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Characterizing Supply-Side Drivers of Structural Change in the Construction of Economic Baseline Projections

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A recent review of common modelling practices conducted during the Workshop "Shaping long-term baselines with Computable General Equilibrium (CGE) models" held at OECD in January 2018 showed that models include different assumptions on changes to the production function along their dynamic baselines. These changes imply shifts in sectoral compositions for the projected economies (i.e. structural change). This paper reviews the assumptions made by 24 modeling teams about supply-side drivers of structural change: primary factor efficiency and changes in input-output structures of the production function over time. We critically review various methodologies, identifying state-of-the-art practices, and we propose simple guidelines, particularly focusing on consistency between data sources and models. The review highlights that most models take into account structural change to some extent. However, more effort is needed in modelling projected changes in input-output structures. Furthermore, this review is helpful for understanding the functioning of dynamic CGE models and in assisting dynamic CGE modelers in building their own baselines.

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1. Introduction

Economic growth, whether driven by primary factor growth (e.g., labor, capital) or overall technical progress, is historically characterized by changes in the sectoral composition of economies, i.e. structural change. Many factors explain why growth rates are not uniform across economic sectors and commodities. On the demand-side, non-homothetic preferences is a first explanation. These preferences imply that, when income grows, households spend proportionately less on necessary goods, such as food products, and more on services. The second explanation for structural change is the varying degree of technological progress across sectors, both during economic transition (Duarte and Restuccia, 2010) and in the long run (Ngai and Pissarides, 2007). This includes efficiency differences across inputs to production. For simplicity, in this paper we will refer to this as supply-side structural change. A third explanation is that the world economy relies on international trade, and patterns of specialization in trade contribute to uneven rates of output growth and commodity demand across sectors.

The calibration process of macroeconomic projections—Gross Domestic Product (GDP), in particular—in the construction of a Computable General Equilibrium (CGE) model's baseline scenario does not imply that all goods produced grow equally. Indeed many CGE models implement endogenous structural change in the dynamic calibration process. This can be done by incorporating non-homothetic preferences, differentiated cost structure across sectors linked with non-uniform evolution of commodity prices, or exogenous assumptions on efficiency improvements of production factors.

The purpose of this paper is to describe how assumptions regarding supply-side structural change (i.e. as induced by temporal shifts in the production function) drive baseline scenarios across different CGE models. The paper provides a synthesis and justification, whenever possible, of the various modeling choices concerning the calibration of supply-side structural change, on the basis of the information provided by the modeling teams that have attended the GTAP-OECD workshop on "*Shaping long-term baselines with CGE Models*" (January 2018). Specifically, we consider three main questions:

(i) what are the main characteristic of supply-side structural change in CGE models that are necessary for forward-looking projections?
(ii) how would alternative supply-side structural change drivers affect baseline economic projections?
(iii) what are the best practices to calibrate these desired projections?

This paper does not consider structural change associated with the shifts in final demand patterns driven by changing income per capita; as this is discussed in Ho et al. (2020) of this special issue (see also Święcki, 2017). Similarly, this paper does not consider underlying macro-economic projections and changes in economic structures resulting from changes in primary factors, nor international trade assumptions. These are discussed respectively in Fouré et al. (2020) and Bekkers et al. (2020) in this special issue.

This paper provides an overview of how prominent global CGE modelling teams calibrate supply-side structural change in their CGE baselines. It does so by combining detailed explanations of modelling methods and simple illustrative simulations with a critical review of the existing modelling literature. Specifically it reviews the baseline construction methods of the 24 CGE models that were represented at the aforementioned GTAP-OECD workshop.

The paper shows that calibrating production parameters for both primary factors and intermediate inputs, leads to more realistic baselines in terms of the future sectoral composition of economies. While most models attempt, to some extent, to take into account structural change in their baseline, more effort is needed in modelling improved projected changes in firms' intermediate demands toward more services as well as possible further developments of new existing technologies, such as electric vehicles.

The remainder of this paper is structured as follows. Section 2 introduces the notion and importance of supply-side structural change, and reviews existing calibration approaches. The following two sections then present more precise aspects of calibration: Section 3 focuses on the role of primary factor efficiency and total factor productivity in supply-side calibration, while Section 4 discusses desired projected changes in the composition of intermediate demands. Section 5 concludes.

2. Calibrating supply-side drivers of structural change in CGE baseline: General overview

2.1 Simple principle of baseline calibration in the one sector neoclassical growth model

The main purpose of dynamic computable general equilibrium (CGE) models is to develop and assess various scenarios of the future of a single-country or the global economy. They generally rely on the development of one or more baseline scenarios that are used as a reference point to assess the costs and benefits of alternative policy scenarios.

CGE models belong to the class of neoclassical growth models. Therefore, the basic set up of their baseline development can be traced back to key assumptions of economic growth theory. Following Barro and Sala-i-Martin (2004), the key assumption of the neoclassical (or Solow-Swan) growth model is a production function *F* (equation 1.) that assumes constant returns to scale, diminishing returns to each primary factor, physical capital (*K*) and labor (*L*), as well as some positive and smooth elasticity of substitution between these factors.

$$Y_t = TFP_t \cdot F\left(L_t \cdot \lambda_{t,L} ; K_t \cdot \lambda_{t,K}\right) \tag{1}$$

where Y is the flow of output produced or GDP at time t, TFP is Total Factor Productivity, λ_K and λ_L are capital and labor efficiency, respectively.

This GDP equation is combined with a constant-saving-rate rule to generate an extremely simple general-equilibrium model. This simple model has the remarkable faculty to reproduce stylized facts such as "conditional convergence" of the economies (Barro and Sala-i-Martin 2004). If one adds to primary factors some exogenous technical progress (TFP in equation 1.), that guarantee long run growth of GDP per capita, the model also reproduces Kaldor stylized facts (1961).

CGE baselines generally target some projected GDP by calibrating one of the three exogenous drivers described above: capital efficiency, labor efficiency or TFP, or some combination thereof. However, since there are three potential calibration variables and one single target (the GDP), there are two degrees of freedom to calibrate another desired characteristic of the baseline. For example, one can calibrate annual TFP to match a desired projection of GDP, while using capital efficiency to target some path for the ratio of efficient capital (capital times its efficiency) to efficient labor (labor times its efficiency)—some times referred to as the balanced-growth assumption.

Therefore, the baseline calibration process of a dynamic general equilibrium model consist of: (i) defining some desired targets in the future, (ii) choosing parameters to use for the calibration (generally a parameter that has a connection to the target); and (iii) checking that other characteristics of the resulting baseline are not unrealistic. It is important to note that this last step is not to be neglected. For example it is possible to calibrate GDP by adjusting only the efficiency of capital in equation 1. While this could make sense since capital efficiency is one driver of growth, within the Solow-Swan model this would result in a permanent increase of the marginal productivity of capital, which is not consistent with any long-run stylized fact. This is why generally labor efficiency is the chosen parameter used to target GDP.

2.2 The complexity of baseline calibration in sectoral CGE models

While CGE models borrow some characteristics of the dynamics of a one sector growth model, they are much more complex as they describe the functioning of numerous commodity markets and sectors of the economy, they include final demand systems as well as the input-output structure of each sector as well as linkages through international trade.

For CGE models, the baseline calibration process does not only consist in calibrating a macroeconomic scenario (GDP, employment, capital accumulation, etc.) as described in Fouré et al. (2020). Indeed, structural change (i.e. shifts in the sectoral composition of economies and in costs structure) also needs to be calibrated. Accounting for these shifts in the construction of a CGE baseline is important for comprehensively projecting the future structure of an economy. Further, realistic projections of sectoral composition can be critical in counterfactual analysis (e.g. model simulations used to assess economic impacts of policies relative to the baseline). For instance, imposing a tax on polluting activities would not have the same impact on a country characterized by a large share of heavy industries as it would on a country characterized by a large share of financial activities.

Formally, in a CGE framework, the production structure is now more complex than in the one sector model. Equation 1 is then replaced by the following set of transformation functions (or production possibilities frontier) for each sector "*s*":

$$\begin{gathered} F_s(t, Y_{1,t}, \ldots, Y_{j,t}, TFP_{s,t} \ldots, L_t \cdot \lambda_{t,L}, K_t \cdot \lambda_{t,K}, T_t \cdot \lambda_{t,T}, NR_t \cdot \lambda_{t,NR}, \ldots, \\ ID_1 \cdot \lambda_1, \ldots, ID_j \cdot \lambda_j, e_1 \cdot \lambda_{e1}, \ldots, e_{ej} \cdot \lambda_{ej}) = 0 \end{gathered} \tag{2}$$

where $Y_1, \ldots Y_j$ stands for the outputs 1,..,*j* of sector *s*. For the sake of simplicity in exposition of determinants of structural change, two kinds of inputs are distinguished:

1) primary factors of production, which includes capital stocks "*K*", labor endowments "*L*", land "*T*", and natural resources "*NR*" and,
2) intermediate demands "*ID*" for various commodities "*j*" (e.g. commodities, crops, manufacturing goods,…) and energy carriers "*e*" (that are subset of the commodities *j* but are distinguished for illustrative purpose).

Moreover, we add to these inputs the efficiency with which they are used: TFP_s is the exogenous Total Factor Productivity of sector *s*, and λ are input-specific efficiency factors. In this paper, the so-called *supply-side structural change* is considered as deriving from changes in production technology across economic sectors. In this context, technological change can be seen as the result of any change across period "*t*" in the efficiency variables λ of the primary factors (*K*, *L*, *T*, *NR*), including changes in technical progress (*TFP*) and in autonomous efficiency of production factors and input use of a commodity *i* (λ_i). Any change in these supply-side variables will imply (i) changes in demand patterns for both final and intermediate demands, and (ii) changes in production modes. At the same time, at the regional level, the domestic production of each good is also likely to grow asymmetrically in order to fit with demand changes resulting from trade specialization.

This increased complexity of the modelling framework means that the calibration process can target much more than GDP, such as the labor income share, energy intensity, the share of services in value added or crop yields. However, it is important to keep in mind Tinbergen's principle that one calibrated variable should be dedicated to one desired target. Indeed, the calibration now involves a complex procedure, which includes: (i) the choice of the main desired characteristics (i.e. targets) a baseline should reproduce, since not everything can be represented, (ii) the choice of the potential calibration variable for each target, and (iii) a check that the resulting baseline from the CGE model has no unpleasant characteristics. If the latest fails, then step (ii) should be done again.

2.3 The importance of targeting supply-side structural change: illustration with a simple simulation

In the previous section we showed that in CGE models efficiency parameters for inputs in the production function provide several degrees of freedom to target baseline characteristics in CGE models. Among these desired characteristics, the baseline should project realistic changes in sectoral composition of the economies and in cost structures (supply side structural change).

