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Building a better trade model to determine local effects: A regional and intertemporal GTAP model

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ABSTRACT

Intertemporal CGE models allow agents to respond fully to current and future policy shocks. This property is particularly important for trade policies, where tariff reductions span over decades. Nevertheless, intertemporal CGE models are dimensionally large and computationally difficult to solve, thus hindering their development, save for those that are scaled-down to only a few regions and commodities. Using a recently developed solution method, we address this problem by building an intertemporal version of a GTAP model that is large in dimension and can be easily scaled to focus to any subset of GTAP countries or regions, without the need for 'second best' recursive approaches. Specifically, we solve using a new parallel-processing technique and matrix reordering procedure, and employ a non-steady state baseline scenario. This provides an effective tool for the dynamic analysis of trade policies. As an application of the model, we simulate a free trade scenario for Vietnam with a focus on the recent Trans-Pacific Partnership (TPP). Our simulation shows that Vietnam gains considerably from the TPP, with 60 of the gains realised within the first 10 years despite our assumption of a gradual and linear removal of trade barriers. We also solve for intertemporal and sector-specific effects on each industry in Vietnam from the trade agreements, showing an added advantage of our approach compared to standard static and recursive GTAP models.

1. Introduction

Free trade agreements affect both commodity supplies and demands for each partner economy over an often long period of time, since tariff reduction schedules are typically designed and implemented gradually to avoid immediate and disruptive impacts on economic activity. For that reason, regional and dynamic CGE models are a natural choice for trade impact analysis. Unfortunately, intertemporal CGE models are dimensionally large and computationally difficult to solve. These challenges have hindered the development of intertemporal CGE models, save for those that are scaled-down, with only a few regions and numbers of commodities. Using a recently developed solution method (Ha and Kompas, 2016), we address the current shortcomings of intertemporal CGE models by introducing a new intertemporal version of the GTAP model, solved with a parallel processing technique and matrix re-ordering procedure. We also build a non-steady-state version of the baseline scenario for policy simulation. This version, combined with the large dimension of our model, allows for more accurate and regionally specific long-run solutions than those obtained by standard recursive methods (Ianchovichina, 2012). Since the model is also easily scaled to focus on any subset of GTAP countries or regions, it provides an effective tool for the dynamic analysis of trade policies.

We choose to work with the GTAP model because of its extensive coverage. The dimensionally large input–output tables, the detailed trade and investment GTAP database and its flexibility in regional coding allow us to focus on any regional setting or aggregation level, while keeping the size of the intertemporal model manageable. Since our model is intertemporal, producer and consumer behaviour is optimised in the long run, thus enabling us to simulate, in particular, producers' anticipation of future tariff reductions, taking into account future investment decision in advance. Standard recursive solutions cannot account for this long-run and optimal behaviour. Using a GTAP model, we can simulate the long-run effects of recent trade agreements, including the Trans-Pacific Partnership (TPP), a trade agreement among twelve Pacific Rim countries on trade and economic policy, which was reached on October 2015 after seven years of negotiation, and the EU-Vietnam Free Trade Area (EVFTA). As an application of the model, we simulate a free trade scenario for Vietnam following the TPP and EVFTA agreements. Our simulation shows that Vietnam gains

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considerably from the TPP, with 50% of the gains realised within the first ten years despite our assumption of a gradual and linear removal of trade barriers.

In Section 2, we provide a detailed background, reviewing recent CGE modelling, contrasting the pros and cons of the various solution methods, and thus highlighting our own contribution. Section 3 builds the full intertemporal GTAP model. Section 4 focuses on the application of the model to Vietnam and Section 5 concludes.

2. Background

This section reviews basic differences between single country versus global or regional approaches and recursive versus perfect foresight CGE models, as well as their computational challenges. It explains the need for a properly defined baseline scenario, and briefly describes our solution method for large scale, regional and global solutions to otherwise computationally challenging models.

2.1. Single country versus global/regional CGE models

A single country model has a standard CGE model structure. It includes a producer, who combines intermediate commodities and primary factors of production to produce output for final demands, along with household consumption, government net expenditure, exports and investment demand. In this model, external demand for exported commodities is modelled as a downward sloping schedule, with equations for market clearing conditions and price linkages, which connect producer and consumer prices. An ORANI model (Dixon et al., 1982), or its latest version ORANI-G (Horridge, 2003), is a typical single country model which has been applied to over 30 countries with often highly detailed sectoral distinctions.

Single country models can also be disaggregated to simulate interacting regional economies within a country, with each regional economy being a CGE model itself (e.g., MMRF-GREEN in Adams et al., 2002; and the regional model for Vietnam in Ha et al., 2015). The commodities produced by each region or state/territory can then be exported to other regions, states or the rest of the world. This 'bottom-up' country model provides comprehensive policy simulations for individual economies under investigation thanks to its detailed sector (commodity) disaggregation and regional breakdown. However, as a single country model, it does not account for feedback effects from trading partners or other countries.

Such feedback effects from trading partners can be analysed using global CGE models, which are a combination of single-country models. In these models, the export of a country is the sum of all import demands of all the other countries in the model. Three most popular global/regional CGE models include GTAP (Hertel, 1997), G-CUBED (McKibbin and Wilcoxen, 1999) and MIRAGE (Bchir et al., 2002). GTAP is a global economic model using the largest available input–output and trade database, which (currently) includes 140 countries and regions and 57 commodities (Narayanan et al., 2015). The MIRAGE model is also built on a GTAP database but varies from GTAP in three important ways: (i) foreign direct investment is modelled explicitly; (ii) product differentiation is considered; and (iii) MAcMaps is used for its trade barriers database (Bchir et al., 2002; Bouët et al., 2002). Despite comprehensive geographical coverage, GTAP and MIRAGE models cannot model any single economy in great detail since data requirements need to be synchronised for every country in the model. Finally, G-CUBED is a relatively smaller regional version of a CGE model with nine countries and 12 commodities, but it is the most comprehensive regional intertemporal (or perfect foresight) CGE model in use to date.

2.2. Recursive versus perfect foresight dynamic CGE models

Dynamic CGE models have been developed to meet the demand for the policy analysis of trade agreements. These agreements are typically designed and implemented gradually to avoid sudden disruptive impacts on the economic activity of partner countries. Therefore, the conventional short- and long-run or 'switching' CGE approaches, where the capital stock is fixed in the short-run and not dynamically optimal in the long-run, are no longer adequate. Rather, dynamic CGE models are more appropriate, with capital as a primary factor of production accumulating or de-accumulating after each period.

There exist two approaches to solving dynamic CGE models, resulting in two classes of models: the recursive and the perfect foresight models. Recursive models are solved forward recursively by guessing (or forming an expectation of) future shadow prices. The guess can be based on the information of the current period or the combined information of the current period and the past (i.e., static or adaptive expectations), or adjusted until convergence is achieved based on a 'shooting approach', or better still, an iterative rational expectations approach proposed by Dixon et al. (2005). Although in theory, the shooting method or iterative rational expectations approach can converge to a solution that is optimal over the long run, it is computationally a very time consuming exercise. Dixon et al. (2005), indeed, claim that the shooting method is disappointing in practice, since it takes 10 or more hours for a modern PC to solve a single country model (using the 113 sector version of the MONASH model, Dixon and Rimmer, 2002, over 20 years, with an iterative rational expectations approach). Therefore, most of the current practical dynamic models, including recursive dynamic versions of the GTAP model, are built with static or adaptive expectations. In these cases, there is no guarantee that the solution is optimal over the long run. Their dynamic recursive setup is 'adaptive', which means that they rely on the past information to form agents' expectations. Without rational expectations or (at least) a forward-looking set of expectations, the solution does not depend on future changes in policy, even though these changes are currently known. Finally, since recursive models are solved sequentially, for one period after another, their computation cannot be enhanced using parallel processing techniques. Model dimension is thus severely limited.

