Validating CGE Models employing an Historical approach

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Abstract

With the widespread usage of multi-region multi-sector CGE models in various areas of policy analysis, there is an increasing need to provide a validation of the commonly employed baseline scenario. So far, there have only been a few attempts to validate CGE model outcomes in a systematic way. This study is a first attempt to validate a multi-country, multi-sector CGE model. The paper broadly follows the 'historical' approach to validate the MAGNET – the GTAP based model of LEI-Wageningen University. The GTAP 6 database with base year 2001 is used to construct projections for the period 2001-2007, which are subsequently compared with historical time-series for output, value added and labour for a large number of countries and detailed sectors. Finally, regression analysis is applied to investigate if forecast performance structurally differs across sectors and countries. This information can be used as a guidance to improve modelling.

1 Introduction

Quantitative impact assessments employing the computable general equilibrium (CGE) framework have become the de facto option when analysing the economic ramifications of a (set of) policy shock(s) within a fully inclusive economic system. Growing demand for CGE work has been principally driven by policy orientated institutions requiring detailed information on how changes in economic policy affect different sectors and actors within an economy. In response, the supply of CGE modelling efforts has been greatly facilitated by significant advances in computing power, the adaptability and flexibility of both mainstream (i.e., GAMS, GAMS/MPSGE) and specialist (i.e., GEMPACK) software packages, open access to models and associated training (e.g., Global Trade Analysis Project - GTAP, GLOBE) and affordable availability of sophisticated databases (e.g., GTAP database). As the credibility of CGE models has steadily improved over the last two decades, this has resulted in an extensive body of CGE literature, much of which initially dealt with trade policy (e.g., Robinson et al., 1993) and market integration (Bach et al., 2000) scenarios, but has subsequently branched out into other areas of the academic literature to include (inter alia) transport (Hensher et al, 2004) and tourism (Blake and Sinclair, 2003), renewable energy (e.g., Bohringer and Loschel, 2006), biofuels (Taheripour,et al., 2011) and climate change (e.g., Bohringer and Rutherford, 2010)

Interestingly, Dixon and Jorgensen (2013) note that, "Behind any policy-relevant CGE result is an enormous amount of background work on data, estimation and computation. Ideally, the result is also supported by model validation" (pp.12, chapter 1). In the case of the former statement, it is beyond doubt that the level of sophistication of CGE modelling and data construction is at unprecedented levels. Notwithstanding, even a cursory view of the literature reveals that the issue of CGE model validation has received relatively scant attention.

This study is a first attempt to validate a multi-country, multi-sector CGE model. The paper broadly follows the ‘historical’ approach to validate the MAGNET – the GTAP based model of LEI-Wageningen University.

2 Methodology

2.1 Previous approaches

A review of the literature reveals only a limited number of studies that systematically verify and validate the results of (multi-country multi-sector) CGE models (see Dixon and Rimmer, 2013 for an overview). Broadly speaking, two approaches to CGE model validation can be distinguished. First, the 'partial' approach, which focuses on how well the model is able to deal with shocks. In this approach, price fluctuations of a single commodity predicted by the model are compared with real world patterns. Typically, commodities are selected that exhibit high price volatility due to supply and demand shocks, such as agricultural products, whose supply is strongly influenced by variation in weather. Time series analysis is used to estimate the distribution of production shocks that are caused by random events for each region in the model. Subsequently, the observed pattern is mimicked by the model by introducing productivity shocks using stochastic simulation. Finally, the real world variance in commodity prices is compared with the variance in prices that result from the model. The two key papers that apply this approach are Valenzuela et al. (2007) and Beckman et al. (2011). The first paper validates the GTAP-AGR model applying the methodology to the international wheat market, while the second paper validates the GTAP-E model by looking at international petroleum prices.

The second validation approach can be referred to as the 'historical' approach because it relies on historical simulations to validate CGE models. The main focus is to get the baseline 'right'. The methodology has been developed by researchers at the Centre of Policy Studies in Australia (Dixon and Rimmer, 2002, 2010). It consists of a two steps. In the first step, the historical simulation, the model is solved using as much information as possible on movements over the simulation period in prices and quantities for consumption, exports, imports and government spending disaggregated by commodity and on changes in employment, investment and capital stocks disaggregated by industry. By treating this information as exogenous, changes in consumer preferences and technologies (i.e. factor augmenting technical change) become endogenous and can be quantified. In the second step, the forecast simulation, it is assumed that changes in preferences and technologies from the past remain the same in the future and are therefore used as exogenous variables in the model. Together with projections for a number of aggregate macro-level variables such as total consumption and GDP, forecast are made at the detailed industry level (e.g. production, capital, labour, imports and exports) as well as consumption and government spending. In the final step, the model results are compared with actual data for the forecast simulation period.