Changes in the production function can cause shifts in economic structure through several mechanisms, including changes in relative input prices. One main characteristic of structural change that a CGE baseline should project is the increasing share of services in total value added. Indeed, Information and Communications Technologies (ICT) have paved the way for simpler and easier production methods that are cost effective and faster. The services activity is currently one of the leading economic sectors due to increased demand for service and leisure industries, among others. This also reflects an intensification of services inputs across all industries, resulting from the ICT revolution (Jorgenson and Vu, 2016) and intensification of research and development (R&D) expenses. Targeting this intensification of services input in manufacturing or in final demand is critical for projecting a realistic future sectoral composition of GDP and output cost structures. Since these processes are not endogenously modeled, the resulting productivity growth needs to be exogenously calibrated by intensifying services input in manufacturing (or in final demand, see Ho et al., 2020).

To illustrate the importance of calibrating supply-side structural change, we run a "*naïve baseline*", using the OECD ENV-Linkages model.[1] In this baseline, we only introduce one assumption on the *supply-side*: the economy-wide efficiency of labor adjusts from 2011 to 2050 to match GDP projections from OECD (2019); no other changes in primary factor and intermediate-demand efficiencies are assumed. Employment and capital accumulation are also taken from the same set of macro-economic projections. On the demand-side, assumptions on preference convergence are maintained such that the share of final demand for services increases (as discussed in Ho et al. 2020).

[1] The list of sectors and regions aggregated for this exercice is reported in Table B.1. of the appendix. The codes of the ENV-Linkages model version used for this paper as well as simulation outputs are available upon request to the corresponding author.

Figure 1 illustrates the conventional growth pattern over the 1980-2015 historical period that, in both the U.S. and China, higher GDP per capita leads to declining shares of agriculture and industry, and a rising share of services. Our *naïve* baseline projects that in the next 35 years, from 2015-2050, income per capita will still grow, and China's standard of living will almost catch-up on the 2015 U.S. level, by 2050. However, with no further assumption on structural change, the projected structure of the economy in 2050 seems unrealistic: the share of services would stay constant in China and even decline a little in the U.S. relative to 2015. Moreover, the share of agriculture in total GDP seems to increase again during the same period.

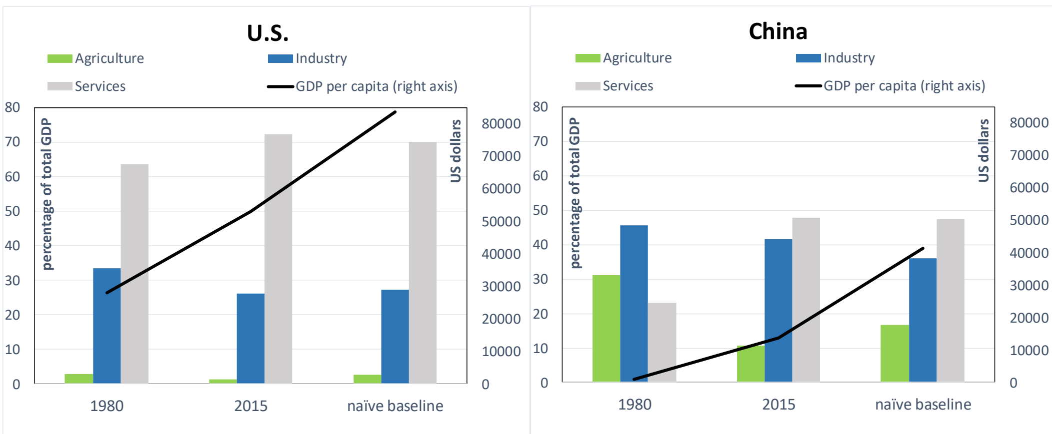

Figure 1.: Value-added by economic activity and GDP per capita: 1980, 2015 and "*naïve* baseline" projection for 2050

Notes: Gross value added at basic prices in percentage of GDP and GDP per capita in constant 2011 USD in PPP terms. The figures shows that an increase in the share of services as living standards improve does not occur in a "*naïve* baseline" projection.

Source: World Bank Indicator Database for historical years and OECD ENV-Linkages Model for projected years. A more detailed table about historical stylized facts is provided in Appendix C.

Therefore, the construction of the baseline projection of CGE models requires calibrating additional parameters of the production function to project a more realistic supply-side structural change. The following discussion will review common practices of a large set of CGE modelling teams about structural change.

2.4 Existing modelling strategies to characterize supply side structural change: general principles

This paper reviews the structural change part of the baseline construction of the CGE models that were reviewed at the GTAP-OECD workshop on "*Shaping long-term baselines with CGE Models*" (January 2018). Out of the 29 models reviewed at the workshop, this paper focuses solely on the 24 CGE models. Tables A.1-A3. in the Appendix report the main characteristics of the models reviewed in the paper.

These are all standard global CGE models where production is implemented as a series of nested constant-elasticity-of-substitution (CES) functions that aims to capture the substitution and complements across all inputs. They are predominantly (recursive) dynamic models with an Armington trade specification. In most models (16), capital (new capital only or total capital) is allocated across activities using a CET transformation function. However, 8 of these models propose an alternative rule for the dynamic allocation of capital, using different vintages of capital: installed capital stocks are sticky while new capital is freely allocated across sectors so as to equalize rates of returns. Following the GTAP-E model (Burniaux and Truong, 2002), most models reviewed bundle energy intermediate inputs and combine them directly with primary factors.

For these standard CGE models where production of each sector is represented by nested CES structure, the baseline calibration of the production side consists in adjusting parameters of the CES function over time (CES shares, scale parameter or input efficiency) to reproduce targets for either input intensity or sector shares (i.e. the desired supply-side structural change). Comparing baselines across the different modelling teams is therefore easier since model structure and calibration methods appear to be similar.

While adopting a similar modelling framework the modelling teams reviewed could be differentiated in two groups regarding the approach they retained for their baseline calibration.

The first group of teams start by defining what should be a realistic scenario about future structural change. In other words, they define a set of desirable characteristics that the projection should take into account, such as a projection about future GDP per capita across countries, the evolution of the share of services, the relative prices of manufacturing, etc. Then, the calibration process consists in choosing which supply-side variables should be calibrated to best reproduce these characteristics. In this context, these modeling teams try to calibrate the size and evolution of certain sectors (e.g. agriculture and food; energy production) or specific characteristics of the structure of the economy (e.g. trade) based on external information. For example, modelling the economics of climate change requires a plausible scenario for the future of energy systems which accounts for: the "electrification" of the economy, decreasing fossil fuel use, increasing shares of renewable electricity (including biomass), and increasing reliance on gas for the energy transition. In general, modeling teams rely on external inputs[2] to target these projected sectoral trends.

[2] Some teams adopt a slightly different methodology for some sectors, relying not on external projections but on external models: incorporating soft or hard links between their CGE model and relevant partial equilibrium model(s). Faehn et al. (2020) in this special

The second group of teams adopt the opposite approach. They take some exogenous projections about supply side variables, such as TFP, labor efficiency by sector, land efficiency, and then check to see if the characteristics of the resulting baseline are more or less realistic. This approach has the advantage to facilitate comparisons across sectors and countries since the values for calibrated variables (efficiencies) are more transparent, and therefore is more adapted to CGE models built for more academic analysis. The drawback is that models partly lose the ability to target specific trends and therefore are less adapted to more applied analysis that need to rely on some specific projected trends. This second approach is sometimes refined by some teams, not overviewed in the present paper, which adopt an hybrid approach consisting in econometrically estimating certain supply side variables to exogenous projections (see next section).

As presented in Fouré et al. (2020), the two approaches are used in the reviewed models to implement their macroeconomic baseline. 20 CGE models (of the 24 for which we have information) calibrate efficiency parameters to reproduce exogenous trajectories of GDP growth. In contrast, a few teams (only 3) directly impose exogenous assumptions on efficiency parameters and leave GDP as endogenous. In the first case, the models use specific, endogenously determined efficiency improvements to match GDP growth trajectories, whereas, in the second case, exogenously set efficiency improvements are implemented.

Other modelling and baseline calibration practices

While most common, the standard approach described is not the only one. As outlined in Jorgenson et al. (2013), an alternative methodology is to represent production processes with more flexible functional forms (such as translog or logit) that allow for more complex substitution patterns than the nested CES. Taking advantage of this flexibility helps in underkaing econometric estimations of the parameters of the production function. This approach is by essence data intensive and makes it very difficult to be applied in global models, where historical information on production variables for numerous countries appear to be almost impossible to obtain.

Between these two approaches, a third intermediate way could be chosen. Dixon and Rimer (2002, 2013) for the MONASH model or, more recently, Britz and Roson (2019) for the G-RDEM model, propose a hybrid approach in which production still relies on the CES-nesting structure but with an effort to back-cast parameter changes, using historical data to project future trends. While this approach is promising, proposing a reasonable compromise between empirical relevance and theoretical aspects, the fact that these models rely on very model-specific functional forms makes it difficult to compare them to models relying on

issue review methods for energy projection, while Delzeit et al. (2020) in the same special issue provide more details on the linking of CGE and with other models.

the standard approach. At last, some of the teams overviewed in this review, propose some econometrically estimated relationship for production, but only in some parts of the model, such as the energy system for CIRED's IMACLIM model (Waisman et al, 2012).

3. Calibration of primary factor efficiency

3.1 The importance of calibrating efficiency parameters across sectors: : an illustration with simple simulations

To illustrate good practices in calibrating efficiency parameters in baseline construction, we run four alternative baselines with the ENV-Linkage model. These are characterized by alternative assumptions on the drivers of supply-side structural change. The full list of scenarios[3] is: (1) the "*naïve* baseline" described in section 2.3, where only aggregate labor efficiency is calibrated to match GDP (2) a baseline with "adjusted efficiencies of primary factors", where labor, land and capital efficiency are sector-specific and calibrated to match sector productivities, (3) a baseline with "adjusted intermediate demands" where intermediate input efficiencies are calibrated, and (4) a baseline with "full structural change" that combines assumption of scenarios (2) and (3).

In Figure 2, additional structural change assumptions address the problem of incorrectly projected sectoral compositions of value added in the "*naïve* baseline". Sector-specific factor efficiency adjustments reduce the share of agriculture in favor of both industry and services, while the calibration of intermediate demand efficiency increases the share of services to the detriment of both agriculture and manufacturing goods.

The baseline with "full supply-side structural change" reported in Figure 2, shows a structural change more in line with historical trends as well as with the explanation of Baumol (1967) that the sectors with lowest productivity (e.g. services and public sector) would see their share in the total economy increase.[4] Since the U.S. economy is already mature, the increase in the share of services from 2015 to 2050 remains limited, rising only slightly from 72% to 74%. This increase may be underestimated, but it is more likely than the decrease to 70%, as shown in the "*naïve* baseline". For China, the share of services increases from 47% in the "*naïve* baseline" to 59% in the "full structural change" baseline. Given the

[3] The details of assumptions on changes in primary factor and intermediate demand efficiencies of these baseline scenarios are provided in the Excel file of the supplementary materials and summarized in Appendix D.