In contrast, perfect foresight CGE models are designed to have optimal long-run solutions. That is, producer and consumer problems are solved in the long run, where producers and representative consumers maximise their profits or utility subject to capital accumulation and/or debt constraints. The method of solving these problems often involves setting up a Hamiltonian function, together with terminal conditions on initial stocks of capital and/or debt, assuming zero growth at the end of a very long time horizon. The solution to this Hamiltonian function is a system of 'saddle path' backward–forward differential (or difference) equations (Dixon et al., 1982; McKibbin and Sachs, 1991; McKibbin and Wilcoxen, 1999; Toan, 2007; Ha and Kompas, 2009). This system, together with other intra-period equations, is usually solved numerically by a finite differencing method for all periods simultaneously.

2.3. Perfect foresight dynamic CGE models: computational challenges and solutions

Although perfect foresight CGE models are preferable for trade analysis, their development has been inhibited by computational complexity. Indeed, the conventional solutions are possible only for small models (Dixon et al., 2005). However, regional intertemporal CGE models are typically huge in data structure. A full, non-aggregated GTAP model, for example, has more than 100 countries and regions, thus requiring more than 10 million equations for each single period in the model.

Solving a CGE model, be it large or small, boils down to finding a way to handle and solve a large system of equations. The larger the model is, the more extensive the system of equations will be, thus requiring efficient computational algorithms for a solution. Popular

CGE modelling software such as GEMPACK and GAMS use a serial direct LU decomposition, but this method is not effective for solving the extensive system of first-order condition equations arising from an intertemporal CGE model solution (Ha and Kompas, 2016). McKibbin and Sachs (1991) and McKibbin and Wilcoxen (1999) propose a so-called MSG technique which is based on a backward-recursion algorithm used for solving dynamic games. This technique is applied, first, to a linearised CGE model to find a rule representing 'jump' (or expectation) variables as a function of known state variables in any period and the future path of exogenous variables. To this end, the entire future of the economy is compressed, helping transform the model into a standard set of difference equations, solved forward. The downside of this method is that the accuracy of its solution is compromised, especially when the model is nonlinear, since its solution is based on the first-order linearisation only. Furthermore, the computation of this model cannot be enhanced using parallel processing techniques due to the iterative forward–backward recursion algorithm of the MSG technique.

Ha and Kompas (2016), on the other hand, introduce a method to convert the matrix of equations for first-order conditions in solving an intertemporal CGE model into a Singly Bordered Block Diagonal (SBBD) form. This SBBD matrix can then be decomposed into LU form and solved using parallel processing techniques. Not only does this significantly enhance computation, but the method also increases the accuracy of the CGE model solution in general since it can be applied in any multi-step or iterative solving procedure. In this paper, we show that this method is key to solving a regional intertemporal CGE model.

Another challenge to solving intertemporal CGE models is the lack of a practical baseline scenario, due also to computational complexity. Unlike static CGE models, which compare economies at different equilibrium points, dynamic CGE models compare the entire and different dynamic paths of economies through time. In addition, where recursive dynamic models need only a single observation of the economy as the baseline scenario, intertemporal dynamic models, in contrast, need an extensive collection of individual databases, one for each time period, which satisfy both intra-period and intertemporal equations. Thus, to avoid any added complexity, common practice in the existing literature is to assume that the observed current state of the economy is already at steady state, and then to adjust or shock the model repeatedly. In some sense this is acceptable, since we are generally concerned with how far the economy deviates from the baseline scenario path, from a given change, and not how the economy evolves along that path (Dixon et al., 1982). However, that said, the assumption that the starting point of the economy is at steady state is clearly unrealistic.

To address this concern, Codsi et al. (1992) and Wendner (1999) proposed a 'slack variable approach' to solve for a non-steady state baseline scenario. Despite the theoretical support for this approach, the application of the non-steady state baseline scenario is limited in practice to small models only (Codsi et al., 1992; Wendner, 1999), or to a single country model (Malakellis, 2012), due to computational constraints. Applying a combination of the 'slack variable approach' by Codsi et al. (1992) and Wendner (1999) and the SBBD ordering method (Ha and Kompas, 2016), we present the first attempt to develop a non-steady state baseline scenario of a fully intertemporal GTAP model.

3. An intertemporal GTAP model: GTAP-INT

In this section, we build the fully intertemporal GTAP model (we call it GTAP-INT) and its baseline scenario. The model is solved using the newly proposed parallel-processing technique and SBBD ordering method for intertemporal CGE models by Ha and Kompas (2016). This method allows us to solve large intertemporal CGE models efficiently with satisfactory regional and sectoral disaggregation. In this section,

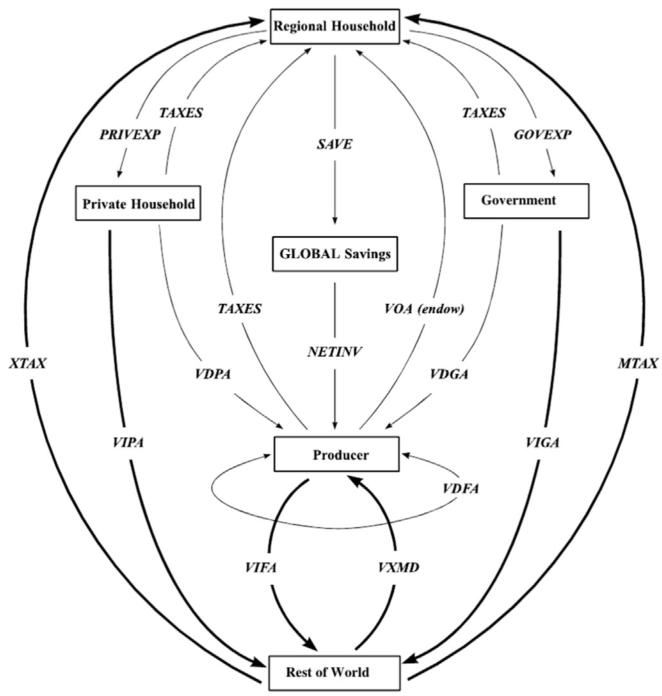

Fig. 1. Graphical representation of a GTAP model. *Source*: Brockmeier (2001).

we first describe the key features of current GTAP models, which are either static or recursive. Second, we highlight the changes we make to build a fully intertemporal version. Finally, the model's non-steady state baseline scenario is presented, followed by a discussion on model parameterisation.

3.1. Overview of GTAP current models

The GTAP model is a global model of the world economy (Hertel, 1997). As indicated, it is a summation of single-country models with an extensive multilateral trade matrix, global investment and transport activities (Fig. 1). Governed by a Cobb–Douglas utility function, regional consumers in GTAP spend income earned from productive factors across three broad categories: private consumption, net government spending and savings (Brockmeier, 2001). The constrained optimising behaviour for domestic commodity consumption and demand for imports and government spending is presented by a nested demand structure of CDE (Constant Difference of Elasticity) and CES (Constant Elasticity of Substitution) equations, while savings are redistributed back to investment in physical capital.