By successively introducing the ‘real’ pattern of exogenous variables (e.g. `macro variables, trade and tariffs, technology and preferences) the impact of different exogenous factors on the forecast can be measured. Dixon and Rimmer (2010) applied the method with the USAGE model, a recursive dynamic 500-industry CGE model of the USA. Using uniform weights for all commodities they found an average gap of 19 percent between the model forecast and the actual percentage change of output. Although the number seems high, a comparison revealed that the USAGE forecasts are still almost twice as good as a simple extrapolation of past trends. Using information on past trends to predict future development is the most basic approach to forecasting and helps put model results into perspective.

2.2 Validating a multi-country multi-sector model

One major problem with validating models with a global coverage as compared to single country models is the lack of datasets that contain historical output and input data for that cover a large number of industries and countries and are consistent in time and space. Moreover to validate model projections using historical data a relative long time period should be covered. To solve this issue the GTAP 6 database with base year 2001 is used to construct projections for the period 2001-2007. These projections are subsequently compared with historical time-series from the KLEMS database, which presents output, value added and labour data for a large number of countries and detailed sectors. In this way, it is possible to compare model projections and historical data of 32 countries and 22 sectors. To measure forecast performance the average error (AE) is applied similar to Dixon and Rimmer (2010), which is computed at the sector, industry and total level. Finally, regression analysis is applied to investigate if forecast performance structurally differs across sectors and countries. This information can be used as a guidance to improve the modelling.

Problems with country coverage and lack of detailed information on a number of variables, combined with the very complex and unusual closure for historical simulations, in particular in the case of multi-country models, causes serious problems in implementing the first step in the method proposed by Dixon and Rimmer (2010). Hence, we directly proceed with step two and assume that the standard assumptions on consumer preferences and technical change in MAGNET adequately represent future patterns. The comparison with historical trends for the period 2001-2007 will indicate whether this assumption is reasonable.

To measure forecast performance we use the average error (AE) introduced by Dixon and Rimmer (2010). As we are analysing a multi-country model we can compute AE both at the sector, industry and total level. AE is defined as:

$$AE = \sum_c^i W_c^i \times \left|f_c^i - a_c^i\right| / \left(1 + \frac{a_c^i}{100}\right), \qquad (1)$$

where f_c^i is the forecast of a variable by the model, in this case the percentage change in the labour productivity, land yield and consumption share of industry *i* in country *c* between 2001 and 2007. a_c^i is the actual percentage change in the labour productivity, land yield or consumption share of industry *i* in country c, and W_c^i is the weight that is associated with industry *i* in country *c.* The AE is the absolute difference between forecast and observed values that is rescaled to the final year for the forecast period (here 2007). We present two versions of AE: a simple and a weighted average. In the latter case country weights (GDP) are used in case of labour productivity and yield while sector weights are used for consumption.[1] If AE is close to zero, the forecast resembles real world patterns.[2] Apart from the AE, which is a formal measure to validate the model, we also present a number of plots that show historical trends in labour productivity. All computations, data analysis and plots are coded in R, a free software programming language and a software environment for statistical computing and graphics (The R Core Team, 2013).

3 Benchmarking data

The main source of information for sectoral output and input data are the EU KLEMS Growth and Productivity Accounts (March 2011 Update – hereafter KLEMS) prepared by

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[1] Only weighting at the country level implies that all sectors are equally important within countries despite obvious differences in output or employment. The EU KLEMS database presents data in national currencies which prevents the computation of industry-level weights. An potential option for future research is to use country PPPs also available on the EU KLEMS site to convert all data in the same currency.

[2] Dixon and Rimmer (2010) also compared their forecasts with simple extrapolations of past trends – the basic alternative in the absence of model forecasts. Such an analysis falls outside the scope of this paper but could be an interesting avenue for follow up work.

the Groningen Growth and Development Centre (GGDC).[3] The database is the result of a research project funded by the EU to produce consistent long-run sectoral productivity data for OECD countries which can be used for comparative analysis on economic growth and structural change. It includes indicators for economic growth, productivity, employment creation, capital formation and technological change at the sector level for 28 OECD countries from 1970 to 2007. The database provides information on up to 71 sectors at the most detailed level, which cover the total economy. It is organised around the growth accounting methodology, which is rooted in neo-classical economic production theory. It includes output measures (total output and value added), inputs (capital (K), labour (L), energy (E), materials (M) and service inputs (S)) and total factor multifactor productivity (MFP). At present, the KLEMS database covers 26 European countries (of the EU27 only Bulgaria is not included), as well as the United States, Canada, Australia, Japan and Korea.[4] More detailed information about the database, sources and methodology can be found in Timmer et al. (2007a, 2007b) and O'Mahony and Timmer (2009).