[4] The purpose of the paper is not to discuss the indicators and projected trends that a realistic baseline scenario should reproduce, but to explain how assumptions on primary factor efficiency and intermediate demand parameters affect these indicators. Nevertheless by sake of realism we add in Appendix C a table about stylized facts compiled from historical data for selected countries.

predominance of China in world GDP in 2050, this correction has considerable importance.

These simple simulations show that for a developed economy, such as the U.S., the intensification of services is a critical assumption, driving the projected increase in the services value-added share over time, while the assumption on differentiated sectoral labor productivity plays a minor role. On the other hand, for an emerging economy, like China, characterized by a lower initial share of services, capital accumulation continues vigorously (see Table 1 that presents macro-economic indicators for these two countries), and the dynamic of different labor efficiencies by sector remains the main channel driving the increase in the services value-added share.

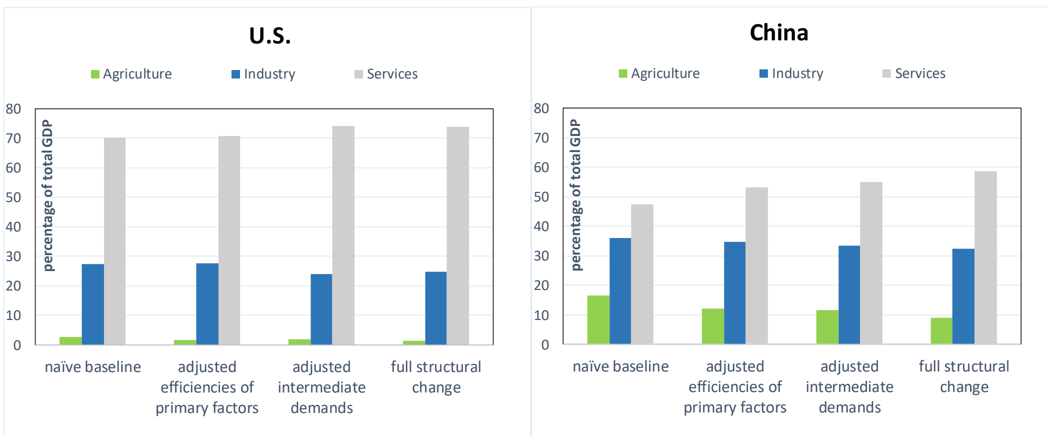

Figure 2. Adopting supply-side assumptions corrects for declining services shares in the *naïve baseline* in 2050

Notes: Gross value added at basic prices in percentage of GDP.

Source: OECD ENV-Linkages Model.

In line with long run stylized facts, the share of wage income in total income (reported in column 3) should increase following an increase in livings standards for emerging economies like China and be relatively stable for a mature economy like the U.S. In the *naïve* baseline, this is not the case for China, but the assumptions on sectoral differences for factors leads to an increasing share of labor income in China.

This steady-state hypothesis for the U.S. is confirmed by the fact that the ration of capital to efficient labor (column 7) increases very little in the U.S. between 2011 to 2050. In contrast, the capital to labor ratio rises steadily over the model horizon in regions that are the most dynamic in terms of potential growth. Consider, for example, China, where the growth path is still far from balanced and capital accumulation remains an important source of its GDP growth. The capital to labor ratio for China rises by a factor of 5 during this same period, relative to a factor of only 2.5 in the "*naïve* baseline". Indeed, in the "*naïve* baseline", the labor productivity growth is uniform across sectors, whereas, in the baselines with changes in efficiency, the labor productivity growth is more important in manufacturing than in services sectors.

Finally, the last two columns present greenhouse gas (GHG) emissions per capita and total primary energy demand (TPED), respectively. By themselves, these are not indicators of structural change. Nonetheless, there is a large variation in these indicators across the four baselines, each with the same GDP and population growth. This variation is indicative of the importance of the supply-side structural change assumptions for dealing with environmental and energy issues.

Table 1. Relevant macroeconomic indicators in 2050 for four illustrative baselines

	Services share[a]	Labor income share[b]	Labor productivity growth [c]	Wage growth [d]	Service Price [e]	Capital to labor [f]	CPI [g]	GHGs per capita [h]	TPED [i]
	% of GDP	% of GDP	Av. annual growth rate	Av. annual growth rate	Base 1 in 2011	efficient units	Base 1 in 2011	Tonnes of CO2 eq. per capita	Billion tonnes of oil eq.
People's Republic of China									
Initial year: 2011	47.5	44.5	-	-	1	8.1	1	7.3	2.8
Naïve baseline	47.4	41.8	4.1	2.8	0.69	19.9	1.15	24.1	11.2
Only factor prod. changes	53.2	48.6	4.1	3.1	0.84	28.5	1.22	16	7.3
Only int. demands changes	55.1	46.3	4.1	3.0	0.76	30	1.09	14.4	7.9
Full structural change	58.6	51.7	4.1	3.2	0.88	40.8	1.18	10.8	5.3
United States of America									
Initial year: 2011	72.7	66	-	-	1	4.8	1	19	2.3
Naïve baseline	70.1	65.8	1.5	1.3	0.97	6	1.21	29.6	5.1
Only factor prod. changes	70.7	64.5	1.5	1.3	0.98	4.3	0.97	19.3	4.6
Only int. demands changes	74.1	66.2	1.5	1.3	0.99	6.4	1.15	22.4	3.2
Full structural change	73.9	65.6	1.5	1.3	0.96	6	1.02	15.3	3.5

Notes: [a] Gross value added of services at basic prices as a percent of GDP.[b] Gross wage income as a percent of GDP. [c] Average annual growth rate over 2011-2050 of GDP to Employment. [d] Average annual growth rate over 2011-2050 of average wage rate divided by the Consumer Price Index (CPI). [e] Laspeyres Index of Service prices . [f] Aggregate capital to labor ratio, both expressed in efficiency units. [g] Laspeyres consumer Price Index. [h] Total greenhouses gases emissions (excluding LULUCF emissions) per person, tonnes of CO_2 equivalent. [i] Total primary Energy demand (TPED) in billion tonnes of oil equivalent.

Source: OECD ENV-Linkages Model.

3.2 The importance of calibrating efficiency parameters across factors: : an illustration with simple simulations

As explained in section 2.4, among the models reviewed, factor efficiencies are used to imply some baseline GDP, the latter being exogenous (and efficiency endogenous) or endogenous (and efficiency exogenous). In both cases, the modeler still has to choose which factors are impacted by the efficiency improvements (i.e., labor-only, non-capital factors[5], or all factors) and how these efficiency improvements will be differentiated across sectors.

The previous discussion highlights the importance of the sectoral differences for calibrated production parameters to target realistic projected relative sector growth (i.e. structural change). However, as discussed in section 2, the second step of the calibration is to select a good calibrated variable to do this. In this section, we use the GTAP-RD model (Aguiar et al. 2019) to illustrate how different productivity (i.e. efficiency) instruments may impact structural change in the baseline calibration. For simplicity, we implement a simple baseline that only tracks real GDP, population and labor force projections.[6] Figure 3 shows the variations in the region-wide efficiency improvement variable used to target real GDP growth in the baseline, with differences dependent on the four instruments used:

(1) Total factor productivity (TFP);
(2) Non-capital factor productivity (TFPXCAP) ;
(3) Labor productivity (LAB); and
(4) Sector-differentiated labor productivity (LABDIFF) with service-wide labor productivity equal to the calibrated economy-wide labor productivity and a positive wedge of 1 percent in agriculture and 2 percent in manufacturing.[7]

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[5] This is the default, region-wide technology shifter to target GDP in the GDyn model.

[6] Using GTAP v9.2 Data Base and population, GDP and labor force growth rates based on SSP2 projections. We also assume upward sloping supply, with uniform 0.5 supply elasticity, for the sector-specific natural resource factor. Sectoral and regional aggregation are described in Appendix B.

[7] Based on the assumption that labor productivity takes the form: $\pi^{l}{}_{l,a} = \alpha^{l}{}_{l,a} + \beta^{l,a}\gamma^{l}$ where γ^{l} is an economy-wide parameter calibrated to target GDP. Uniformity implies α^{l}=0 and β=l is one for all skill types and activities. Under LABDIFF, we assume that α^{l} =1 percent in agriculture and 2 percent in manufacturing, thereby implying that the calibrated γ^{l} represents labor productivity in services and that there is a constant (positive) wedge in agriculture and manufacturing relative to services labor productivity.

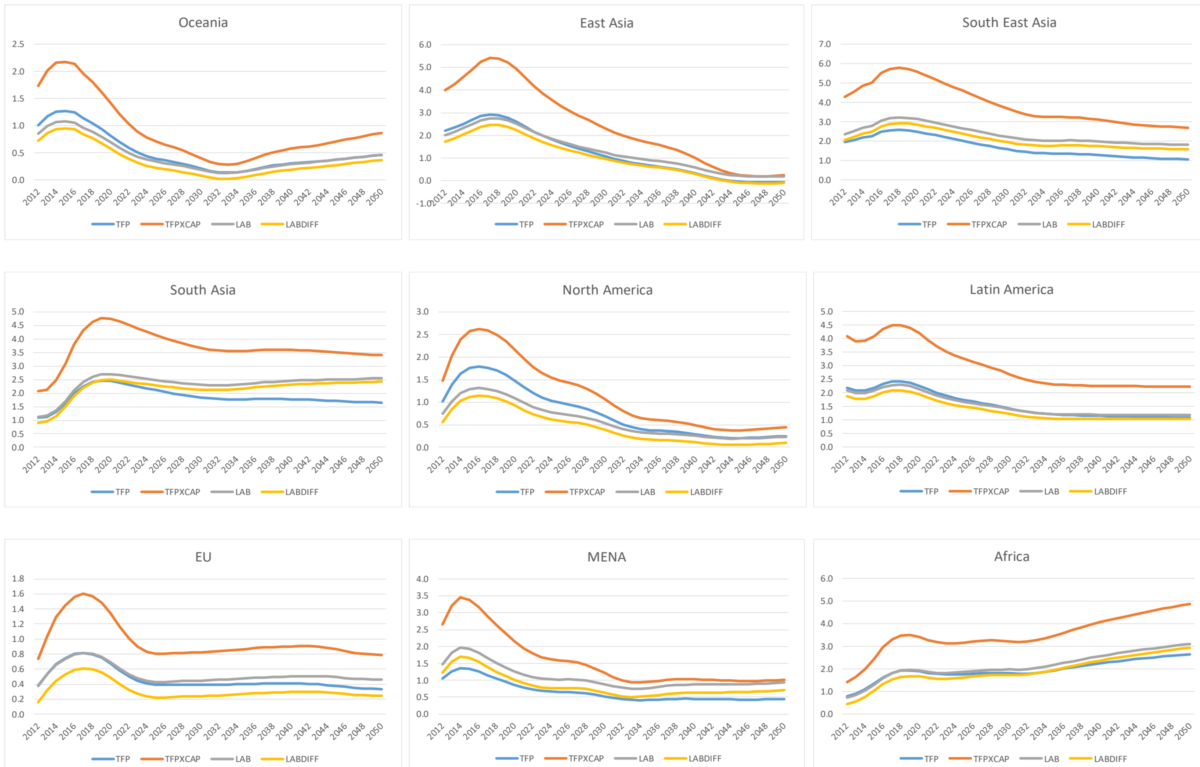

Figure 3. Endogenous efficiency improvements to target GDP growth (in % change)

Notes: The diagrams have varying scales.