The regional producer in GTAP has a nested production structure of CES functions which determine how much of each category of intermediate goods and factors of production are required to generate output, and where to purchase them (domestically or through imports). Total investment is savings-driven and governed by the rental rate of capital. This investment is then added to the capital stock at the end of each period, while the demand for investment commodities is presented by a nested demand structure of CES functions. Finally, the demand for transportation service in GTAP is attached to international trade flows, while the supply is pooled from countries in a Cobb–Douglas functional setup.

By its nature, a GTAP model is a static model. Even in the current version (version 6.2), GTAP relies on a short-run closure, where the capital stock for the whole economy at the beginning of a period is fixed and serves as the initial stock to calculate the end of period stocks, accounting for net investment. To mimic a dynamic outcome, this end of period capital stock can then serve as the beginning capital stock for the next period in a recursive sequence of simulations. Ianchovichina

(2012) relies on this recursive sequence to build a recursive dynamic GTAP model. While being more informative than the static model, the recursive dynamic GTAP model has all of the inherent drawbacks of a recursive dynamic models discussed earlier.

3.2. Intertemporal GTAP-INT model

Our intertemporal GTAP-INT model is built based on the current GTAP model, version 6.2. However, our model fundamentally differs from GTAP models in terms, principally, of how investment behaviour is modelled. In our approach, the regional producer maximises long run investment returns instead of reacting only to a current rate of return, as in recursive dynamic GTAP models; and all individual capital stocks are treated as variables, rather than simply fixing the composition of the global capital stock as in static GTAP models. Accordingly, the long-term optimisation problem of the regional producer is in the form:

$$\max_{I_{r,t}} \int_0^\infty \{\tau_{r,t}K_{r,t} - \rho_{r,t}I_{r,t}\}e^{-\Theta_t t}dt \quad \text{subject to } \dot{K}_{r,t} = \Psi_{r,t} - \delta_r K_{r,t} \tag{1}$$

where $\tau_{r,t}$ and $K_{r,t}$ are, respectively, the rental price and capital stock in region r at time t; $I_{r,t}$ and $\rho_{r,t}$ are total investment and the cost (price) of investment in region r at time t; $\Theta_t = \frac{1}{t}\int_0^t \theta_s ds$ is the world average interest rate up to time t, θ_s is the world interest rate at time s; $\Psi_{r,t}$ is the increment in capital from investment activity in region r at time t; and δ_r is the regional depreciation rate. It is assumed that more than \$1 investment $I_{r,t}$ is needed to achieve a \$1 increase in capital $\Psi_{r,t}$ or

$$I_{r,t} = \Psi_{r,t}\left[1 + \frac{\phi_{r,t}\Psi_{r,t}}{2K_{r,t}}\right] \tag{2}$$

where $\phi_{r,t}$ is a positive coefficient.

The current value Hamiltonian function for this problem is:

$$\mathcal{H} = \tau_{r,t}K_{r,t} - \rho_{r,t}I_{r,t} + \mu_{r,t}[\Psi_{r,t} - \delta_r K_{r,t}] \tag{3}$$

and the first order conditions of the Hamiltonian function provide a system of motion equations, given by:

$$\dot{K}_{r,t} = \Psi_{r,t} - \delta_r K_{r,t} \tag{4}$$

$$\dot{\mu}_{r,t} = \mu_{r,t}[\theta_t + \delta_r] + \frac{\partial I_{r,t}}{\partial K_{r,t}}\rho_{r,t} - \tau_{r,t} = \mu_{r,t}[\theta_t + \delta_r] - \frac{\phi_{r,t}}{2}\left(\frac{\Psi_{r,t}}{K_{r,t}}\right)^2\rho_{r,t} - \tau_{r,t} \tag{5}$$

which can be solved (numerically in this case) if we have two terminal conditions. As common in the existing literature, these two conditions are obtained based on an assumption that capital K and its shadow price μ will remain constant at some terminal time T (large) or, put differently, the model has essentially reached a steady state at time T, represented by:

$$K_{r,T} = \frac{\Psi_{r,T}}{\delta_r} \tag{6}$$

$$\tau_{r,T} = \mu_{r,T}[\theta_T + \delta_r] - \frac{\phi_{r,T}}{2}\left(\frac{\Psi_{r,T}}{K_{r,T}}\right)^2\rho_{r,T} \tag{7}$$

Other components in GTAP (version 6.2) remain unchanged in our model. Most importantly, the regional household's utility function in this version, and hence in our model, includes savings. As a result, its derived expenditure equations are equivalent to those in an otherwise standard intertemporal optimisation problem (Hertel, 1997, Chapter 2).

3.3. Baseline scenario

A baseline scenario is required as a starting point for calculations using any CGE model. This requirement imposes a considerable computational challenge for intertemporal models. To circumvent this challenge, the existing literature, as mentioned, typically adopts an unrealistic assumption, i.e., the observed current state of the economy is the steady state.

To build a non-steady state baseline scenario, we begin with the observed database for the initial period as in static or recursive dynamic models. Since data for future periods are unknown, we use the observed data as an initial proxy for all periods. This string of identical databases will satisfy intra-period but usually not the intertemporal equations. Following Codsi et al. (1992) and Wendner (1999), we write the motion equations (4) and (5) in the finite difference form and include a slack variable for each of them:

$$K_{r,t+h} = [h\Psi_{r,t} + (1 - h\delta_r)K_{r,t}]E_{r,t} \tag{8}$$

$$\mu_{r,t+h} = \left[\mu_{r,t}[(\theta_t + \delta_r)h + 1] - h\frac{\phi_{r,t}}{2}\left(\frac{\Psi_{r,t}}{K_{r,t}}\right)^2\rho_{r,t} - h\tau_{r,t}\right]F_{r,t} \tag{9}$$

where h is the step size (i.e., the length of time between every two grid points), and $E_{r,t}$ and $F_{r,t}$ are the new slack variables. Different values of the slack variables ensure that the left- and right-hand side of Eqs. (8) and (9) are equal. To get the non-steady state scenario, we shock (or force) the value of slack variables to one and solve the entire system. This solution will satisfy all intertemporal and intra-period equations, serving as a non-steady state baseline scenario for our analysis.

3.4. Parameterisation

Since our model is built on a GTAP model, all parameters in the intra-period equations are those from GTAP version 6.2. We only need to specify the values for parameters in the intertemporal equations including $\delta_{r,t}$ and $\phi_{r,t}$. The existing literature has little agreement on the value of $\phi_{r,t}$ (see, for example,King and Wolman, 1996; Bernanke et al., 1999; Fisher, 2005; Ca'Zorzi and Rubaszek, 2012). Fisher (2005) suggests that $\phi_{r,t}$ is inversely related to the speed of adjustment toward steady state. In this paper, we follow Ca'Zorzi and Rubaszek (2012) and calibrate the value of $\phi_{r,t}$ so that the average half-life of the capital stock adjustment for all countries is roughly 15 years, which gives the value of $\phi_{r,t} = 20$ years in our case. We set the depreciation rate $\delta(r, t) = 0.08$ and the initial international interest rate $\theta = 4\%$, following Ca'Zorzi and Rubaszek (2012).

4. GTAP-INT model application: the impact of regional trade agreements on Vietnam

In the section, we apply the GTAP-INT model to analyse the impact of Regional Trade Agreements on Vietnam. We focus on TPP and EVFTA. This section starts with a review of the various future bilateral and multilateral free trade agreements signed by Vietnam, followed by a description of the calibration of the GTAP-INT model in our application and simulation scenarios. The section concludes with a discussion of results and a sensitivity analysis on the baseline scenario.