Table 1 presents a list of KLEMS countries that are used for the analysis as well as some key variables that are needed for the comparison. Five countries for which data is available are excluded from the analysis. Australia was only later added to the database and therefore could not be included in time for this project. For Japan, Portugal, Poland and Slovenia, data is only available up to 2006 which makes comparison with MAGNET projections with end year 2006 problematic. For the remaining countries output, value added and labour data is available for the period 1970-2007. Capital stock and, hence, TFP is available for a limited number of countries and in most cases for a shorter period starting in 1981. KLEMS and GTAP vary with respect to the level of detail in certain industry groups. For historical reasons, GTAP provides a very detailed breakdown of the agricultural sector in 14 subsectors, while KLEMS only gives one composite sector called 'agriculture, forestry and fishing'. On the other hand, KLEMS offers detailed information for a few industries, in

[3] All data can be downloaded from: www.euklems.net [accessed December 6, 2012]. World KLEMS, a related project, is currently making an effort to collect similar data for a number of large emerging economies. See www.worldklems.net [Accessed December 6, 2012].

[4] Australia was only added in a later edition of EU KLEMS and is therefore not included as a separate country in the validation exercise.

particular chemicals (3 subsectors) and wholesale and retail trade (3 subsectors) which are captured by a single aggregate in GTAP. Overall, GTAP has a finer industry breakdown than KLEMS. To match the two sources, sub-sectors where aggregated where needed. **Table 4** in the Annex shows the concordance between KLEMS and GTAP sectors.

Table 1: KLEMS country and data coverage

Code	**Country**	**Period**	**Output, value added and employment**	**Capital stock and TFP**
AUT	Austria	1970-2007	X	X
BEL	Belgium	1970-2007	X	X
CZE	Czech Republic	1995-2007	X	X
DNK	Denmark	1970-2007	X	X
ESP	Spain	1970-2007	X	X
EST	Estonia	1995-2007	X	
FIN	Finland	1970-2007	X	X
FRA	France	1970-2007	X	X
GBR	United Kingdom	1970-2007	X	X
GER	Germany	1970-2007	X	X
GRC	Greece	1970-2007	X	
HU	Hungary	1995-	X	X

N		2007		
IRL	Ireland	1970-2007	X	X
ITA	Italy	1970-2007	X	X
JAP	Japan	1970-2006	X	X
LVA	Latvia	1995-2007	X	
LTU	Lithuania	1995-2007	X	
LUX	Luxembourg	1970-2007	X	
MLT	Malta	1995-2007	X	
NLD	Netherlands	1970-2007	X	X
PRT	Portugal	1970-2006	X	
POL	Poland	1995-2006	X	
SVK	Slovakia	1995-2007	X	
SVN	Slovenia	1995-2006	X	X
SWE	Sweden	1970-2007	X	X
USA	United States	1977-2007	X	X

Source: Timmer et al. (2007b)

Note: Capital stock and TFP are often not available for the complete period but cover the period 1981-2007 for most countries.

4 MAGNET model setup[5]

4.1 Aggregation

In order to fully exploit the data we distinguish a large number of individual countries and only aggregate countries for which no additional data is available. Using the concordance table, we mapped the GTAP sectors to KLEMS sectors.

4.2 Standard model settings

Unless otherwise noted, the MAGNET model we use in this paper is the version described in Woltjer and Kuiper (2013). Key modules and setting for this particular analysis include:

- Segmented factor markets
- Endogenous land supply
- Consumption corrected for PPP
- Input technology shifters (ASCALE)
- Standard GTAP elasticities
- Standard GTAP CES nest

We do not switch on the CAP and biobased modules since these extensions are not relevant to the measures being examined within this research. Furthermore, we prefer to use a relatively simpler setup to be able to isolate the effects of changes in assumptions on technological change and consumption.

4.3 Drivers

To make forecasts with MAGNET, projections are required on the growth of GDP and the four production factors whose supply is exogenous (natural resources, capital stock, skilled labour and unskilled labour). The standard approach is to assume that natural resources increase at a a quarter of the rate of GDP growth; capital stock growth increases at a similar

[5] For detailed information see Woltjer and Kuiper (2013)

rate to GDP and skilled and unskilled labour increase at a the same speed as population growth. **Table 2** shows the development of the standard drivers in MAGNET for the period from 2001 to 2007. All data is taken from USDA/ERS and reflect actual trends for 2001-2007 not projections. It also presents the growth in actual employment and capital stock from KLEMS. KLEMS provides different series for employment, including corrections for hours worked and self-employment. We use the series for the number of persons engaged which resembles the population series, also expressed in persons, and captures self-employment which is important in the agricultural sector. Capital stock is constructed using the Perpetual Inventory Method, which aggregates past investments with weights given by the relative efficiencies of capital goods at different ages. The macro-data from KLEMS is used to analyse the impact of better data on drivers on MAGNET forecasts for labour productivity and yield.