Source: GTAP-RD Model.

Figure 3 shows that non-capital factor productivity (TFPXCAP) results in the largest endogenous change in region-wide efficiency improvements to target GDP, followed by either TFP or both versions of labor-biased technical change. The TFP results are somewhat mixed—i.e., regional variations exist with TFP resulting in the lowest endogenous change in South East Asia, South Asia, and MENA, whereas sector-differentiated labor productivity (LABDIFF) results in the lowest endogenous change in Oceania, North America, EU, and Latin America. Africa shows a slightly different impact, with TFP having a strong initial endogenous response, but eventually surpassed by sector-differentiated labor productivity (LABDIFF) from the middle to the end of the simulation period.

To further illustrate the importance of calibrating efficiency parameters across factors, we now look at how the different productivity efficiency instruments may affect sectoral output changes in Africa. Africa has been retained in this illustrative experiment because this region's productivity increases over time compared to all other regions. In general, Figure 4 shows that factor intensities drive a sector's productivity-induced output impacts. In the extraction sector, non-capital factor productivity (TFPXCAP) results in the highest output expansion, followed by TFP, given the importance of natural resources in total value added of the sector. Figure 4 also shows that sectorally-differentiated labor productivity results in the greatest impacts on productivity-induced output for agriculture, manufacturing, and the services sectors. The choice of productivity efficiency instrument also has important implications for sectoral factor shares. Figure 5 shows the changes in factor shares, relative to their corresponding 2011 base year shares, by broad activity in Africa. In agriculture, labor-biased productivity instruments (LAB and LABDIFF) demonstrate the expected outcome that labor shares in agriculture go down over time. Labor shares fall even further when we allow for sectoral differentiation in labor productivities—i.e., where agriculture has an additional 1 and 2 p.p. productivity relative to manufacturing and services, respectively. In contrast, labor shares in agriculture increase when TFP is used.

Figure 4. Output changes in Africa (in % change)

Notes: The diagrams have varying scales.

Source: GTAP-RD Model.

While labor shares in the extraction sector fall regardless of the productivity instrument used, we see that the share of natural resources varies significantly. Indeed, by 2050, the share of natural resources in the extraction sector's value added increases from 58% under TFP to as high as 74% under the labor-biased productivity instrument. However, the share of natural resources falls to 27% when the non-capital productivity instrument (TFPXCAP) is used. For manufacturing and services, labor shares fall under TFP but increase slightly when implementing the other three productivity instruments.

As seen above, calibrating through TFP or labor efficiency has consequences on the structural change characteristics of the baseline. For a given macroeconomic scenario, when calibration of TFP (on value added or gross output) is chosen relative to labor efficiency only, firms will face higher real wages. The labor income share in total GDP would be higher, and so is the share of services in total value added, as the productions of services are more labor intensive. In a closed economy context it would also result in an increase of the average price level (or total consumer prices). In a global world, for emerging small open economies, with low initial level of services and specialized in agriculture and manufacturing goods, the price level could sometimes be lower. In conclusion, using labor productivity instead of TFP seems more justified when the modeler want to project a larger share of services in total value added in the baseline.

Figure 5. Factor shares by broad activity for Africa

Notes: Computed from Gross Value Added at basic prices.

Source: GTAP-RD Model.

3.3 General practices and existing modelling strategies for calibrating primary factor efficiency

No consensus about the efficiency parameter chosen for calibrating production

Among the models reviewed, there is no consensus on which factors should be influenced directly by productivity improvements. However, two different groups stand out. The most common approach (adopted by about 2/3 of the models reviewed) is to consider labor-efficiency improvements as drivers of GDP per capita (for example, ENVISAGE, MIRAGE, or REMIND), whereas another significant share of models (1/3) considers an all-factor TFP improvement (among them DART, AIM, MAGNET, and G-RDEM).

Calibrating efficiency parameters across sectors is a common practice

The majority of the modelling teams reviewed in this paper differentiated technical progress (either through TFP or labor efficiency) by sector; this assumption is the core of supply-side structural change for the majority of CGE baselines.[8]

Generally the sectoral differentiation of technological progress is very crude. First, only three aggregate sectors (Services, Agriculture and Industries) are considered. Second, the productivity wedge is assumed to be uniform across these three aggregate sectors in all countries. Examples of this simple sector differentiation can be found for MIRAGE-e (Fontagné et al., 2013), MAGNET (Woltjer and Kuiper, 2014) and the ENVISAGE model (van der Mensbrugghe, 2008), where agricultural productivity is exogenously imposed (stemming from an estimated convergence mechanism) and a constant 2 percentage point (p.p.) productivity growth gap is imposed between manufacturing and services for both models. While this approach is relatively easy to implement in any CGE model, it is also subject to criticism. First, data envelopment analysis (DEA) methods used for estimating agricultural productivity frontiers fail to validate the stylized fact that productivity in agriculture may have grown faster than in manufacturing. Second, the 2 p.p. growth gap between manufacturing and services, although broadly consistent with some past estimates (e.g. Wolff, 1999), plays against the recently-observed development of services inputs.

As explained in Delzeit et al. (2020), some teams, using time-series across countries and sectors, derive more differences in productivity improvements across more sectors and countries. Examples of this deeper implementation of sectoral and regional differences in productivity could be found in the following models: G-RDEM, ENGAGE, MIRAGE-AGRODEP, ENV-Linkage, AIM or MAGNET. While this helps to fix some issues associated with agriculture-service-

[8]Note that this assumption and the commodity-differentiated Armington elasticities are the mechanisms which, in combination, drive the projected convergence in the PPP exchange rate in CGE baselines. This follows *the Balassa Samuelson effect* as explained in Obstfeld and Rogoff (2001).

manufacturing productivity, distinguishing differences in productivity across manufacturing or services sectors will not solve all problems. This is one reason why changes in input-output structure should also be considered (as in the following section) and why assumptions about the evolution of sector-specific labor productivity are important.

Indeed, some teams add scenarios about the developments in sectoral labor productivity. For example, the central scenario in ENV-Linkages reproduces a region-specific forecast of the growth rate of average labor productivity. This calibration technique is based on sector-specific productivities and region-specific gaps between sector productivities and the economy-wide average productivity (OECD, 2008). For the sake of realism, an additional convergence assumption is introduced which progressively phases out these productivity gaps across countries, with a 2% speed of convergence towards the OECD standard of productivity differences across sectors (Chateau et al., 2011). Without this latter assumption fast growing countries will project high growth but with limited shift away from agriculture sectors.

Various practice for land efficiency and TFP in agriculture production

While sectoral labor efficiency (or TFP) is the standard instrument retained to target the average characteristic of structural change in CGE baselines, most teams give a particular attention to agricultural output projections and therefore calibrate land efficiency or agriculture TFP to target these.

Most of the teams obtain estimates for exogenous crop yields, by agricultural product and by region, from external sources. Some teams use sector-specific TFP in crop-producing sectors to reproduce either crop output or crop yields from the external projections (see Delzeit et al., 2020). Others teams directly implement external productivity projections for agricultural sectors. For example, in MIRAGE-e exogenous TFP is differentiated between crop and livestock agriculture. These TFP projections come from a data envelopment analysis model which accounts for the impact of land use efficiency on each sector's TFP (Fontagné et al., 2013). However, targeting sectoral TFP instead of a direct land efficiency coefficient results in an undesired impact on land demand.

Other teams impose land efficiency or exogenous yields from crop models (DDSAT, LPJML). These estimates may be complemented with projections of agriculture production or output from agricultural models (IMPACT, GLOBIOM, IMAGE) in order to achieve a more realistic future scenario (see, for example, ENV-Linkages in OECD, 2017).

If future improvements in land yields are not accounted for, implausible structural change could occur in the baseline, such as presented in the "*naïve baseline*" of Figure **6.** Here, the share of agriculture in total value added increases in countries where land supply is abundant (e.g. the U.S.), even if this is counterintuitive (Valin et al., 2014).

3.4 Gaps in calibrating primary factor efficiency and towards better practices

Non-calibrated natural resource efficiency in CGE baseline

Capital efficiency gains, or improvements in the quality and types of machines, are generally not considered beyond general improvements in TFP in CGE model baselines. Models that have a vintage capital specification allow, to some respect, for "endogenous" change in the quality of average capital but it is not used for targeting any specific characteristic. This could appear as a weakness of CGE baselines as historical evidence shows a non-negligible acceleration in the growth rate of embodied technological change at the aggregate level (e.g. quality improvement is embodied in capital goods); see, for example, Sakellaris and Wilson (2004). However, it is difficult to find numerical evidence of sectoral differences in improvements in the quality of capital or of any supply-side structural change that such differences would imply. Therefore, a reasonable assumption could be to assume no capital efficiency gains, at either the aggregate or sectoral level.

Using the degree of freedom of capital efficiency to target some desired baseline characteristics

But if none of the models reviewed assume some capital efficiency improvements, we present now with a simple simulation that it could be a good practice to calibrate the average quality of capital to target the aggregate labor income share to GDP. We again use the ENV-Linkages model along with the set of indicators presented section 2 to examine the extent to which the assumptions on aggregate capital efficiency affect supply-side structural change. Starting from the baseline with "full structural change", as described in section 2.3, we add the following assumptions on autonomous efficiency of capital:

- Following Burniaux et al. (1992), we assume aggregate capital efficiency is dynamically adjusted to maintain "constant the capital to efficient-labor ratio" at the 2011 level.
- Aggregate capital efficiency is used to calibrate a given trajectory for the share of wage income in total income.[9]

In the long run, for a mature economy like the U.S., the average capital-labor ratio, in efficiency units, should remain relatively stable (column 6 of Table 2), indicating that the economy is on a balanced-growth trajectory. While this is a common feature of one-sector macroeconomic models, structural change in CGE models takes longer to stabilize in the baseline, and, therefore, the capital-labor ratio does not reach steady state, even after several decades.