4.1. Economic reforms, integration and trade in Vietnam

Vietnam started to reform its economy in 1986. As seen in Fig. 2, it has sustained strong economic growth ever since, with an annual growth rate of 7% in the period from 1991 to 2014 (ADB, 2006, 2015), while achieving remarkable poverty reduction (WB, 2012). From being a closed, centrally planned economy, Vietnam has quickly integrated into world trade, signing trade agreements with the European Union (EU) in 1992, joining the Association of Southeast Asian Nations (ASEAN) in 1995, signing a bilateral trade agreement with the US at the end of 2001, and by gaining entry to the World Trade Organization (WTO) in 2007, along with numerous other bilateral and regional trade agreements. Vietnam has thus swiftly turned itself into an open economy, with average annual growth of the value of exports and

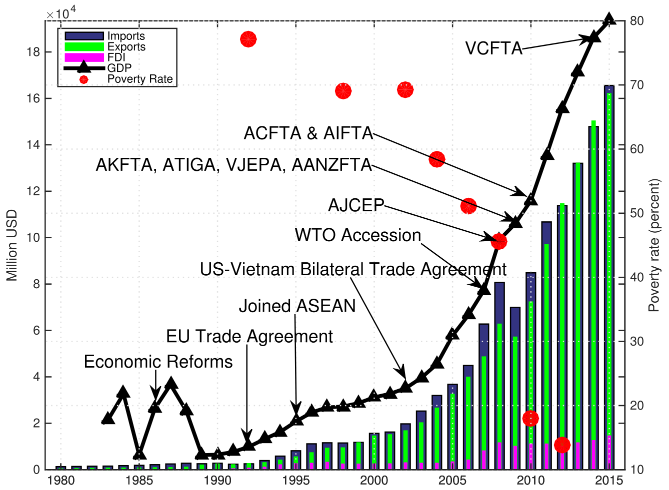

Fig. 2. Economic reforms, integration, trade and poverty in Vietnam. *Notes*: FDI, Foreign Direct Investment; GDP, Gross Domestic Product; VCFTA, Vietnam Chile Free Trade Agreement (FTA); ACFTA, Association of Southeast Asian Nations (ASEAN) China FTA; AIFTA, ASEAN India FTA; AKFTA, ASEAN Korea FTA; ATIGA, ASEAN Trade in Goods Agreement; VJEPA, Vietnam Japan Economic Partnership Agreement; AANZFTA, ASEAN Australia New Zealand FTA; WTO, World Trade Organization; EU, European Union; *Sources*: Data are from Vietnam's General Statistics Office, the World Bank and CEIC database.

imports of 20.6% and 16.7%, respectively, during the period from 1986 to 2014, and a total export–import turnover ratio to GDP of 154.5% in 2014 (ADB, 2015).

Although Vietnam has trade relationships with more than 200 countries and territories, the most significant trade agreements for this country are its regional agreements on free trade. These agreements can be classified into four broad frameworks as shown in Fig. 3. The first is the ASEAN Trade in Goods Agreement (ATIGA), which is a free trade agreement among ten ASEAN member countries including Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Vietnam and Thailand. According to this agreement, import duties on all products (with some exceptions) were eliminated by 2010 for ASEAN-6 (i.e., Brunei, Indonesia, Malaysia, Philippines, Singapore, and Thailand) and accordingly by 2015–2018 for CLMV (i.e., Cambodia, Laos, Myanmar and Vietnam). Currently, ASEAN-6 have eliminated 99.65% of their tariff lines, while CLMV have reduced their import duties to 0–5% on 98.86% of their tariff lines (ASEAN, 2010).

The second framework is ASEAN+6, which is a set of free trade agreements among the ten ASEAN countries and China, Korea, Japan, India, Australia and New Zealand. The agreement between China and ASEAN, called ACFTA, came into effect in 2010 and is expected to be near fully complete in 2018 for a majority of tariff lines (ASEAN, 2016). The agreement between Korea and ASEAN was signed in 2009 and implemented to 2018 with some flexibility for Laos and Cambodia until 2024 (AKFTA, 2016). The agreement between Japan and ASEAN on the ASEAN-Japan Comprehensive Economic Partnership came into force in 2008, and it is expected to be complete in 2026 (Ministry of Foreign Affairs of Japan, 2016). The agreement between India and ASEAN (AIFTA) came into effect in 2010, which eliminates tariffs imposed by India and ASEAN-6 between 2013 and 2018, except for the Philippines and a longer schedule for CLMV (IE Singapore, 2016). Also in effect in 2010 is the agreement on free trade areas between ASEAN and Australia and New Zealand, which eliminates at least 90% of all tariff lines from 2009 to 2025 (Department of Foreign Affairs and Trade, 2016).

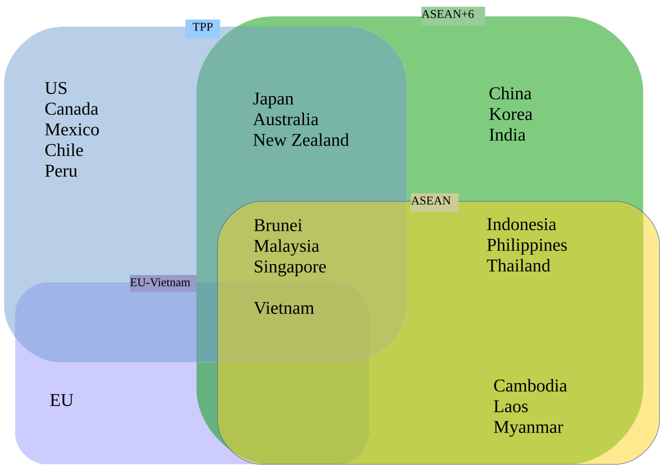

Fig. 3. Regional free trade agreements involving Vietnam.

The third framework is the EU-Vietnam Free Trade Agreement (EVFTA) which is expected to take effect from 2017 or 2018 and be completed within 11 years (European Commission, 2016). With the difference in development levels and the size of EU economy, the EVFTA is expected to allow Vietnam to exploit its comparative advantage and improve its competitiveness.

The final framework is the Trans-Pacific Partnership Agreement, a trade agreement among 12 member countries including Australia, Brunei Darussalam, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, USA, and Vietnam. The negotiations concluded in October 2015 but are pending subject to approval by signatory governments, including (with potential opposition from) the US government.

Vietnam's trading patterns reveal both its advantages and disadvantages during the integration process. Fig. 4 shows the country's key exports and imported commodities over the last 20 years or so. Thus far, Vietnam has focused on the production of labour-intensive goods such as clothing products (e.g., textiles, footwear, apparel, etc.), food (e.g., fishery products, rice, coffee, rubber, etc.) and, to a lesser extent, machinery (e.g., electronic goods, phones and their component parts). Fuel (crude oil) also accounts for a significant share in Vietnam's exports. As of 2014, Vietnam's largest export markets are the US (28.6 billion USD), followed by the EU (27.9 billion USD) and China (14.9 billion USD) (CEIC, 2016). On the other hand, as a developing country, Vietnam has imported considerable amounts of chemicals (e.g., fertiliser and mineral fuels), machinery and transport equipment, and materials for the textile and clothing sectors. Most of its imports come from China, South Korea, Japan and the EU. The import values from these markets are 43.6 billion USD, 21.7 billion USD, 12.9 billion USD and 8.8 billion USD, respectively, as of 2014 (CEIC, 2016).