For a number of countries, Table 2 reveals substantial differences between the USDA/ERS and KLEMS series. Most striking is the divergence between the two sources in the population/employment data for EST, HUN, LTU and LVA, whose trend is negative for population and positive for employment. For GDP/capital stock, the differences are less obvious but can be observed for a number of countries such as DNK, FIN, IRL and ITA. The correlation between population/employment and GDP/capital stock is 0.45 and 0.76, respectively. This suggests, at least in the medium run, that population projections are not a good approximation for employment growth, while using GDP as a proxy for capital stock is a more reasonable assumption.

Table 2: Development of key Drivers by source (2001-2007)

Country	**Population (USDA/ERS)**	**Employment (KLEMS)**	**GDP (USDA/ERS)**	**Capital stock (KLEMS)**
AUT	0.84	3.59	15.69	9.09
BEL	0.98	5.18	13.38	-
CYP	12.47	10.54	22.59	-
CZE	-0.33	4.92	32.93	25.35
DEU	-0.10	1.04	8.68	13.23

DNK	2.10	4.12	11.01	20.55
ESP	10.15	21.38	22.06	34.31
EST	-3.95	14.76	61.05	-
FIN	1.12	6.98	22.43	13.00
FRA	3.58	3.73	11.45	14.44
GBR	3.16	5.41	16.53	21.95
GRC	1.18	7.25	28.29	-
HUN	-0.94	1.20	20.27	20.95
IRL	14.13	21.46	37.24	58.17
ITA	2.93	7.65	6.29	14.40
JPN	0.53	-	11.23	-
KOR	2.27	8.63	32.44	-
LTU	-1.93	13.41	61.51	-
LUX	7.97	19.62	30.25	-
LVA	-4.17	15.41	69.33	-
MLT	2.55	8.72	15.39	-
NLD	1.90	3.99	12.56	-
POL	-0.32	-	30.46	-
PRT	2.47	-	6.03	-
SVK	0.79	6.86	47.31	-
SVN	-0.10	-	31.66	-
SWE	1.02	2.89	21.52	25.68
USA	5.94	4.24	16.48	18.36

Source: USDA/ERS for GDP and population, KLEMS for employment and Capital stock

Note: for JPN, POL, PRT and SNV data for 2007 is missing and therefore figures are not presented.

4.4 Technical change

Apart from assumptions on several macro-level drivers, parameters for technical change are a key determinant of long-term projections within MAGNET. In the standard design of MAGNET, a combination of two variables/parameters define technological change in the model. First, ALAND is a proxy for the change in exogenous yields, for instance because of the introduction of high-yielding seeds or climate change. Values for ALAND are region specific and cover the period 2001-2030, taken from Bruinsma (2003). At present there is no data on actual yield improvement per country for the period 2001-2007 to improve the projections.[6] Secondly, ASCALE is a technology shifter that distributes the rate of overall country-level technical change (AKNREG). In the standard set-up ASCALE is based on expert knowledge and assumes different rates of technical change for three broad groups of sectors, (agriculture, manufacturing and services) as well as across factors of production.

4.5 Consumption

In GTAP, private (household) consumption behaviour is modelled via a Constant Difference of Elasticity (CDE) function, which is a relatively flexible, non-homothetic function allowing for non-constant marginal budget shares, and is calibrated by GTAP using data on income and price elasticities of demand. Since the use of the CDE function in practice results in constant income elasticities over time – leading to unrealistically high consumption of food items in fast growing economies – in MAGNET income elasticities are adjusted over time using real (PPP-corrected) GDP per capita. This module uses the CDE function from the standard GTAP model, but calibrates the price and income elasticities in each step of the Euler optimization routine, based on a functional relationship between real (PPP-corrected) GDP per capita and income elasticities, and on exogenously given price elasticities that are normally taken from the GTAP database. In calculating the income elasticities commodities

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[6] In theory one could use FAOSTAT data on yields to improve the historical projection. However, yields are influenced by a myriad of factors such as weather shocks, (inter)national agricultural and trade policies, extension services and R&D. It requires extensive qualitative and quantitative analyses to separate these elements which beyond the scope of this paper.

are divided into different groups that determine the order of calculation. At this moment the commodities categorized in the service sector are scaled in order to guarantee that the sum of the income elasticities equals one.