[9] In particular, the labor share for U.S. is kept constant at its 2011 level, and all other countries converge to the U.S. level at a rate of 2% per year.

In order to target a constant capital to output ratio for mature economies and high capital accumulation for developing economies (Madison, 2001), a significant drop in the autonomous efficiency of capital could be calibrated in each period. This, however, does not seem reasonable as, most recently, innovations in information technology have been one of the main drivers of growth, especially in OECD countries. Although the GDP composition shifts towards more services with income growth (column 3 of Table 2), decreasing the autonomous efficiency of capital triggers a fall in the labor income share of total GDP (column 2 of Table 2). This contradicts historical evidence which only shows very slight declines for more advanced countries. Another undesirable outcome is that capital stock growth sharply decreases as its efficiency declines.

The second scenario first directly targets a stable labor income share, in accordance with stylized facts from Kaldor (1961)[10], and, then, calibrates average capital efficiency to avoid any substantial declines in this share. Under this scenario both the valued-added share of services and the capital to output ratio converge to realistic levels, while the rest of the indicators present values close to those of the baseline with “full structural change”. Thus, it appears promising to control the labor share via the efficiency of capital. Nonetheless, one needs to determine an appropriate projection of labor income share based on historical evidence, rather than imposing an ad-hoc convergence as implemented at present.

[10] Recent trends show that these stylized facts could be partly amended and that labor income shares have been in decline in OECD countries in the last decades (IMF, 2017), together with lower wage growth than capital income returns. But the actual fall in return to capital may be indicative that this phenomenom will not continue into future decades. For this reason, an overly sharp decline in labor shares over time may be not a realistic macroeconomic feature of long run growth.

Table 2. Baseline with alternative assumptions on capital efficiency: Macroeconomic Indicators in 2050

	Services share[a]	Labor income share[b]	labor productivity growth [c]	wage growth[d]	Service Price [e]	Capital to labor [f]	CPI [g]	GHGs per capita [h]	TPED [i]
	% of GDP	% of GDP	Av. annual growth rate	Av. annual growth rate	Base 1 in 2011	efficient units	Base 1 in 2011	Tonnes of CO2 eq. per capita	Billion tonnes of oil eq.
People's Republic of China									
Full structural change	58.6	51.7	4.1	3.2	0.88	40.8	1.18	10.8	5.3
Constant capital to labor ratio	62.6	46.0	4.1	2.6	1.02	8.1	1.26	10.5	4.8
Convergence in labor share	59.1	56.2	4.1	3.3	0.90	23.0	1.21	10.8	5.1
U.S.									
Full structural change	73.9	65.6	1.5	1.3	0.96	6.0	1.02	15.3	3.5
Constant capital to labor ratio	74.2	65.7	1.5	1.3	0.97	6.0	1.06	15.5	2.4
Convergence in labor share	72.7	66.0	1.5	1.4	0.95	6.2	1.06	15.2	2.4

Notes [a-i]: see Table 1.
Source: OECD ENV-Linkages Model.

Non-calibrating natural resource efficiency

Similarly, natural resources efficiency in natural resources sectors is held fixed across all models, aside from the calibration of TFP as mentioned above. A potential explanation for this homogeneity would be that the models incorporate mechanisms for resource depletion or natural resource supply across fossil resources (coal, oil, gas) present in the GTAP database. But in either case, it is difficult to distinguish between resource depletion and technological improvements in the extraction sectors. In particular, the calibration of natural resources is often achieved through an endogenous parameter (such as the reserve depletion factor in MIRAGE-e) which could be interpreted as a change in productivity, a change in natural resource stocks, or a combination of both effects. Either an explicit resource depletion model or coupling with a technical model could be a solution for disentangling the two effects. However, the high-level of requirements in terms of data and modeling assumptions would be hard to justify given that very few teams need to address the issue.

But there is no real reason that calibration of some resource efficient is absent of baseline construction. There exist, for example, some evidence that in some mining extraction sectors for a given amount of metallic ores extracted, the corresponding amount of pure metals available could change with some technical improvements (OECD, 2019).

The exogenity of primary factor efficiency

Another gap is the lack of endogenous efficiency mechanisms in CGE baselines. Nearly all efficiency improvement in primary factors, as discussed before, occurs via "no-cost technical change". While technically it is possible to add such an endogenous process as a baseline feature (e.g. linking human capital and education expenses to labor efficiency or adding an R&D sector that captures TFP improvements), it seems that empirical evidence to build such internal mechanism are presently limited for the entire economy and at global level. Thus, when these mechanisms do exist, they remain limited to the sector of predilection of each team; for instance, an endogenous TFP in crops sectors for the MIRAGE-AGRODEP models; learning curves in Power sectors (DART or AIM models) or in Iron and Steel (ENGAGE model).

Future efforts on the role of primary factor efficiencies in CGE baseline construction should address three main topics: (1) the collection of evidence on factor (and especially labor) intensity trends, by sector and by country, (2) an examination of how and why these sectoral productivities change over time, and (3) the identification of when a sector's production should be better calibrated via TFP or via labor productivity.

Further, previous experiments in section 3.3 showed that improvements to capital and land efficiency in CGE baselines deserve additional attention as possible tools for targeting realistic labor income shares or crops yields, in the long run.

4. *Calibrating firms' intermediate demands*

4.1 The importance of calibrating firms' intermediate demands: an illustration with simple simulations

Changes in non-factor input structures (i.e. the change in the composition of intermediate demand) across sectors represent a crucial aspect in the calibration of CGE baselines. Indeed, current trends and evidence show an intensification of services—increase in relative demand for service inputs as a share of total intermediate demand—in the production processes, which should be taken into account in CGE baselines. This intensification of services use in production process is a result of two different economic transformations: the "servitization" of manufacturing production, and the "digitalization" of economies which implies that all activities are more-service intensive. To illustrate the importance of calibrating firm's intermediate inputs, in this section we consider broad changes to input structure from servitization.

As discussed in Ho et al. (2020) of this same issue, almost all modelling teams assume non-homothetic preferences. These assumptions, together with growing GDP per capita and ageing population, help to project in the baseline a gradual increase in the share of services. The previous section of this paper highlighted that the assumption of differentiated sectoral productivity also implies an increasing share of services in the long run. Nonetheless, it may be relevant to add an additional driver of structural change towards more services: an increase in the demand for services inputs by all sectors.

To illustrate the importance of this additional driver, we use the ENV-Linkages model to implement three additional scenarios departing from the baseline “with full structural change” (described in section 3) but with alternative assumptions on the input-output structure of manufacturing and services sectors:

1. A baseline that assumes “no Service Intensification”, where no changes in the input-output structure of industries and services sectors are assumed.
2. A baseline that assumes “service intensification in manufacturing sectors” only. In this scenario, it is assumed that the CES coefficients of manufacturing sectors are adjusted such that coefficients for public and business services (transportation services excluded) increase by 1% each year (up to a limit of 0.6).[11] This illustrative scenario of increasing services’ contribution to manufacturing is in line with recent trends since 1980, as discussed, for example, by the U.S. International Trade Commission (USITC, 2013).
3. A baseline that assumes “service intensification in Services sectors” only. In this scenario, it is assumed that the CES coefficients of all services sectors are adjusted, such that coefficients for public and business services (transportation services excluded) increase by 0.2% each year (up to a limit of 0.75).

In Figure 6, the projected valued added for services in the “no Service Intensification” scenario is 3-5 percentage points lower (as % of GDP) than in the baseline “with full structural change”, varying by the region considered. Both assumptions of the baseline with “service intensification in manufacturing sectors” and the baseline with “service intensification in Services sectors” roughly equally restore value-added share in services from the baseline “with full structural change”, as observed in Table 3. Moreover a more careful examination of simulation results (not reported here) shows that, without these assumptions about services intensification, the share of services in value added could be lower in 2050 than in 2011 for OECD countries as well as for India.

[11] The CES coefficients for non services intermediate demands are proportionately decreased such that the sum of all CES coefficients for intermediate demands still equals one in each period. A similar assumption is done for the next scenario.

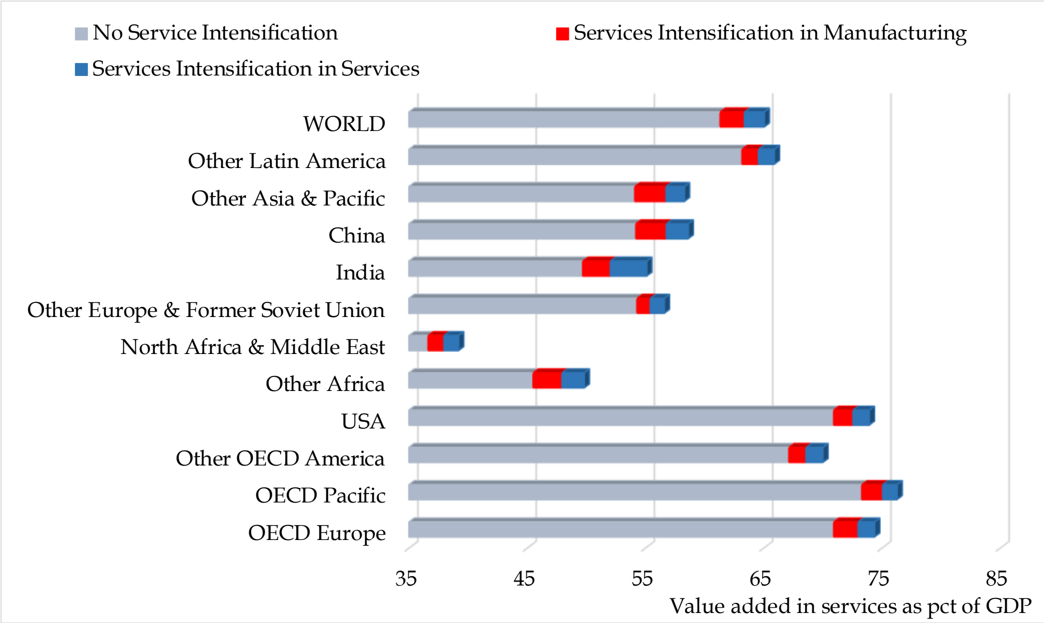

Figure 6. The intensification of services in production processes drives the increase in the share of services in total GDP: Gross value added at basic prices in percentage of GDP in 2050

Notes: For sake of readability, the axis starts at 30%. The grey bars show a baseline "with no service-intensification". We then add the red bar to obtain the baseline with "services intensification in manufacturing". Then the total bars show the value added for services in the "full structural changes" baseline mentioned in section 2. The blue bar is obtained in the figure as residual difference.

Source: OECD ENV-Linkages Model.