4.2. GTAP-INT application to Vietnam: calibration and simulation scenarios

As indicated, our GTAP-INT is calibrated using the GTAP database, version 9. This version has 140 countries and regions with 57 products, hence allowing for both feedback from countries in a FTA agreement as well as those outside the particular FTA. To keep our attention on the impact of TPP, EVFTA and other regional free trade agreements on Vietnam, we aggregate this database into 44 countries and regions with 35 commodities (see Appendices A and B for details). As the model is solved numerically, as seen in Eqs. (8) and (9), the smaller the step size h is, the more accurate the solution will be. Since it takes time for the system to converge to a steady state, it is desirable to keep h unchanged for a sufficiently long time period before the terminal point. In this paper, we set h equal to 1 and 2 for the first 50 years and then keep h constant at 4 for the remainder of the 200-year time horizon. To this end, the model is solved for 76 time-steps with 108.5 million equations and endogenous variables and 35.9 million exogenous variables.

Regarding simulation scenarios, we use a linear approximation approach to build a bilateral tariff reduction schedule between 44 regions and countries under the above four regional frameworks,

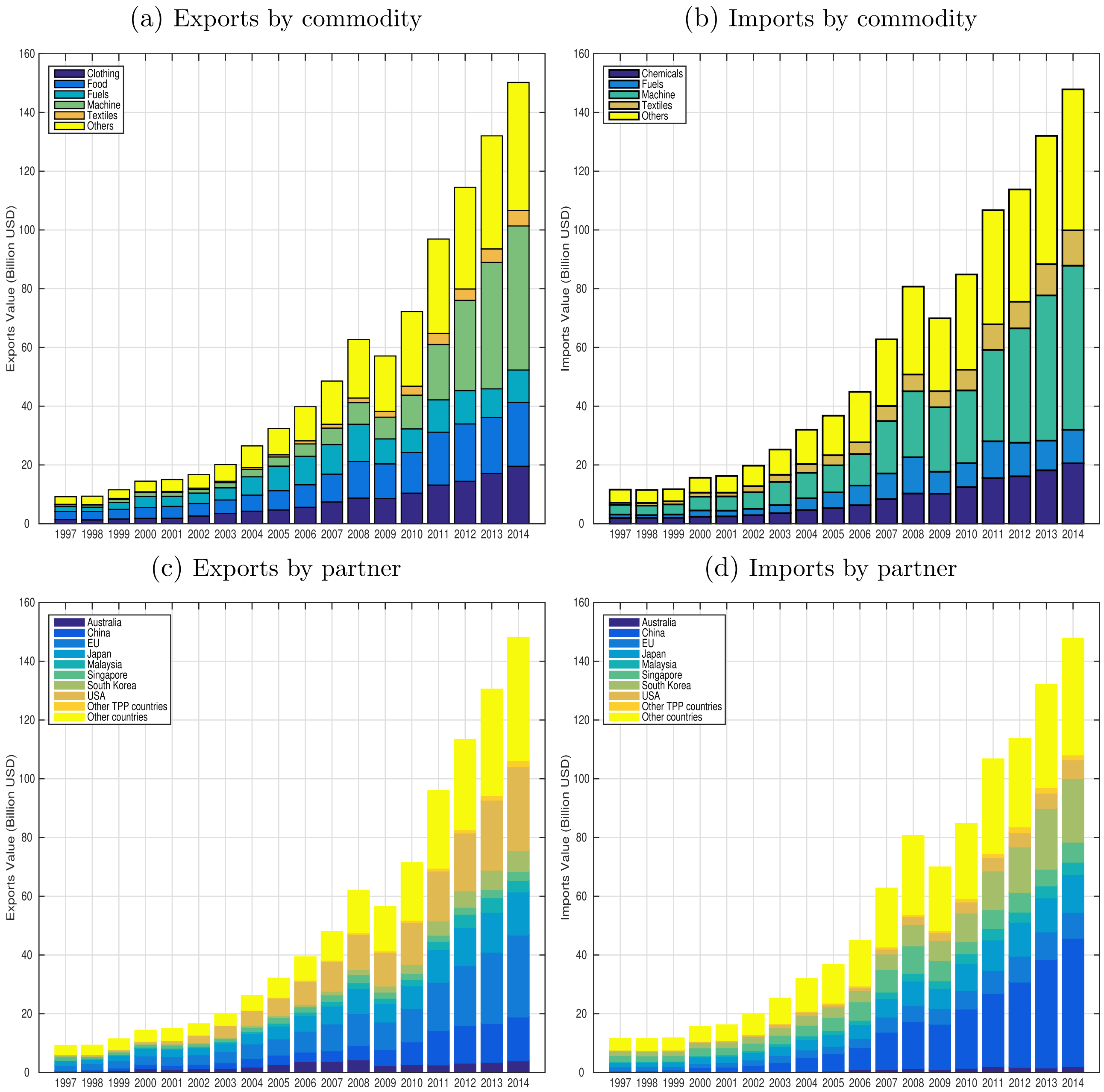

Fig. 4. Vietnam's trade values by key commodity and partner. *Sources*: Data are from CEIC database.

following Petri et al. (2012). The reason is that tariff reduction schedules, though available in the form of legal documents, are difficult to interpret and are as yet incomplete. Furthermore, the tariff reduction schedule for TPP is yet to be published, pending approval by signatory countries. Since the tariff reduction schedules for all current regional FTAs, except the TPP (under final approval) and EVFTA, are almost finished or at least half-way completed for ASEAN-6 countries, with added flexibility for CLMV, the impact on Vietnam from this simulation is largely induced by TPP and EVFTA. Finally, to take into account the fact that FTAs are usually under-utilised, we also follow Petri et al. (2012) and assume that the utilisation and maximum reduction rates are approximately 0.62 and 0.92, respectively.

4.3. Simulation results

At the global level, our simulation results suggest a clear gain for Vietnam among all trading partners, at least in terms of GDP percentage changes. Indeed, Vietnam's GDP is projected to increase from 0.12 to 0.72% in the period 2015–2019, which is much higher than the growth rate of 0.03–0.21% of the second best case, Malaysia. In the period 2020–2024, the projection is even more optimistic for Vietnam, with a GDP growth rate of 0.87–1.45%, realising about 50% of the long-run gain in GDP growth in this period due to the trade agreements. In the long run, Vietnam's GDP growth reaches 2.91%, far better, compared to the second best outcome, Malaysia, with its long-run growth rate of 0.88% (see Appendix C and Table 1, columns 2–3).

The results on changes in GDP are mixed for other trading partners. Countries or regions that do not participate in any of the seven regional trade agreements are projected to have reduced GDP levels, since less trade is expected between these countries and other countries under member trade agreements. In spite of being part of EVFTA, EU is projected to have negative GDP growth since, in part, Vietnam is a relatively small market for EU, and the benefit from EVFTA would be well offset by the loss due to TPP and, to a lesser extent, ASEAN+6. Although being part of ASEAN+6, China appears to be more negatively affected by TPP compared to the second most populous economy,

Table 1
Change in GDP by country/region (%).