5 Results

5.1 Model validation

Table 3 presents the results from applying Equation (1) to labour productivity projections with MAGNET using different weights and samples. Labour productivity is defined as production volume (VALOUTPUTxqo) divided by employment (VFMxqf). Basic AE is the simple mean (equal weights) of all sectors and countries in the sample. Weighted AE uses GDP as weights to aggregate the countries, whilst no weights are used for the sectors within a country. Weighted AE KLEMS represents the weighted AE of a subsample of countries, namely the 17 countries for which we have complete data (all countries in the last column of **Table 1**) This measure will clearly show the impact of changes in assumptions on capital stock and TFP, for which data is only available for KLEMS countries. The three indicators are presented for three experiments, which together offer a validation of MAGNET with respect to labour productivity projections in comparison to the KLEMS database. In the pure forecast, MAGNET is used employing standard macro projections (population growth for employment growth and GDP growth for capital stock growth). In the second and third experiments, actual KLEMS data on employment and capital stock from **Table 2** are successively introduced. All other drivers and assumptions on technical change remain the same.

The analysis indicates that the basic AE for a typical industry and country is 17.32 percent. In other words, the average error for labour productivity projections with MAGNET is 17 percent which seems rather high. In particular, in comparison an average labour productivity growth of 26.44 percent that is observed for the period 2001-2007. However, if we take a closer look at the data, things are not as bad as they seem. In fact, the average labour productivity per industry and country ranges from -49 to 240 percent with a standard deviation of 34 percent and therefore substantially deviates from the average in most countries and sectors. The table also shows that if we introduce better data on employment, the forecast error is reduced by 0.7 percent. Subsequently adding capital stock data, the AE declines a further 0.04 percent.

So far we have treated all countries in our sample as equally important. However, in most policy experiments for which we are using MAGNET, we are interested in projections for large economies, such as the USA or the total European economy, which is dominated by Germany, France, Italy and the United Kingdom, instead of small countries like Latvia, Cyprus and Malta. The Weighted AE of around 11 per cent shows that the forecast error is much smaller in large economies than in small ones. Using GDP as weights reduced the AE by approximately 5 to 6 per cent. If we only look at the subsample of 17 KLEMS countries, the forecast error is reduced even further. Similar to the simple AE, the results suggest that using employment instead of population trends will reduce the forecast error, although the improvement is less large. This is not surprising since the largest difference between the population and employment figures occur in a group of small countries that are not in the core KLEMS group (**Table 2**). Applying capital stock figures, on the other hand, does not seem to gain much and can even slightly deteriorate the quality of the forecast. The reason for this might be the well-known difficulties in constructing capital stock series. As the employment projections provide the best results we employ this model set up in all subsequent analysis.

Table 3: AE for MAGNET forecasts of labour productivity (2001-2007)

Experiment	**Basic AE**	**Weighted AE**	**Weighted AE KLEMS**
Standard MAGNET	17.32	11.30	10.84
Standard MAGNET + Employment	16.62	11.03	10.64
Standard MAGNET + Employment + capital stock	16.58	11.07	10.68

Table 3 provides a basic aggregate measure of the extent to which model forecasts correspond to actual trends. But what causes these errors? And are the forecast errors similar across countries or are a few countries performing very poorly while the forecast is almost perfect in others? Similarly, is the AE the same across all industries or are we missing something in the model which causes a persistent deviation for high-tech or low-tech sectors? Answers to these questions will provide directions on how to improve the model, for instance