Interestingly, changing Input-Output coefficients towards increasing services use has relatively neutral implications for the other macroeconomic indicators (see Table 3). While it has a positive impact on the services share, it has almost no effect on other indicators. The GHGs emissions and labor income share are slightly lower, and the Services Price Index is slightly higher (as a response to higher demand for intermediate services).

Table 3. Macroeconomic indicators: "services intensification" baselines

Macroeconomic Indicators in 2050

	Services share[a]	Labor Income Share[b]	labor productivity growth [c]	wage growth[d]	Service Price [e]	Capital to labor [f]	CPI [g]	GHGs per capita [h]	TPED [i]
	% of GDP	% of GDP	Av. annual growth rate	Av. annual growth rate	Base 1 in 2011	efficient units	Base 1 in 2011	Tonnes of CO2 eq. per capita	Billion tonnes of oil eq.
People's Republic of China									
No Services Intensification	54.2	52.4	3.9	3.2	0.8	40.9	1.2	11.1	5.3
Services Intensification in Manufacturing	56.8	51.7	3.9	3.2	0.9	40.7	1.2	10.9	5.3
Services Intensification in Services	56.0	52.4	3.9	3.2	0.9	41.0	1.2	11.0	5.3
Full structural change	58.6	51.7	3.9	3.2	0.9	40.8	1.2	10.8	5.3
U.S.									
No Services Intensification	70.9	65.3	1.6	1.3	0.9	5.9	1.2	15.7	2.4
Services Intensification in Manufacturing	72.5	65.4	1.6	1.3	1.0	6.0	1.1	15.6	2.4
Services Intensification in Services	72.3	65.5	1.6	1.3	1.0	6.0	1.1	15.4	2.4
Full structural change	73.9	65.6	1.6	1.3	1.0	6.0	1.1	15.3	2.4

Notes [a-i]*: see Table 1.*
Source: OECD ENV-Linkages Model.

4.2 General practices and existing modelling strategies for calibrating firms' intermediate demands

An examination of practices across modelling teams shows that very few teams control the future input-output structures of their baseline, beyond introducing limited assumptions on energy efficiency and adjustments to food and agriculture related products. Likewise, for most teams, the demands for service inputs by firms are not controlled.

Some teams do assume a transformation of economies towards an intensification of service inputs in production processes. However, there is a lack of evidence on how structural change is driven by changes in composition of intermediate inputs in production. Therefore modelling teams proceed to implement ad-hoc manipulations of the input-output structure in order to project an intensification of service use—such as in the ENV-Linkages model (OECD, 2015)—rather than properly calibrate the baseline on existing external projections. Researchers at the Joint Research Center of the European Commission (JRC Seville) are currently working towards providing such projections.

General practices for calibrating energy demand in CGE baselines

While there is limited work done on an improved calibration of the services sectors, there are multiple examples of calibration of firms' intermediate demands in sectors that help respond to specific policy questions (e.g. energy and food production). In particular, the role of energy projections in CGE baseline construction is one of the most explored topics, as highlighted by Faehn et al. (2020) in this special issue.

All the models reviewed assume autonomous energy efficiency improvements (AEEI) which imply structural change concerning the value added of energy sectors in total GDP. Most teams assume a constant exogenous rate of about 1% annual growth for all activity sectors and the energy carriers (ENVISAGE, FARM, ICES). Other modelling teams adopt sector and fuel specific assumptions, though still implemented on a constant basis (MIRAGE-E, DART, and AIM). Finally, as described in Delzeit et al. (2020), other modelling teams calibrate these AEEI to reproduce external projections of energy demand from simulations with partial equilibrium (PE) or energy-system models. For example, the OECD ENV-Linkages Model is soft linked with the IEA-WEM model, IMACLIM is soft linked with the POLES model, and GEM-E3 is soft linked with the PRIMES model.

The example of energy calibration highlights tradeoffs in the choices of supply-side calibration. CGE baselines should reflect common characteristics of most available energy projections, such as the increased electrification of the energy system in the future (IEA, 2017). These trends are fully reflected when models directly reproduce external projections. On the other hand, some of the teams that set a uniform AEEI trend for all fuels and sectors and impose an increase of the CES share parameter of electricity in the energy bundle (ENVISAGE model). Further investigations should examine the extent to which controlling the CES-coefficients versus adjusting AEEI best calibrates increasing electrification in baselines. Either way, calibrating to exogenous energy projections through model parameter changes (AEEI or CES coefficients) is advantageous in that it explicitly aligns the CGE baseline to be in track with energy models[12] (see Delzeit et al., 2020).

4.3 Gaps in calibrating firms' intermediate demands and towards better practices

As highlighted in the previous section, modelling teams make some efforts in targeting intermediate demands in order to imply realistic changes to the sectoral composition of GDP in CGE baselines.

[12] In the paper of Faehn et al. (2020), a comparison of the energy system under the "naïve baseline" and the "full structural change baseline", as discussed in sections 2, shows how this calibration process matters for projected energy demands, using the OECD ENV-Linkages model.

Calibrating some intermediate demands is sometimes missing

However, some important trends have been overlooked. Indeed, projections of certain sectors in CGE baselines can be unrealistic because the changes to household preferences are insufficient, and, to compensate, a modeler could calibrate intermediate demands for these goods by firms. However, the problem is that empirical validation is generally weak. Checking projections of the share of services versus that of agriculture or industries is one recommended step, but, in general, modelling teams do not go beyond this step.

Certain commodities appear to be crucial inputs for particular sectors in many models. However, when external projections or historical evidence are missing, the corresponding variables in the CGE baseline are not calibrated (e.g. iron and steel demand by the construction sector or by vehicle manufacturers). In the best case, where efficiency parameters for certain commodities are calibrated (e.g. feed efficiency for livestock sectors) to target a desired projection for these commodities (e.g. feed demand), the justification of the target themselves is generally not discussed. As additional example, while most modelling teams pay attention to the calibration of food demand parameters in order to indirectly calibrate the production level of agricultural sectors, generally little attention is paid to the calibration of textile demand parameters.

The issue of consistency between existing projections of intermediate demands and their implementation in CGE baselines

Even when projections or evidence for certain efficiency trends are available and well documented (such as fertilizer efficiency projections from agricultural models like IIASA-GLOBIOM or IFPRI-IMPACT), it is still not easy to "import" these trends into CGE baselines. Indeed, there is a lack of consistency between the theoretical structure of CGE and the PE models that prevents parameters calibrated in PE models from being directly used in CGE models. For example, in the IFPRI-IMPACT agricultural model international trade assumes product homogeneity while CGE models are characterized by product heterogeneity and distinction between domestic and imported goods. Similarly, modelers should avoid implementing efficiency parameters calibrated with another model which was calibrated to a different baseline, because factor efficiency calibration is model dependent

The problem is even more acute for projections of the energy system, where energy demand by one sector is targeted but the production of the same sector is not. This is problematic as energy demand alone is less relevant if related projections of energy intensive industry production (e.g. steel, cement) or other energy intensive activities (e.g. transportation) are not considered. A desirable, albeit difficult, good practice should be that targeted projections of input demand by certain sectors are aligned with consistent projections of activity levels for the same sector. For example, when reproducing energy projections of a partial equilibrium model in a CGE baseline, the modeler should also take into account projections for GDP, and for key sectors (e.g. steel, cement, and transport). Not accounting for these economic factors of the energy model could potentially be a major source of errors (Chateau, Magné and Cozzi, 2013).

A good practice in a CGE baseline intended to target projections of exogenous intermediate demand would be to calibrate intermediate demand parameters (efficiency or CES shares) to match sectoral intermediate demand intensities and not demand levels. But here again the relevant information should be available

5. Conclusion and further research efforts

This review of common practices used in CGE provides some simple guidelines about supply-side drivers of structural changes to design baseline projections, and highlights gaps in modelling practices.

Simple simulations with different assumptions on drivers of structural change show that CGE baselines that exploit available information on projected supply-side structural change tend to be more realistic than baselines that leave structural changes to be endogenously determined by the model.

A review of 24 models similarly concludes that when teams calibrate production parameters (efficiency or scale and CES parameters) for both primary factors and intermediate inputs, they produce a more realistic baseline in terms of the future sectoral composition of economies. The review indicates that there is no common practice on the choice of the production parameters used to target differences of productivity across sectors and GDP. While a majority of the modelling teams choose labor efficiency to play this role, a non-negligible number of teams opt for TFP. This choice has an impact on the projected structural change in the baseline, generally involving different GDP shares of labor income and services. The review also highlights that the calibration of capital (and natural resources) efficiency is generally not exploited by modelling teams and could for example be used to successfully target plausible wage income shares.

In terms of future developments, more efforts could be used to identify the main characteristics of supply-side structural change associated with economic growth that dynamic CGE models should try to mimic. Using information on the projected dynamics of key sectors, such as services, energy and agriculture, are common good practice among the reviewed models. However, the projections for other sectors are still poorly represented in most CGE baselines. For example, improving the realism of projections for key manufacturing sectors (heavy industries, textiles) could greatly improve the baseline calibration of CGE models, especially when agriculture or energy are the key focus of the modelling analysis.

While most models try to exploit available sectoral projections, it is difficult to collect comprehensive information on what future economic growth means for future changes in the sectoral composition of the economy. Furthermore, in the future there might be new sectors and goods arising thanks to technological improvements. These are difficult to foresee and therefore model. Nevertheless, some efforts are being made in modelling future developments of new technologies and sectors. Examples include the case of electric systems. Indeed, half of the teams reviewed in this paper adopt multiple technology for electricity generation and impose in their baseline some projections about future electricity mix across power technologies. Other examples include the introduction of multiple technologies for agricultural production, such as the distinction between rain-fed and irrigated technologies in the GTAP-W model (Calzadilla et al. 2011), or multiple technologies for metals production in ENGAGE-materials (Winning et al. 2017) and in ENV-Linkages (OECD 2019). Despite these examples, more work is needed to integrate new technologies in CGE baselines, at least regarding the introduction of key existing technologies such as large electric or hydrogen vehicles or the "digitalization" of traditional activities. This would offer a more realistic picture of long run structural change.

Another interesting aspect that deserves further attention is the incorporation of *supply-side structural changes* due to the projected impacts of climate change and other environmental damages (e.g. pollution costs, water scarcity). These shocks are generally integrated in CGE baselines as sector-specific exogenous shocks to the production function, as discussed by Sue Wing and Lanzi (2013), and they can be considered as drivers of *supply-side structural change*. Examples of integration of environmental damages in CGE baselines can be found in several papers on climate (Roson and van der Mensbrugghe, 2012; Ciscar et al., 2011; Eboli et al., 2010; Bosello et al. 2012; Dellink et al., 2019) and a few on air pollution (Lanzi et al., 2018; Vrontisi et al. 2016; Vandyck et al., 2018). Even if introducing environmental damages in a baseline might not be essential for all CGE teams, this issue will gain increasing importance as climate change impacts become more apparent. As such, it will be important to further develop these aspects.