Country or countries	Non-steady state baseline scenario		Steady state baseline scenario	
	2015	2233	2015	2233
Indonesia, Philippines, and Thailand	0.01	0.19	0.01	0.32
Australia	0.00	0.14	0.00	0.17
Argentina	−0.01	−0.10	−0.01	−0.09
Brazil	0.00	−0.06	0.00	−0.05
Brunei Darussalam	0.00	0.08	0.00	0.33
Canada	0.00	0.03	0.00	0.03
Chile	0.00	0.02	0.00	0.05
China	0.00	−0.06	0.00	−0.08
Cambodia, Lao, Myanmar, and Timor Leste	0.02	0.38	0.02	0.42
Germany	0.00	−0.05	0.00	−0.04
France	0.00	−0.06	0.00	−0.06
United Kingdom	0.00	−0.04	0.00	−0.04
India	0.02	0.24	0.02	0.17
Italy	0.00	−0.08	0.00	−0.07
Japan	0.00	0.12	0.00	0.13
Korea Republic of	0.01	−0.01	0.01	−0.01
Malaysia	0.03	0.88	0.03	1.00
Mexico	0.00	0.02	0.00	0.06
New Zealand	0.01	0.27	0.00	0.32
Peru	0.00	0.00	0.00	0.00
Russian Federation	0.00	−0.05	0.00	−0.04
Singapore	0.00	0.00	0.00	0.00
United States of America	0.00	0.00	0.00	0.00
Vietnam	0.12	2.91	0.20	4.06
South Central Africa	0.00	−0.03	0.00	−0.01
Central America	0.00	−0.10	0.00	−0.11
Caribbean	0.00	−0.09	0.00	−0.06
Central Africa	0.00	−0.05	0.00	−0.03
Rest of East Asia	0.00	−0.09	0.00	−0.09
Eastern Africa	0.00	−0.05	0.00	−0.04
Rest of Eastern Europe	0.00	−0.08	0.00	−0.09
European Free Trade Association (EFTA)	0.00	−0.04	0.00	−0.03
Rest of Europe	0.00	−0.07	0.00	−0.06
Rest of EU	0.00	−0.06	0.00	−0.05
Rest of North America	−0.01	−0.10	−0.02	−0.13
North Africa	0.00	−0.05	0.00	−0.05
Rest of Oceania	−0.01	−0.16	−0.01	−0.20
Rest of South Asia	−0.01	−0.07	−0.01	−0.17
South African Customs Union	0.00	−0.09	0.00	−0.06
Rest of South America	0.00	−0.07	0.00	−0.05
Rest of Former Soviet Union	0.00	−0.03	0.00	−0.03
Rest of the World	0.00	−0.08	0.00	−0.08
Western Africa	0.00	−0.03	0.00	−0.02
Western Asia	0.00	−0.08	0.00	−0.04

Source: Authors' calculations.

India. Other developed economies that are members of both TPP and ASEAN+6, such as Australia, New Zealand and Japan, are projected to increase their GDP by 0.12–0.27%. Meanwhile, North American, Latin American economies and Singapore enjoy marginal gains from TPP (Appendix C and Table 1, columns 2–3).

Our simulation results corroborate and refine previous studies on Vietnam using CGE models. For instance, using much more basic models, existing studies (Petri et al., 2012; Itakura and Lee, 2012; Areerat et al., 2012; Kawasaki, 2015) show that Vietnam experiences the largest gain from TPP. Depending on different assumptions on the removal of the non-tariff barriers, the GDP gain for Vietnam varies: 13.5% in Petri et al. (2012), 9.9% in Kawasaki (2015), 5.6% in Itakura and Lee (2012), and 2.4% in Areerat et al. (2012). The magnitudes of the gains in previous studies differ from our results because our model is fully inter-temporal and we focus on the tariff reduction schedule only, while other researchers attempt to account for the impact of removing non-tariff barriers, which is expected to increase the gains in GDP.

We now turn attention to change in production by sector in Vietnam's economy. Long-run changes are sorted in descending order in Table 2, column 9, with the largest five winning and losing sectors highlighted in grey. As can be seen, production in textiles and its supplier, plant-based fibres, are expected to increase the most, by 40% and 25%, respectively, in the long term. Wheat production also substantially increases, by 15%, to meet the demand of an increasingly wealthier population. In spite of this growth, the wheat sector remains relatively small in the economy (GSO, 2015). The free trade agreements also result in the expansion of construction and transport sectors since infrastructure, capital accumulation and transportation are all needed to facilitate trade and realise the full potential of other expanding industries.

The five largest losing sectors, which are all in agriculture or are agriculturally related, save transport equipment. Forestry and wood industries are the most severely affected, with likely falls in production from 5% to 7%. The domestic production of transportation equipment is less competitive in the context of new trade deals, falling by almost 4%. Production in oil seeds, food processing and ‘other crops’ is expected to fall by about 1.6%.

The impact of the trade agreements on agriculture deserves special attention due to its strong implications for poverty and development in Vietnam. It is evident from Table 2 that some primary sources of rural employment such as paddy, rice, vegetables, fruits and nuts, other crops, and sugar are severely affected, given the projected contractions in these sectors. In contrast, some industries such as wheat, other grains, bovine cattle, sheep and goats, horses, animal products, and fishing expand. Nonetheless, these expanding sectors are unlikely to absorb all of the redundant labour from the other contracting (and much larger in scale) primary agricultural sectors. Fortunately, the expanding textile sector, which is also labour intensive, could help relocate labour from farms to textile factories. This labour movement is expected to be strong and steady throughout, but precise magnitudes are unknown.

Changes in growth rates for export volumes and prices (see Table 3), due to Vietnam's increasing integration, further illustrate the concern. Overall, the change in sectorial production can be explained by changes in export performance in each sector. The growth in the textiles sector, for example, is due to rapid increases in exports under FTAs, as evident in Table 3. A similar result applies to other sectors such as wheat, transport, paddy rice, etc. However, for primary agricultural sectors, export quantities are projected to fall for most sectors, especially in the long run. Indeed, although export prices are projected to be higher for most agricultural exports, they are generally outweighed by the reduction in export volumes. These results again indicate challenges for Vietnam's agricultural sector, as well as for ongoing poverty reduction and economic development in Vietnam, since two-thirds of its population and most poor households live in rural areas and are highly dependent on agricultural production for their livelihoods.

4.4. Brief remarks on sensitivity and a comparison with the standard baseline scenario

Eqs. (8) and (9) show how the capital dynamic in our baseline scenario is calibrated and how it would be sensitive to initial parameter values. The values of the initial capital stock, investment expenditure, and the world interest rate, together with the depreciation rate and investment coefficient, determine how far the initial value of the capital stock is from its future steady state value, and how thus fast the capital stock adjusts toward the steady state. With non-linearity in the investment equation (Eq. (2)), along with equations of motion, Eqs. (4) and (5), our baseline scenario is expected to be sensitive to these parameter values, even if final results do not vary much.

Table 2
Change in output (%) by sector in Vietnam's economy.

