	0.061	-	0	1	0.074	-
MC	Dynamic, IRTS, imperf. comp., capital stock accumulates, AE low	dummy	0	1	0.028	-	0	1	0.026	-
MC	Dynamic, IRTS, imperf. comp., capital stock accumulates, AE high	dummy	0	1	0.003	-	0	1	0.003	-
MC	Static, CRTS, perf. comp., capital stock accumulates, AE low	dummy	0	1	0.132	-	0	1	0.120	-
MC	Static, CRTS, perf. comp., capital stock accumulates, AE high	dummy	0	1	0.106	-	0	1	0.098	-
MC	Static, IRTS, imperf. comp., capital stock is fixed, AE high	dummy	0	1	0.000	-	0	1	0.070	-
MC	Static, IRTS, imperf. comp., capital stock accumulates, AE low	dummy	0	1	0.070	-	0	1	0.060	-
MC	Static, IRTS, imperf. comp., capital stock accumulates, AE high	dummy	0	1	0.021	-	0	1	0.020	-
MC	Added restrictions on factor mobility/supply	dummy	0	1	0.240	-	0	1	0.220	-
MC	Pre-simulation projection of database: Length of the run in years	years	0	14	1.890	3.86	0	14	1.820	3.85
MC	Dynamic Models: Length of the simulation run in years	years	0	28	4.290	5.91	0	28	4.290	5.91
MC	One or more countries' trade balance has been fixed	dummy	0	1	0.050	-	0	1	0.100	-
MC	Number of regions*No. of sectors	count	1	1665	354.1	246.4	1	1665	355.5	237.1
MC	Number of agricultural product aggregates	count	1	158	17.4	31.9	1	158	16.1	31.0
MC	Author report *ad hoc* modifications to literature-based elasticities	dummy	0	1	0.015	-	0	1	0.010	-
MC	Author use some or all elasticities based on own econometric estimates	dummy	0	1	0.020	-	0	1	0.020	-
LE	Changes in tariffs, export subsidies and yellow box measures	million US$	-2506000	257000	-49920	144463	-12790000	372400	-63200	321306
LE	Changes in non-tariff barriers	million US$	-3794000	0	-15320	128064	-3794000	0	-15540	126644
LE	Changes in blue/green box policies	million US$	-6898000	726700	-50500	324142	-6898000	726700	-50500	317577
LE	Trade volume of country in all sectors covered by the model	million US$	0	2570000	181600	278604	0	2570000	183100	278797
LE	Shocks to technical change or related variables in per cent	million US$	-441000	11050	-189.4	7153	-441000	11050	-175.2	6879
DB	Database GTAP-4	dummy	1	0	0.112	-	1	0	0.145	-
DB	Database GTAP-5	dummy	1	0	0.353	-	1	0	0.355	-
DB	Database GTAP-6	dummy	1	0	0.275	-	1	0	0.260	-
DB	Non-GTAP database	dummy	1	0	0.182	-	1	0	0.169	-

Source. Own calculations with literature sample.

[a] *B+L refers to 3 studies (408 observations) based on the Michigan Model of Production and Trade (Brown et al., 2002; Brown et al., 2003; Brown et al., 2005), as well as 32 observations from Lodefalk and Kinnman (2006), that simulate much larger welfare gains than the rest of the sample. See discussion in text.*

Table 3: OLS regression results for the estimation of equation (1), dependent variable is simulated welfare change in million US$