Overall, it is encouraging to see that most CGE models exploit sectoral existing information to tailor their baseline calibration to their needs. Further collaboration and data exchange could be beneficial for different teams, and for new model developments.

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Appendix A. Details on Models

Table A.1. Main characteristics of models reviewed

	Model Name	Institution	Model TYPE	Country Coverage	Capital vintage	Trade
1	**ADAGE**	RTI/US-EPA	CGE	GLOBAL / US	yes	Armington
2	**AIM**	NIES	IAM (CGE + Spatial explicit land use model)	GLOBAL	yes	Armington
3	**DART**	KIEL institute for world Economy	CGE	GLOBAL	No	Armington
4	**EC-MSMR**	ENV Canada	CGE/Macro	GLOBAL / Canada	yes (?)	Armington
5	**ENGAGE**	UCL	CGE	GLOBAL	no	Armington
6	**ENVISAGE**	GTAP	CGE	GLOBAL	yes	Armington
7	**GAPS-ENVISAGE**	FAO	Partial AG(GAPS) / CGE (ENVISAGE)	GLOBAL	yes	net trade (GAPS)
8	**ENV-Linkages**	OECD	CGE	GLOBAL	yes	Armington
9	**EPPA**	MIT/US-EPA	CGE	GLOBAL	yes	Armington
10	**EU-EMS**	PBL	CGE		no	?
11	**EXIOMOD**	TNO	IO/CGE		?	?
12	**FARM**	US-DA	CGE	GLOBAL	?	?
13	**Gdyn**	GTAP	CGE	GLOBAL	no	
14	**GEM-E3**	JRC	CGE	GLOBAL	no	Armington
15	**GLOBIOM-MESSAGE**	IIASA	IAM/PE	GLOBAL	no	
16	**ICES**	CMCC	CGE	GLOBAL	no	Armington
17	**IGEM**	Jorgenson et al.	RE model	US	no	closed economy
18	**IMACLIM-R**	CIRED	CGE	GLOBAL / France	yes	Armington
19	**MAGNET**	LEI	CGE	GLOBAL	no	Armington
20	**MAGNET**	THUNEN	CGE	GLOBAL	no	Armington
21	**MIRAGE-e**	CEPII	CGE	GLOBAL	no	
22	**PACE**	ZEW	CGE	GLOBAL	no?	

	Model Name	Institution	Model TYPE	Country Coverage	Capital vintage	Trade
23	**REMIND**	PIK	Macro/ENRG	GLOBAL		New approach
24	**SNoW-NO**	Statisics Norway	CGE	Norway	no	Armington /small open economy
25	**TEA**	PPE/COPPE	CGE	GLOBAL	no	Armington
26	**WEGDYN_AT**	Wegener Center	CGE	GLOBAL / Austria	no	Armington
27	**MIRAGRODEP**	IFPRI	CGE	GLOBAL	yes	Armington

Table A.2. Assumptions about primary factor efficiency of models reviewed

	Model Name	Institution	TFP	λ_L	λ_K	λ_{LAND}	λ_{NatRes}	λ_e	λ_{feed}	$\lambda_{fertilizer}$	$\lambda_{emissions}$
1	**ADAGE**	RTI/US-EPA	Exogenous	Endogenous / GDP endogenous	?	?	?	EXO ?	?	?	?
2	**AIM**	NIES	Endogenous	Endogenous / GDP endogenous	EXO constant for non-energy transformation sectors (ETP) / ENDO	EXO (FAO/IFPRI)	For fossil fuel, reserve and cumulative consumption are considered	increase pref. for ELY	EXO / 1%	EXO / 0%	LAP emissions rates / GAINS
3	**DART**	KIEL institute for world Economy	ENDO (Aggregate) / GDP EXO + TFP crops ENDO / crop yield EXO (source?)	Exogenous (human capital projections)	?		?	EXO (source?)	EXO / 0%	EXO / 0%	?
4	**EC-MSMR**	ENV Canada	Exogenous	?	?	?	?	EXO (using another model)	?	?	?

	Model Name	Institution	TFP	λ_L	λ_K	λ_{LAND}	λ_{NatRes}	λ_e	λ_{feed}	$\lambda_{fertilizer}$	$\lambda_{emissions}$
5	**ENGAGE**	UCL	Endogenous at aggregate level	Endogenous and sectoral / GDP endogenous	No	EXO (FAO/IFPRI)	No	ENDO to reproduce a given energy mix	No	No	No
6	**ENVISAGE**	GTAP	Exogenous	Endogenous and sectoral / GDP endogenous	?	EXO (FAO)	NO	EXO : 1%/yr	EXO (FAO)	?	?
7	**GAPS-ENVISAGE**	FAO	Exogenous	with ENVISAGE:Endogenous and sectoral / GDP endogenous	(same as ENVISAGE)	EXO (FAO)	NO	EXO (ENVISAGE)	GAPS based on FAO GLEAM model	for agriculture post-solve in GAPS; for the rest of the sectors same as ENVISAGE	for agriculture post-solve in GAPS; for the rest of the sectors same as ENVISAGE
8	**ENV-Linkages**	OECD	Endogenous for Crops only / Crops output exogenous	Endogenous and sectoral / GDP endogenous+	ENDO / Aggregate for labour share EXO	EXO (IFPRI)	NO	ENDO / energy intensity (IEA)	EXO (GLOBIOM)	EXO / 0%	LAP emissions rates (GAINS) - industrial and

	Model Name	Institution	TFP	λ_L	λ_K	λ_{LAND}	λ_{NatRes}	λ_e	λ_{feed}	$\lambda_{fertilizer}$	$\lambda_{emissions}$
				Convergence of sectoral Productivity to OECD							Fugitive GHG (US-EPA/IEA)
9	**EXIOMOD**	TNO	Exogenous	Exogenous (from CEPII) / endogenous GDP	?	EXO (FAO)		EXO (CEPII)	?	?	?
10	**FARM**	US-DA		Endogenous and sectoral / GDP endogenous	Fixed constant some exception SOL&WIND	EXO (IFPRI)		EXO / 1%	?	?	?
11	**Gdyn**	GTAP	EXO adjustment for Food - TFP oil ENDO / OIL PRICE EXO	Endogenous and sectoral / GDP endogenous	?	ENDO sectoral / GDP EXO	ENDO sectoral / GDP EXO	EXO	?	?	?
12	**GEM-E3**	JRC	ENDO (sectoral difference) / GDP EXO	Endogenous and sectoral / GDP	ENDO sectoral / GDP EXO	na	EXO	EXO	na	na	EXO

	Model Name	Institution	TFP	λ_{L}	λ_{K}	λ_{LAND}	λ_{NatRes}	λ_{e}	λ_{feed}	$\lambda_{fertilizer}$	$\lambda_{emissions}$
				endogenous							
13	**ICES**	CMCC		Endogenous and sectoral / GDP endogenous	na	EXO: Source ISI-MIP / Level: Based on historical yield trend	na	EXO (IEA) <1%	na	na	na
14	**IGEM**	Jorgenson et al.	Exogenous and sectoral / GDP endogenous					projected with energy eq. System			Adjustment to US-EPA
15	**IMACLIM-R**	CIRED	Exogenous fixed	Endogenous and sectoral / GDP endogenous	ENDO: Capacity constraint	Exo: hardlinked NLU model	for fossil fuel: cost curves (grades)	ENDO catch up of efficiency	Exo: hardlinked NLU model	EXO	?
16	**MAGNET**	LEI	ENDO (sectoral difference) / GDP EXO	Endogenous and sectoral / GDP endogenous	no	EXO (IMAGE) + ENDO factor (via sumstitution with other	ENDO sectoral / GDP EXO	EXO for feedstock (enrgy models, 0 in case no information),	EXO (IMAGE) + ENDO factor (via sumstitution with other	ENDO sectoral / GDP EXO	EXO (IMAGE), EXO/ENDO depending on CO2 price in

	Model Name	Institution	TFP	λ_L	λ_K	λ_{LAND}	λ_{NatRes}	λ_e	λ_{feed}	$\lambda_{fertilizer}$	$\lambda_{emissions}$
						primay input and fert.		EDNO/sectoral for other input	primay input and fert.)		place (IMAGE or other external data)
17	**MAGNET**	THUNEN	Endogenous (aggregate level) / GDP exogenous	na	na	na	na	na	na	na	na
18	**MIRAGE-e**	CEPII	ENDO (sectoral difference) / GDP EXO + Transportation specific	?	?	EXO: 0		EXO (own source)	EXO: 0		EXO: 0
19	**REMIND**	PIK		Endogenous and sectoral / GDP endogenous		EXO (MagPIE)		EXO (Energy Model)			No
20	**TEA**	PPE/COPPE	ENDO (sectoral difference) / GDP EXO	EXO / sectoral diff	No	EXO : 1%	No	COFFEE energy Model	No	No	No

	Model Name	Institution	TFP	λ_L	λ_K	λ_{LAND}	λ_{NatRes}	λ_e	λ_{feed}	$\lambda_{fertilizer}$	$\lambda_{emissions}$
21	**WEGDYN_AT**	Wegener Center	ENDO (aggregate) / GDP EXO	effective labor supply: EXO: 1%yr in addition to population growth	ENDO: investment drives K stock, which gives effective K supply	EXO (IIASA SSP crop landcover)	no	EXO : 1%/yr	no	no	no
22	**MIRAGRODEP**	IFPRI	**Non Ag sector**: Targeted on IMF projection from baseyear to 2025. Average TFP growth rate over between 2015-2025 applied between 2025-2030. **Ag sector**: Adjusted to duplicate AglinkCosimo or FAO yield projections	n.a.	n.a.	n.a.	n.a.	no change in 2030 baseline.	no change in 2030 baseline.	n.a.	n.a.

Model Name	Institution	TFP	λ_{L}	λ_{K}	λ_{LAND}	λ_{NatRes}	λ_{e}	λ_{feed}	$\lambda_{fertilizer}$	$\lambda_{emissions}$
		(for commodities not included in AgLinkCosimo)								

Table A.3. Assumptions about intermediate demand efficiency of models reviewed

		Other Technological Changes					
	Model Name	Natural Res. Supply (shifter)	new Technology / new Goods	Changes in Multiple Technology	Changes in intermediate demand	Trade	Preferences
1	**ADAGE**	?	Adv POW / Adv BioFuel	POWER / calib : ?	?	?	?
2	**AIM**	NatRes to target prices	Adv POW / Hydrogen, 2d Gen BF None in BaseYear	increase pref. for renew / Cost curves for ren. POWER	Steel input: 3% per annual Food to service sector: calibrated from FAO projection	No	Food; Income elasticity is calibrated based on FAO proejction
3	**DART**	?		POWER learning curves for renew / learning curves for renew. in general	?	?	convergence?