Sector	2015	2016	2017	2018	2019	2020	2025	2233
Textiles	0.50	2.02	4.24	7.10	8.80	10.62	19.68	39.64
Plant-based fibres	0.23	1.26	2.78	4.74	5.87	7.11	13.13	25.04
Wheat	1.66	3.71	5.97	8.51	9.21	9.93	11.92	15.21
Construction	5.00	5.41	5.77	6.05	6.17	6.29	6.41	5.56
Transport	1.03	1.60	2.18	2.78	2.91	3.05	3.50	4.16
Trade, Hotels, Restaurants	0.27	0.41	0.57	0.75	0.94	1.13	1.95	3.74
Other grains	0.01	0.13	0.31	0.54	0.68	0.83	1.61	3.00
Electricity, Water	−0.17	−0.03	0.13	0.29	0.42	0.54	1.12	2.95
Other Services	−0.20	−0.21	−0.22	−0.24	−0.11	0.01	0.66	2.77
Communication	−0.32	−0.31	−0.31	−0.32	−0.23	−0.13	0.36	2.27
Bovine cattle, sheep and goats, horses	0.17	0.24	0.32	0.41	0.52	0.63	1.14	2.05
Other animal products	0.17	0.22	0.29	0.37	0.46	0.56	1.00	1.80
Wool, silk-worm cocoons	0.11	0.18	0.28	0.38	0.46	0.55	0.92	1.46
Non-Metallic Mineral Products	0.46	0.40	0.33	0.23	0.28	0.33	0.55	1.43
Public Administration	−0.07	−0.12	−0.19	−0.25	−0.19	−0.13	0.16	1.07
Mining	0.10	0.14	0.17	0.17	0.21	0.23	0.30	1.02
Fishing	−0.09	−0.09	−0.11	−0.15	−0.13	−0.11	0.04	0.56
Rubber	−0.53	−0.43	−0.36	−0.35	−0.31	−0.36	−0.58	0.42
Sugar cane, sugar beet	−0.24	−0.36	−0.51	−0.69	−0.69	−0.69	−0.61	−0.14
Sugar	−0.24	−0.37	−0.53	−0.71	−0.71	−0.71	−0.61	−0.15
Coal, Oil, Gas	−0.21	−0.26	−0.36	−0.48	−0.53	−0.58	−0.78	−0.34
Processed rice	−0.12	−0.14	−0.17	−0.22	−0.28	−0.29	−0.36	−0.45
Other Manufacturing	−0.66	−0.32	−0.11	0.02	−0.06	−0.12	−0.75	−0.45
Paddy rice	−0.17	−0.24	−0.31	−0.41	−0.48	−0.50	−0.63	−0.80
Vegetables, fruit, nuts	−0.14	−0.16	−0.26	−0.37	−0.45	−0.49	−0.66	−0.81
Financial services	−1.00	−1.26	−1.58	−1.96	−2.07	−2.14	−2.40	−0.94
Paper	−0.73	−0.94	−1.24	−1.59	−1.69	−1.78	−2.11	−1.09
Raw milk	−0.46	−0.50	−0.62	−0.81	−0.90	−0.97	−1.13	−1.19
Metal Products	−0.65	−0.51	−0.44	−0.49	−0.60	−0.78	−1.82	−1.56
Oil seeds	−0.41	−0.56	−0.76	−1.00	−1.17	−1.29	−1.66	−1.60
Food processing	−0.45	−0.51	−0.66	−0.91	−1.02	−1.11	−1.38	−1.65
Other Crops	−0.27	−0.36	−0.41	−0.46	−0.40	−0.56	−1.24	−1.89
Transport Equipment	0.10	−0.25	−0.70	−1.27	−1.62	−1.98	−3.27	−3.67
Forestry	−1.22	−1.61	−2.18	−2.89	−3.23	−3.57	−5.05	−4.76
Wood	−1.60	−2.10	−2.82	−3.72	−4.18	−4.61	−6.57	−6.70

Source: Authors' calculations.

In this regard, it is important to note that given a time step h, the further the gap between the initial capital stock and its steady state value, the bigger the shock to $E_{r,t}$ and $F_{r,t}$. Note, however, that the value of h cannot affect the gap between the initial and steady state value of capital, as the gap spans a long period of time. A smaller h, in other words, means a smaller the gap between $K_{r,t}$ and $K_{r,t+h}$, but it does not mean a smaller gap between the initial and terminal (steady state) values for capital. Rather, h governs the stability of our finite difference scheme: a smaller h contributes to added stability of our solution to the system of finite difference equations. However, the smaller h is, the larger the system of finite difference equations and the larger the computational burden of the model. In practice, one has to weigh the tradeoff between stability and computational capacity.

As an example of the sensitivity of our results, we run the model with the conventional steady state baseline scenario as an extreme case of our non-steady state baseline scenario and compare the two sets of results. Full results for the steady state baseline scenario are available on request from the authors. Here, we only briefly discuss how the results on scenario choice are different. Table 1 shows the difference in GDP for countries in the world given the impact of the above FTAs. For most countries, the change in GDP is similar in both scenarios. However, there are also large discrepancies, especially for the case of Vietnam, where the difference between the two scenarios is as high as 40% or 1.16% in GDP growth rate, with the non-steady state baseline scenario showing smaller gains. More precisely, the steady-state baseline scenario predicts a 4.06% increase in GDP in the long run, whereas our non-steady state scenario predicts only a 2.91% increase. The reason is straightforward. In the steady state baseline scenario, the share of production across economies is fixed at the steady state, and the difference between initial and terminal values, compared to the non-steady state scenario, is potentially large in magnitude. The added realism of the non-steady state baseline thus alters growth rates throughout.

The other benefit of comparing the results of the two scenarios is that we can also test the legitimacy of using the steady state as a baseline scenario. Although the discrepancies between the two approached are not significant for most of the variables, the large discrepancies for Vietnam (and other countries that experience relative gains) indicate the need for a more precise and realistic baseline provided by our approach.

5. Conclusion

Intertemporal CGE models have an advantage in their use of rational expectations, and optimal adjustment, allowing agents in the model to respond to a policy event even before its realisation, maximising their profit (or utility) over a greater time horizon. However, because of its large dimension, the use of intertemporal CGE modelling in policy analysis has been very limited, with only small scale models in use, and has severely lagged behind the 'second best' adaptive-recursive CGE modelling approaches. Indeed, in addition to their computational limits, intertemporal CGE models have also been criticised because of their reliance on a steady state baseline scenario, which is unlikely to be relevant or applicable in practice.

We address these two shortcomings by introducing a new intertemporal version of the GTAP model, building on a non-steady state baseline scenario for policy simulation. This, combined with the use of a new parallel-processing technique and matrix reordering procedure, allows us to solve the model more efficiently, with a very large dimension. Our method also allows for a non-steady state baseline

Table 3
Change in quantity and price of Vietnam's exports (%).