Weighting scheme →	Unweighted						Weighted by [1/(observations in study)]					
Sample →	Without B+L[a]			With B+L[a]			Without B+L[a]			With B+L[a]		
↓Variable	Coeff.		Std.err	Coeff.		Std.err	Coeff.		Std.err	Coeff.		Std.err
Intercept	5223	***	965	1566		1450	9335	***	1005	7158	***	594
Dependent variable in percent change in GDP	2205	**	1068	2881	**	1304	7236	***	822	6226	***	394
Dependent variable is absolute change in GDP	3502	***	897	3192	***	981	886		1338	-564		571
Dependent variable is PE Welfare	-6112	***	2353	-4724	*	2811	-2187	***	601	-2168	***	282
Partial vs. general equilibrium	3761		3616	887		4392	2339	***	803	266		623
Model uses Johansen closure	2569		2061	7938	***	3039	2138	*	1141	2633	***	894
Dynamic, CRTS & perf comp, cap fixed, Arm high	4589	***	1295	3578	***	1363	9419	***	2741	8124	***	859
Dynamic, CRTS & perf comp, cap accum, Arm low	-1363		836	-2556	**	1132	3357	***	1028	2781	***	511
Dynamic, CRTS & perf comp, cap accum, Arm high	4950	***	811	3982	***	1088	17335	***	1366	18628	***	1260
Dynamic, IRTS & imp comp, cap accum, Arm low	1455	*	798	-198		1127	3970	*	2109	1126		1229
Dynamic, IRTS & imp comp, cap accum, Arm high	8215		5626	6823		5744	9063	***	2857	5675	***	1616
Comp stat, CRTS & perf comp, cap accum, Arm low	434		446	673		615	1249	***	446	1038	***	276
Comp stat, CRTS & perf comp, cap accum, Arm high	-709		803	-290		1160	3185	**	1609	2518	***	860
Comp stat, IRTS & imp comp, cap fixed, Arm high[b]				12330	***	4012				19568	***	5398
Comp stat, IRTS & imp comp, cap accum, Arm low	2249	***	705	1999	**	797	6224	***	1257	4631	***	560
Comp stat, IRTS & imp comp, cap accum, Arm high	6662	***	1951	6958	*	3670	8288	**	3946	6219	*	3383
Added restrictions on factor mobility/supply	413		478	247		708	-2336	***	527	-1940	***	327
Length of pre-simulation projection of database	-66	*	36	-70		58	-15		93	-172	**	71
Length of dynamic simulation run	-633	***	169	-472	**	198	-388	***	112	-443	***	71
[Length of dynamic simulation run]^2	44	***	12	38	***	14	29	***	7	36	***	5
One or more countries' trade balance fixed	1908	**	816	-3854		3035	-2674	***	617	-4265	***	1174
Number of regions*No. of sectors	-3.1	***	0.6	-0.593		1.1	-6.0	***	0.9	-5.5	***	0.8
Number of agricultural product aggregates	-45.4	**	18.4	-38.4	*	22.3	-73.2	***	12.7	-62.9	***	8.5
Ad hoc modifications to elasticities	-1799	***	645	-775		1404	3136	***	959	2198	**	869
Own econometric estimates of elasticities	-462		617	1327		1113	-2859	***	403	-537	*	292
Changes in tariffs, exp subsidies & yellow box	-0.017	**	0.007	-0.041	***	0.011	-0.016	***	0.004	-0.056	***	0.007
(Changes in tariffs, exp subsidies & yellow box)^2	8.0E-9		9.9E-9	-2.6E-9	***	7.6E-10	2.5E-8	***	2.2E-9	-3.6E-9	***	1.1E-9
Changes in non-tariff barriers	-0.015	**	0.006	-0.011	**	0.006	-0.008		0.009	-0.004		0.004
Changes in blue/green box policies	0.001	*	0.001	0.005	**	0.002	0.005	***	0.002	0.001		0.002
Trade volume of country as covered in the model	0.007	***	0.001	0.015	***	0.003	0.009	***	0.001	0.014	***	0.002
Shocks to technical change or related variables	0.085	***	0.019	0.086	***	0.018	0.086	***	0.020	0.086	***	0.020
Database GTAP-4	-1250		926	-1987		1325	-8205	***	1214	-8443	***	708
Database GTAP-5	-3959	***	961	-3411	***	1240	-8171	***	1059	-8468	***	745
Database GTAP-6	-4682	***	945	-4584	***	1137	-10696	***	1335	-11199	***	729
Non-GTAP database	-690		2221	3663		2598	-3104	***	1010	-1169	**	549
Degrees of freedom	5361			5800			5361			5800		
Adjusted R^2	0.38			0.19			0.67			0.46		

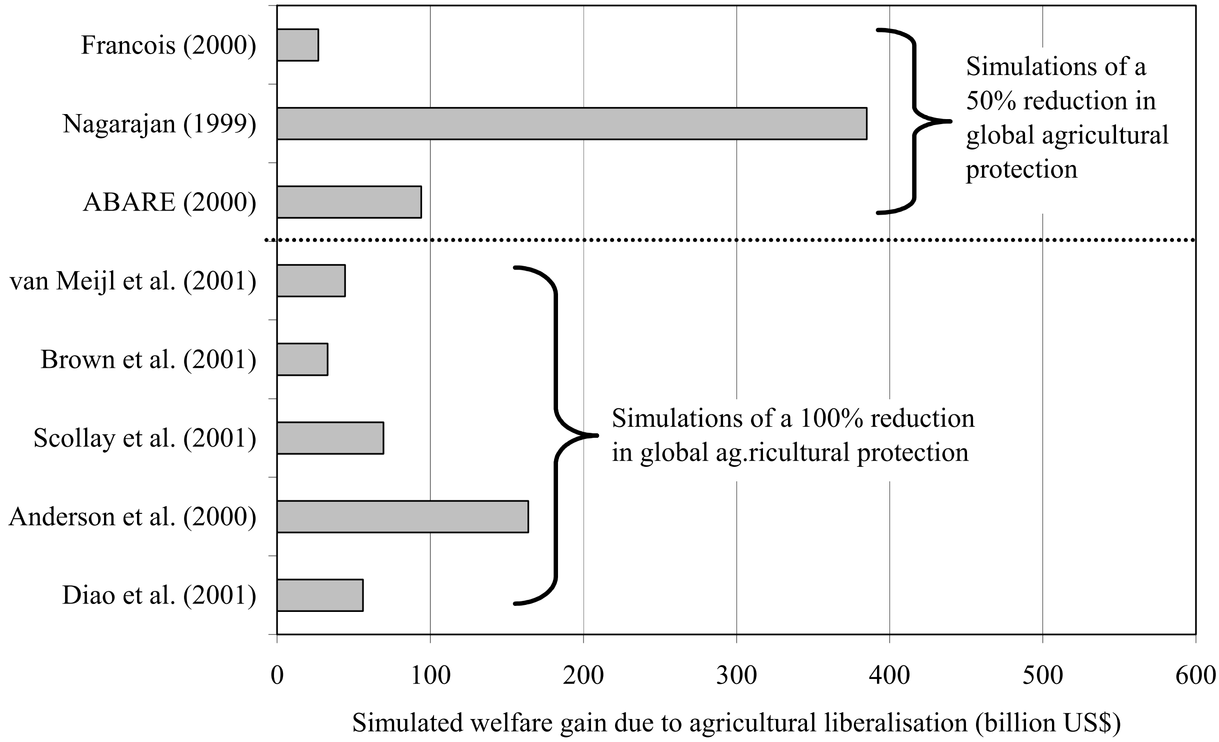
Note: Variable descriptions are provided in Table 2. *, ** and *** refer to significance at the 10, 5 and 1% levels, respectively. Standard errors are heteroskedastic consistent.