		Other Technological Changes					
	Model Name	Natural Res. Supply (shifter)	new Technology / new Goods	Changes in Multiple Technology	Changes in intermediate demand	Trade	Preferences
4	**EC-MSMR**	?	backstops for Power & Transport + Hydrogen + CCS	?	?	?	?
5	**ENGAGE**		No CCS power	Reproduce a given power mix (from TIAM-UCL)			No in BAU
6	**ENVISAGE**	?	CCS - POWER & Adv POW	increase pref. for renew in POWER & CC for renewable	AG&Food Coeff adjustments / increase pref. for ELY vs NON-ELY for transport	Itl. Transport cost : EXO - 1%	control of food demand & Agr. / increase pref. for ELY vs NON-ELY

	Model Name	Other Technological Changes				Trade	Preferences
		Natural Res. Supply (shifter)	new Technology / new Goods	Changes in Multiple Technology	Changes in intermediate demand		
7	**ENV-Linkages**	ENDO / Fossil Fuel Price EXO (IEA)	NO CCS - POWER in BAU	reproduce a given power mix (IEA)	Increase of services input in production / AG&Food Coeff (IFPRI)	Itl. Transport cost : EXO - 1% / Increase Services trade / Increase import by OECD from Non-OECD	ENDO pref. For energy demands (IEA) / for Agr and Food (IFPRI) + conditional convergence of preference towards OECD
8	**EPPA**	?	POWER CCS + backstops for Power & Transport	?	?	?	control food demand via non-homothetic pref.

		Other Technological Changes					
	Model Name	Natural Res. Supply (shifter)	new Technology / new Goods	Changes in Multiple Technology	Changes in intermediate demand	Trade	Preferences
9	**FARM**	?	?	deline cost of SOL & WIND (how?)	AG&Food Coeff	?	control food demand food + control of min subsitiance to mact what?
10	**GEM-E3**	Exo (POLES) - internatinal prices and volumes	Exo (PRIMES, POTEnCIA, POLES) - both costs and market share	Exo (PRIMES, POTEnCIA, POLES) - both costs and market share	Electrification trend	Long Term convergence (in 2125) of current account to 0 (except for energy producers)	Exo Food, Transport, Energy (POLES, POTEnCIA, PRIMES)

	Model Name	Other Technological Changes					
		Natural Res. Supply (shifter)	new Technology / new Goods	Changes in Multiple Technology	Changes in intermediate demand	Trade	Preferences
11	**IMACLIM-R**	IEA, cost curves	none, because not competitive (but EV, CCS, … available)	endogenous technology mix (PE), or exogenous (IEA)	Exogenous trends for services/transport/agrifood	Itl. Transport cost : EXO - 1% + exo scenarios	conditional convergence of preference towards OECD
12	**MAGNET**				AG&Food coeff in services sector linked to primary demand	trade scenarios	Control food demand food via (clibrated) income el. function of PPP-RGDP/cap
13	**MIRAGE-e**	ENDO / Fossil Fuel Price EXO (IEA)				trade scenarios / NTM calibrated with Iceberg Costs	None

		Other Technological Changes					
	Model Name	Natural Res. Supply (shifter)	new Technology / new Goods	Changes in Multiple Technology	Changes in intermediate demand	Trade	Preferences
14	**REMIND**		NO CCS in BAU	learning curves for renew. in general			increase pref. for ELY vs NON-ELY
15	**TEA**	Fossil Fuel (IEA)	No backstop techs	No	AG&Food Coeff adjustments	No change in intl. transport costs	control of food demand & Agr. / shift of preference over energy carriers
16	**WEGDYN_AT**	NatRes ENDO / target prices	no	portfolio standard pathways for electricity mix	no	no	ENDO (CES function)

	Model Name	Other Technological Changes Natural Res. Supply (shifter)	new Technology / new Goods	Changes in Multiple Technology	Changes in intermediate demand	Trade	Preferences
17	**MIRAGRODEP**	Calibrated to world price target for oil, coal (IEA), to regional price target (natural gaz)	n.a.	n.a.	no change by 2030	no change in volume, cost (price) endogenous	adjustment in food demand (income elasticity)l. Threshold on calories per capita consumption

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Appendix B. Model aggregation for baseline/scenario runs

Table B.1. Sectoral and Regional Aggregation[1]

	Sectors	Regions	
cro-a	Crops	USA	U.S.
lvs-a	Livestock	OAM	Other OECD America: Canada, Chile, Mexico
fsh-a	Fisheries	OUE	OECD Europe
frs-a	Forestry	OPA	OECD Pacific: Australia, Japan, New-Zealand, South Korea
omn-a	Other mining	CHN	People's Rep. of China and Hong Kong
coa-a	Coal extraction	IND	India
oil-a	Crude oil extraction	LAM	Other America
gas-a	Natural gas extraction & dist.	RAN	Eurasia: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Russian Federation, Tajikistan, Turkmenistan, Uzbekistan
crp-a	Chemicals	MEN	Middle East & North African countries
fdp-a	Food products	OAF	Other Africa
txt-a	Textiles	ODA	Other Asia
ppp-a	Pulp, paper & publishing		
crp-a	Chemicals	***Aggregate***	
p_c-a	Petroleum & coal products	OECD	OECD
nmm-a	Non-metallic minerals	NONOECD	Non-OECD
i_s-a	Iron and steel	WORLD	World
nfm-a	Non-ferrous metals		
oma-a	Other manufacturing		
cns-a	Construction		
clp-a	Coal powered electricity		
olp-a	Oil powered electricity		
gsp-a	Gas powered electricity		
nuc-a	Nuclear power		
hyd-a	Hydro power		
wnd-a	Wind power		
sol-a	Solar power		
xel-a	Other power		
etd-a	Electricity transmission & dist.		
wts-a	Water collection & dist.		
otp-a	Land transport		

[1] Aggregated from GTAP Data Base V9?

atp-a	Air transport
wtp-a	Water transport
osc-a	Other services & dwellings
osg-a	Other services (Government)

Appendix C. Stylized Facts, selected countries: 1957-2017

		GDP per capita (constant PPP)		Capital to labor ratio (persons)		Capital to output ratio		Labor productivity (persons)		Share of labor	Share of Services
Country	Year	level	Growth[a]	level	growth[a]	level	growth[a]	level	growth[a]	% of GDP	% of GDP
China	1957	1206		1667		1.2		2819		59%	
	1967	1259	0.4%	2538	4.3%	1.9	4.4%	3070	0.9%	59%	
	1977	1548	2.1%	4007	4.7%	2.3	2.0%	3353	0.9%	59%	22% [b]
	1987	2552	5.1%	6337	4.7%	2.3	-0.1%	4812	3.7%	59%	30%
	1997	3563	3.4%	12213	6.8%	2.8	2.3%	6295	2.7%	59%	35%
	2007	7055	7.1%	40480	12.7%	3.4	1.7%	12641	7.2%	55%	43%
	2017	13043	6.3%	133700	12.7%	5.0	4.0%	22481	5.9%	58%	52%
France	1957	8994		60930		4.1		19994		70%	
	1967	13583	4.2%	91704	4.2%	4.0	-0.2%	33177	5.2%	67%	
	1977	20334	4.1%	154894	5.4%	4.4	1.0%	49718	4.1%	70%	65% [b]
	1987	21996	0.8%	174836	1.2%	4.7	0.8%	54253	0.9%	64%	69%
	1997	27039	2.1%	214355	2.1%	4.8	0.1%	66212	2.0%	62%	74%
	2007	35753	2.8%	356433	5.2%	4.6	-0.4%	84884	2.5%	61%	77%
	2017	39461	1.0%	539770	4.2%	4.9	0.7%	96365	1.3%	63%	79%
Nigeria	1957	3106		3596		1.9		6807		25%	
	1967	3287	0.6%	5442	4.2%	3.3	5.5%	7814	1.4%	25%	
	1977	6945	7.8%	13343	9.4%	3.6	0.8%	17277	8.3%	25%	32% [b]
	1987	1133	-16.6%	10546	-2.3%	5.7	4.8%	3514	-14.7%	31%	27%
	1997	461	-8.6%	2990	-11.8%	3.9	-3.7%	1407	-8.7%	33%	22%
	2007	4437	25.4%	16524	18.6%	2.1	-6.1%	13662	25.5%	30%	27%
	2017	4285	-0.3%	37781	8.6%	2.2	0.5%	12618	-0.8%	49%	60%
USA	1957	16799		128290		3.8		42637		64%	
	1967	22214	2.8%	149579	1.5%	3.6	-0.6%	55991	2.8%	63%	
	1977	27603	2.2%	194770	2.7%	3.6	0.0%	63962	1.3%	62%	66% [b]
	1987	34065	2.1%	220364	1.2%	3.5	-0.2%	71661	1.1%	62%	70%
	1997	41664	2.0%	247521	1.2%	3.3	-0.6%	85381	1.8%	61%	75%
	2007	50965	2.0%	355316	3.7%	3.2	-0.3%	104771	2.1%	60%	77%
	2017	54795	0.7%	394492	1.1%	3.2	-0.2%	114693	0.9%	60%	79%

Notes: [a] average annual growth rate over the corresponding period, [b] value for 1980

Source: Penn World Table (Feenstra et al., 2015) and World Development Indicator Database (World Bank) for the last column: share of services in GDP

Appendix D. Details about baseline scenarios discussed in section 3.1

(1.) The "naïve baseline" assumes that labor efficiency is homogenous across sectors and calibrated to target projected regional GDP, given some population and labor participation exogenous projections and investment to GDP projections. These socio-demographic and savings assumptions are the same for all scenarios considered.

(2.) The "baseline with adjusted efficiencies of primary factor" assumes that primary factor efficiencies (λ_L, $\lambda_{K,}$ $\lambda_{Land,}$ TFP) are sector specific. The main assumptions implemented in this scenario are: (i) differentiated growth rates of labor efficiency by sector, (ii) exogenous yield efficiency for crops extracted from the IFPRI IMPACT model (Robinson et al. 2015) and (iii) non-zero growth rates of capital efficiency.

(3.) The baseline with "adjusted intermediate demands" is similar to the "naïve baseline" but assumes some adjustments to intermediate demand efficiencies, including: (i) increased use of services as inputs into both manufacturing and services production processes, (ii) improvements in autonomous energy efficiency, (iii) changes in the electricity mix, and (iv) assumptions on feed and fertilizer efficiencies in agricultural production.

(4.) The baseline with "full structural change" combined both the adjustment of efficiencies of primary factor of scenario (2.) and the adjustments of intermediate demands of scenario (3.).

The numeric values of these assumptions and outcomes are available in the Excel file in the supplementary materials (Table D.1).