Sector	Export volume				Export price			
	2015	2020	2025	2233	2015	2020	2025	2233
Textiles	0.88	13.00	23.26	46.08	−0.09	−0.76	−0.68	−0.62
Wheat	2.80	14.56	16.30	18.97	−0.05	−0.39	−0.62	−0.76
Transport Equipment	−0.42	2.31	3.02	3.94	0.07	−0.41	−0.50	−0.48
Transport	0.76	3.56	3.60	3.44	−0.31	−1.37	−1.38	−1.40
Oil seeds	0.72	2.40	2.72	1.65	−0.05	−0.21	−0.31	−0.05
Food processing	−0.37	0.88	1.39	0.57	0.21	0.41	0.62	0.75
Non-Metallic Mineral Products	−0.32	0.43	−0.32	−0.45	0.24	0.58	0.85	0.91
Other Manufacturing	−0.68	0.18	−0.59	−0.69	0.11	0.04	0.15	0.23
Rubber	−0.80	−0.21	−1.06	−0.94	0.18	0.30	0.50	0.61
Mining	−0.50	−1.01	−1.45	−1.42	0.39	0.87	1.19	1.19
Coal, Oil, Gas	−0.52	−1.16	−1.64	−1.47	0.05	0.16	0.21	0.18
Other animal products	−0.31	−0.77	−1.09	−1.52	0.14	0.37	0.57	0.92
Sugar	−1.65	−3.02	−2.01	−1.64	0.28	0.82	1.24	1.46
Other Crops	−0.24	−0.44	−1.14	−1.85	0.10	0.65	0.77	0.93
Metal Products	−0.96	−0.84	−2.11	−2.17	0.17	0.26	0.46	0.55
Fishing	−0.56	−1.49	−2.55	−3.13	0.34	1.03	1.65	2.05
Paper	−1.06	−1.70	−3.10	−3.56	0.24	0.45	0.72	0.81
Raw milk	−1.14	−1.98	−2.90	−3.70	0.12	0.15	0.25	0.36
Processed rice	−0.53	−1.52	−2.39	−3.79	0.22	0.82	1.20	1.50
Construction	−1.00	−2.20	−3.28	−3.85	0.26	0.58	0.87	1.01
Vegetables, fruit, nuts	−0.23	−1.58	−2.65	−4.06	0.18	0.85	1.23	1.68
Other Services	−2.38	−5.61	−6.91	−4.73	0.63	1.51	1.87	1.25
Trade, Hotels, Restaurants	−1.64	−4.00	−5.53	−6.31	0.43	1.07	1.48	1.69
Forestry	−0.63	−2.32	−4.87	−6.68	0.27	1.10	1.71	2.09
Wood	−1.65	−4.55	−6.58	−6.78	0.31	0.87	1.27	1.37
Other grains	−0.44	−2.73	−4.29	−6.79	0.24	1.36	2.08	3.08
Communication	−2.13	−5.42	−7.15	−6.98	0.56	1.45	1.94	1.88
Bovine cattle, sheep and goats, horses	−0.92	−3.39	−5.13	−7.55	0.22	0.84	1.28	1.92
Wool, silk–worm cocoons	−1.01	−2.28	−4.56	−8.06	0.08	0.19	0.34	0.58
Financial services	−2.18	−5.93	−7.98	−8.60	0.57	1.60	2.19	2.37
Electricity, Water	−2.64	−6.68	−9.16	−9.48	0.46	1.21	1.69	1.75
Public Administration	−1.89	−5.52	−7.89	−10.14	0.49	1.48	2.15	2.82
Sugar cane, sugar beet	−0.88	−4.51	−7.16	−10.70	0.14	0.81	1.31	2.04
Paddy rice	−1.25	−5.05	−7.40	−10.87	0.19	0.83	1.20	1.52
Plant-based fibres	−0.54	−4.93	−8.03	−12.33	0.11	1.29	2.14	3.44

Source: Authors' calculations.

scenario, representing a first attempt to solve such intertemporal CGE models with a large dimensional scale.

Our model is also flexible with a scalable GTAP database. As an example, we have simulated trade liberalisation for Vietnam with a focus on the recent TPP and EVFTA. Our simulation shows that Vietnam experiences major gains from the regional free trade agreements, with 50% of the gains realised within the first ten years despite our assumption of a gradual linear removal of trade barriers. Although the country's GDP will increase with the implementation of regional FTAs, the results for agricultural sectors (currently the primary source of employment in rural areas of Vietnam) are mixed. Some agricultural sectors gain, some lose. Performance in some export markets also shows a considerable decline. This result highlights the need for a policy response, with a significant shift in the agricultural sector predicted and resulting impacts on employment likely to occur with free trade; results that are not possible to obtain in otherwise standard GTAP models.

With the above impacts in mind, a key policy focus for the Vietnamese government is to mitigate the impacts of the FTAs on agricultural sectors and rural areas, including the facilitation of the movement of labour out of agricultural sectors and rural areas toward the expanding industrial sectors such as textiles and construction.

Finally, we have two suggestions in mind for future research. First, it would be useful to use our modelling approach to determine the effects of past trade agreements undertaken by Vietnam on growth, output and the capital stock. Not only would this allow for a decomposition of the various and numerous trade agreements and their effects, but it would also allow the model to be tested against actual data. We plan to do this next. Second, and finally, more needs to be done on testing the sensitivity of our model parameters. This is very difficult in a model this complex, and it would pay to develop an efficient computational routine to this effect. One approach that we plan to test is to use growth paths generated (say) by IMF forecasts to determine resulting values for GDP, output total factor productivity, and so on, and then compare these values with the macroeconomic variables generated by our GTAP model to see if they match, or not. That, combined with the effects of changes in key parameter values, both by themselves and in terms of this comparison, would help further establish the robustness of our approach and indicate where changes need to be made.

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Appendix A. Country/region code

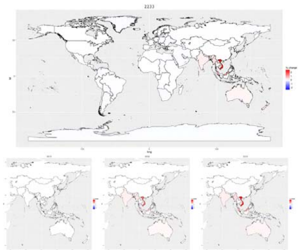
ID	Country/region code	Country/region name
1	ase	Indonesia, Philippines, and Thailand
2	aus	Australia
3	arg	Argentina
4	bra	Brazil
5	brn	Brunei Darussalam
6	can	Canada
7	chl	Chile
8	chn	China
9	clm	Cambodia, Lao, Myanmar, and Timor-Leste
10	deu	Germany
11	fra	France
12	gbr	United Kingdom
13	ind	India
14	ita	Italy
15	jpn	Japan
16	kor	Korea Republic of
17	mys	Malaysia
18	mex	Mexico
19	nzl	New Zealand
20	per	Peru
21	rus	Russian Federation
22	sgp	Singapore
23	usa	United States of America
24	vnm	Vietnam
25	xac	South Central Africa
26	xca	Central America
27	xcb	Caribbean
28	xcf	Central Africa
29	xea	Rest of East Asia
30	xec	Eastern Africa
31	xee	Rest of Eastern Europe
32	xef	EFTA
33	xer	Rest of Europe
34	xeu	Rest of EU25
35	xna	Rest of North America
36	xnf	North Africa
37	xoc	Rest of Oceania
38	xsa	Rest of South Asia
39	xsc	South African Customs Union
40	xsm	Rest of South America
41	xsu	Rest of Former Soviet Union
42	xtw	Rest of the World
43	xwf	Western Africa
44	xws	Western Asia

Appendix B. Sector/commodity code

ID	Sector code	Sector name
1	pdr	Paddy rice
2	wht	Wheat
3	gro	Cereal grains nec
4	v_f	Vegetables, fruit, nuts
5	osd	Oil seeds
6	c_b	Sugar cane, sugar beet
7	pfb	Plant-based fibres
8	ocr	Crops nec
9	ctl	Bovine cattle, sheep and goats, horses

10	oap	Animal products nec
11	rmk	Raw milk
12	wol	Wool, silk-worm cocoons
13	frs	Forestry
14	fsh	Fishing
15	cog	Coal, Oil, Gas
16	pcr	Processed rice
17	sgr	Sugar
18	fpr	Food processing
19	omn	Mining
20	tal	Textiles
21	pap	Paper
22	woo	Wood
23	rub	Rubber
24	nmt	Non-Metallic Mineral Products
25	tre	Transport Equipment
26	met	Metal Products
27	oma	Other Manufacturing
28	egw	Electricity, Gas, Water
29	cnt	Construction
30	tra	Transport
31	com	Communication
32	thr	Trade, Hotels, Restaurants
33	fis	Financial services
34	pub	Public Administration
35	osr	Other Services

Appendix C. Impact on the world economy (by time step)



Source: Authors' calculations.

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