[a] B+L refers to 3 studies (408 observations) based on the Michigan Model of Production and Trade (Brown et al., 2002; Brown et al., 2003; Brown et al., 2005), as well as 32 observations from Lodefalk and Kinnman (2006), that simulate much larger welfare gains than the rest of the sample. See discussion in text.

[b] Only observations in Brown et al. (2002, 2003 and 2005) display this combination of characteristics, so the corresponding dummy variable is not included in the estimation of equation (1) using the 'without B+L' sample.

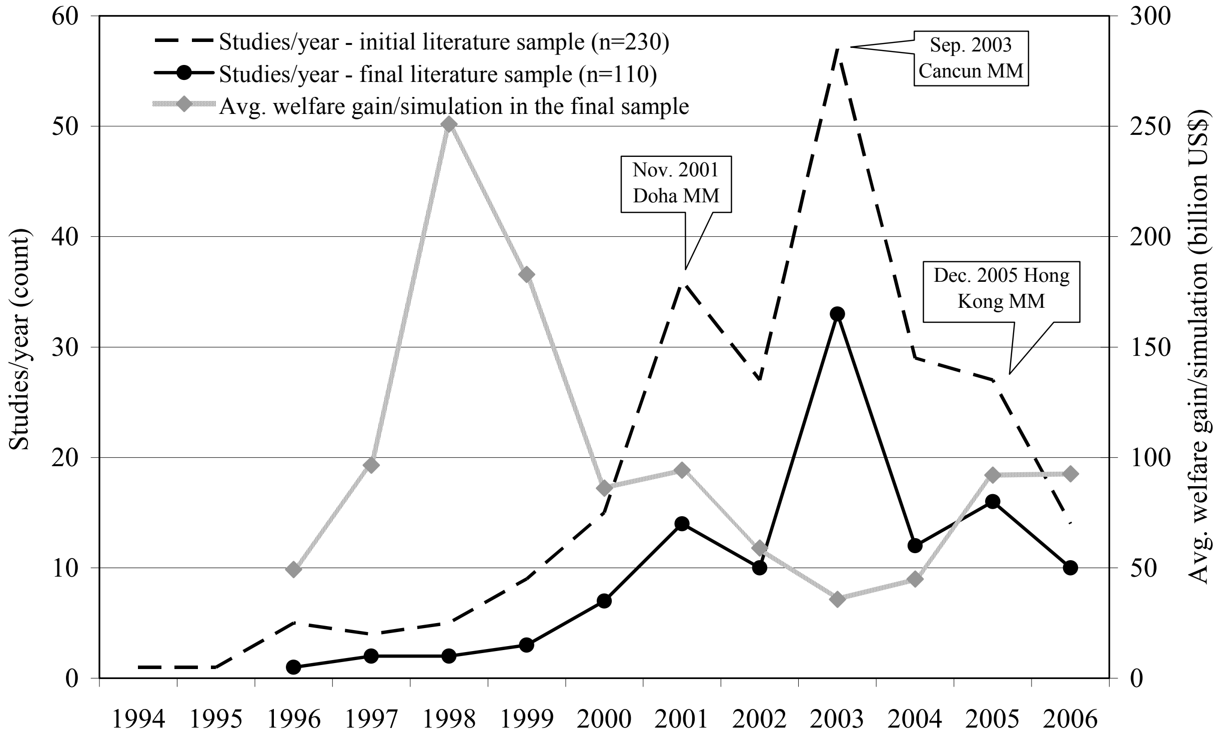
Figures

Figure 1: Simulated welfare gains from agricultural liberalisation, selected studies



Source: UNCTAD (2003).

Figure 2: Number of studies in the literature sample, and average reported welfare gain (1994 – October 2006)



Source: Own calculations based on literature sample.

Note: MM = ministerial meeting. No correction for different welfare measures (GDP, equivalent variation).

Appendix 1:

Plese refer to the following website:

http://memo-agecon.uni-goettingen.de/memo/Appendix1_SearchStrategy.pdf

Appendix 2:

Plese refer to the following website:

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