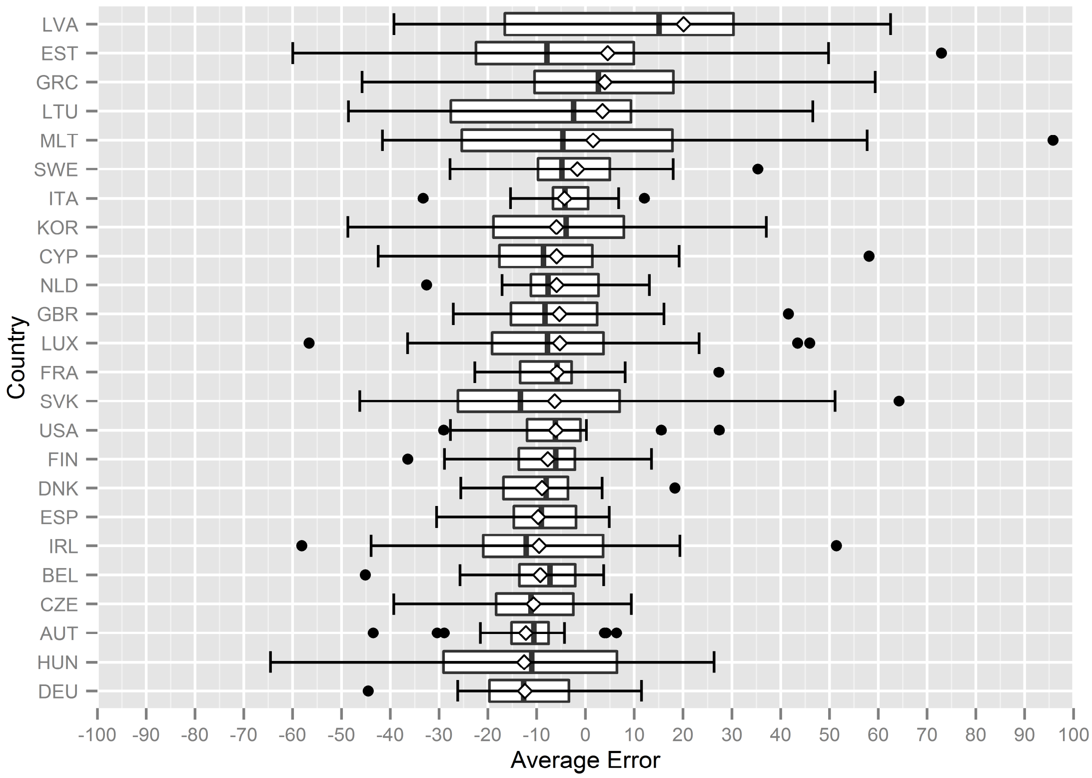
by improving the SAMs of certain countries or changing the parameters for technological change. To investigate the AE distribution by country and industry, we present a number of box plots (also sometimes referred to as box and whisker plots). A box plot consists of a box whose bottom and top reflects the first and third quartiles. The band inside the box represents the second quartile (the median). In addition we added a diamond inside the box to indicate the mean of the distribution. The upper whisker extends from the hinge to the highest value that is within 1.5 * IQR of the hinge, where IQR is the inter-quartile range, or distance between the first and third quartiles (the size of the box). The lower whisker extends from the hinge to the lowest value within 1.5 * IQR of the hinge. Data beyond the end of the whiskers are outliers and plotted as points.

Figure 2present the box plots for AE per country and sector, respectively. In contrast with Equation (1) we refrain from taking the absolute value of the difference between actual and forecasted growth. In this way, the figures also present information of the direction of the error (i.e. overshooting or undershooting). The mean of each country/sector is used to rank the boxes. Units with the highest mean are on the top.

Clearly MAGNET is not performing well for a number of small economies, in particular Latvia, Malta and Lithuania. These countries are also characterised a high dispersion of the AE, a mean that is far from zero and a few extreme outliers. Of the larger countries, Hungary and Greece exhibit the largest dispersion in forecast error, while the forecast for Germany on average undershoots actual growth, indicated by an average below zero. Without further information it is difficult to come up with explanations why these countries give problems. One possible reason might be the structural quality of the SAMs which is not in line with economic reality. Another reason might be the occurrence of country specific structural change or socio-economic events within the sample period which have not been picked up by the model.

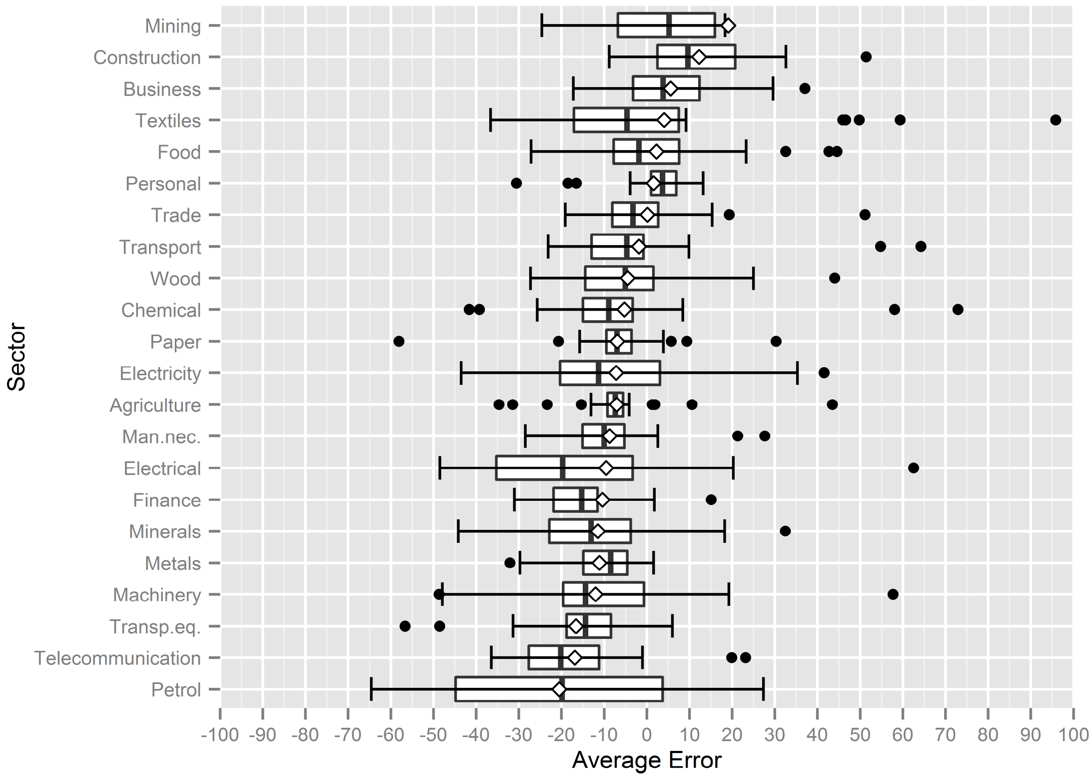
Figure 2 indicates that there are also large differences in the forecast error across sectors. The petrol and electricity sectors show large dispersion and means that are different from zero, whereas for agriculture and paper the fit seems very good. Also here the explanations might be twofold. On the one hand, the large AE in the petrol sector might indicate a turbulent period of radical technical change or industry specific events (e.g. manipulation of the oil production by the OPEC) that is very specific for a short to medium period and therefore not picked up by the model. On the other hand, it might reflect the long run pattern of technological advancement of the electronics sector which is not appropriately modelled in MAGNET. The Calibration report aims to address the second explanation.

Figure 1: Box plot for labour productivity AE per country



Note: figures based on standard MAGNET+employment model. Some outliers are not depicted as they are out of the plot range.

Figure 2: Box plot for labour productivity AE per sector



Note: figures based on standard MAGNET+employment model. Some outliers are not depicted as they are out of the plot range.

5.2 Regression analysis

[To be added]

6 Conclusions

[to be added].

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8 Annex

Table 4: EU KLEMS – GTAP concordance

GTAP Number	GTAP code	GTAP description	KLEMS code	KLEMS description
1	PDR	Paddy rice	AtB	Agriculture, Hunting, forestry and fishing
2	WHT	Wheat	AtB	Agriculture, Hunting, forestry and fishing
3	GRO	Cereal grains nec	AtB	Agriculture, Hunting, forestry and fishing
4	V_F	Vegetables, fruit, nuts	AtB	Agriculture, Hunting, forestry and fishing
5	OSD	Oil seeds	AtB	Agriculture, Hunting, forestry and fishing
6	C_B	Sugar cane, sugar beet	AtB	Agriculture, Hunting, forestry and fishing
7	PFB	Plant-based fibers	AtB	Agriculture, Hunting, forestry and fishing
8	OCR	Crops nec	AtB	Agriculture, Hunting, forestry and fishing
9	CTL	Bovine cattle, sheep and goats, horses	AtB	Agriculture, Hunting, forestry and fishing
10	OAP	Animal products nec	AtB	Agriculture, Hunting, forestry and fishing
11	RMK	Raw milk	AtB	Agriculture, Hunting, forestry and fishing
12	WOL	Wool, silk-worm cocoons	AtB	Agriculture, Hunting, forestry and fishing
13	FRS	Forestry	AtB	Agriculture, Hunting, forestry and fishing

14	FSH	Fishing	AtB	Agriculture, Hunting, forestry and fishing
15	COA	Coal	C	Mining and quarrying
16	OIL	Oil	C	Mining and quarrying
17	GAS	Gas	C	Mining and quarrying
18	OMN	Minerals nec	C	Mining and quarrying
19	CMT	Bovine meat products	15t16	Food products, beverages and tobacco
20	OMT	Meat products nec	15t16	Food products, beverages and tobacco
21	VOL	Vegetable oils and fats	15t16	Food products, beverages and tobacco
22	MIL	Dairy products	15t16	Food products, beverages and tobacco
23	PCR	Processed rice	15t16	Food products, beverages and tobacco
24	SGR	Sugar	15t16	Food products, beverages and tobacco
25	OFD	Food products nec	15t16	Food products, beverages and tobacco
26	B_T	Beverages and tobacco products	15t16	Food products, beverages and tobacco
27	TEX	Textiles	17t19	Textiles, textile products, leather and footwear
28	WAP	Wearing apparel	17t19	Textiles, textile products, leather and footwear
29	LEA	Leather products	17t19	Textiles, textile products, leather and footwear
30	LUM	Wood products	20	Wood and products of wood and cork
31	PPP	Paper products, publishing	21t22	Pulp, paper, paper products, printing and publishing

32	P_C	Petroleum, coal products	23	Coke, refined petroleum products and nuclear fuel
33	CRP	Chemical, rubber, plastic products	23t25	Chemical, rubber, plastics and fuel products
34	NMM	Mineral products nec	26	Other non-metallic mineral products
35	I_S	Ferrous metals	27t28	Basic metals and fabricated metal products
36	NFM	Metals nec	27t28	Basic metals and fabricated metal products
37	FMP	Metal products	27t28	Basic metals and fabricated metal products
38	MVH	Motor vehicles and parts	34t35	Transport equipment
39	OTN	Transport equipment nec	34t35	Transport equipment
40	ELE	Electronic equipment	30t33	Electrical and optical equipment
41	OME	Machinery and equipment nec	29	Machinery, nec
42	OMF	Manufactures nec	36t37	Manufacturing nec, Recycling
43	ELY	Electricity	E	Electricity, gas and water supply
44	GDT	Gas manufacture, distribution	E	Electricity, gas and water supply
45	WTR	Water	E	Electricity, gas and water supply
46	CNS	Construction	F	Construction
47	TRD	Trade	G	Wholesale and retail trade
48	OTP	Transport nec	60t63	Transport and storage
49	WTP	Water transport	60t63	Transport and storage
50	ATP	Air transport	60t63	Transport and storage
51	CMN	Communication	64	Post and telecommunications
52	OFI	Financial services nec	J	Financial intermediation
53	ISR	Insurance	J	Financial intermediation

54	OBS	Business services nec	71t74	Real estate, renting and business activities
55	ROS	Recreational and other services	LtQ	Community social and personal services
56	OSG	Public Administration, Defense, Education, Health	LtQ	Community social and personal services
57	DWE	Dwellings	NA	NA

Source: Timmer et al. (2007b) and GTAP database

Table 5: FAOSTAT – GTAP concordance

GTAP number	**GTAP code**	**GTAP description**	**FAO code**	**FAO description**
1	pdr	Paddy rice	A27	RicePaddy
1	pdr	Paddy rice	A2804	RicePaddyE
2	wht	Wheat	A15	Wheat
2	wht	Wheat	A2511	Wheat2
6	c_b	Sugar cane, sugar beet	A157	Sugarbeet
6	c_b	Sugar cane, sugar beet	A2537	SBE
6	c_b	Sugar cane, sugar beet	A156	Sugarcane
6	c_b	Sugar cane, sugar beet	A2536	SCA

Source: FAOSTAT and GTAP database

Table 6: Sector aggregation

Code	**description**
PDR	Paddy rice
WHT	Wheat
GRO	Cereal grains nec
V_F	Vegetables, fruit, nuts
OSD	Oil seeds
C_B	Sugar cane, sugar beet
PFB	Plant-based fibers
OCR	Crops nec
CTL	Bovine cattle, sheep and goats, horses
OAP	Animal products nec
RMK	Raw milk
WOL	Wool, silk-worm cocoons
FRS	Forestry
FSH	Fishing
C	Minerals nec
15t16	Beverages and tobacco products
17t19	Leather products
20	Wood products
21t22	Paper products, publishing
23	Petroleum, coal products
23t25	Chemical, rubber, plastic products
26	Mineral products nec
27t28	Metal products
34t35	Transport equipment nec

30t33	Electronic equipment
29	Machinery and equipment nec
36t37	Manufactures nec
E	Water
F	Construction
50t52	Trade
60t63	Air transport
64	Communication
J	Insurance
70t74	Business services nec
LtQ	Public Administration, Defense, Education, Health

Table 7: Region aggregation

Code	description
AUT	Austria
BEL	Belgium
DNK	Denmark
FIN	Finland
FRA	France
DEU	Germany
GBR	United Kingdom
GRC	Greece
IRL	Ireland
ITA	Italy
LUX	Luxembourg
NLD	Netherlands
PRT	Portugal
ESP	Spain
SWE	Sweden
CYP	Cyprus
CZE	Czech Republic
HUN	Hungary
MLT	Malta
POL	Poland
SVK	Slovakia
SVN	Slovenia
EST	Estonia
LVA	Latvia

LTU	Lithuania
RUS	Russian Federation
CHN	China
USA	United States
JPN	Japan
KOR	Korea
IND	India
BRA	Brazil
LAC	Latin America
AFR	Africa
WEO	Western European countries
ASIA	Asia