Long run trends in international trade. The impact of new technologies

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ABSTRACT: We use the WTO Global Trade Model (GTM) to generate long-term projections on international trade and examine the potential impact of the development of digital technologies on trade. The GTM is a recursive dynamic CGE-model featuring imperfect competition, the integration of margin activities in private consumption, and baseline projections based on macroeconomic projections of the Shared Socioeconomic Pathways (SSP). We examine the potential impact of expected changes in technology, focusing on trends such as robotization, big data and artificial intelligence, additive technology (3D printing), and e-commerce. Robotization is expected to change the factor intensity of production thus affecting the pattern of international specialization (reshoring). 3D printing could have large effects for the size and pattern of international trade, leading to a shift away from trade in physical goods to digital trade. And E-commerce will reduce trade costs and raise productivity in retail sectors. We model these trends and evaluate their potential impacts.

Keywords: Dynamic CGE-Modelling, Structural Change, Digitalization

JEL codes: F14, F43, I25

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1 Introduction

In the last 30 years, technological advancements in information and telecommunication technologies (ICT), including access to the internet, have significantly impacted the way in which goods, services and information are bought, sold and exchanged, by bringing electronic or digital markets and platforms into being. More and more cross-border trade is now digital in nature, a trend likely to continue in the future.

These technologies have benefitted from the exponential growth in computing power, bandwidth, and data generation, collection and storage. Without massive computing power to process and analyze data, the interconnectedness that the Internet creates and the bandwidth that makes instantaneous and bulk transfer of information feasible, the digital technologies that are the focus of this report — such as 3D printing, robotics and artificial intelligence, and e-commerce —would not have been possible.

Qualitative analysis can be useful to identify the ways in which new technologies and digitalization could affect international trade. In this paper we complement this qualitative analysis with quantitative projections on changes in the size and patterns of international trade using the dynamic computable general equilibrium (CGE) model developed for the WTO, the Global Trade Model (GTM). This serves three important goals. First, it disciplines the qualitative predictions, as it forces analysts to translate the storylines into quantitative shocks in a micro-founded economic model. Second, the use of a consistent general equilibrium model implies that indirect effects of shocks are all taken into account. Third, the fact that the model is computable makes it possible to go beyond qualitative predictions and provide actual numbers on the expected effects of new technologies on international trade. However, since some of the changes expected are difficult to predict, these quantitative predictions should be treated with care.

The GTM has been developed by a team of GTAP in cooperation with the Economic Research and Statistics Division at the WTO. The model is a recursive dynamic CGE model featuring multiple sectors, multiple production factors, intermediate linkages, and a host of taxes. It is based upon the GTAP model so retains many of its features including CDE preferences and an Armington trade structure. But the model is also flexible enough to switch between different trade structures (Armington, Ethier-Krugman, Melitz). In the WTO Global Trade Model, a fixed share of income is saved. This saving could be allocated to domestic or foreign investment depending on the expected rate of return that could be earned. Thus, the model allows for endogenous capital accumulation with capital mobility equalizing expected rates of return across countries. However, agents are not forward-looking and different periods are only connected through the stock of capital. [1]

Given the focus on long-term projections, the model incorporates several features that allow it to examine the impact of technological change on trade. First, it incorporates the "twist" preference parameters (based on Dixon and Rimmer (2002)) to better capture changes in the bundles of domestic and imported goods as well as labor and capital. Second, it uses a 'make' matrix that allows activities to produce one or more commodities and for commodities to be the aggregation of output by one or more activities (e.g. electricity). To study the effects of digitalization of trade, goods and associated margin activities are integrated in the final stage of consumption following the approach in Cardona et al. (2015).

Before exploring the impact of new technologies and digitalization, we first construct a baseline scenario for the world economy. In particular, we combine baseline data on the world economy from GTAP92 for 2011 with projections on growth in different aggregate variables. Short-run and long-run growth in GDP per capita comes from respectively IMF and OECD projections. The growth rates in population and labor force are based on UN projections and the growth rates in skills (mapped from changes in education levels) come from IIASA. We impose these growth projections on the model inferring the productivity growth required to achieve this level of economic growth given our projections on population and skill growth and allowing for endogenous capital accumulation. We extend the described standard approach to baseline projections in four ways. First, we allow for differential productivity growth across sectors to capture the phenomenon of structural change, i.e. changing sectoral shares over time. Second, we incorporate changing income elasticities as countries grow richer. Third, we allow for changes in the trade to income ratio. These three additions are based on past trends observed in the data. Fourth, we discipline the savings rate based on external projections from CEPII in order to take into account that savings patterns change over time related to demographic developments.

We use the GTM to examine the potential impact of important trends in technological development. In particular we will focus on the impact of the following four trends on the

[1] Abstracting from forward looking behavior enables us to include many more details relevant for international trade in the model.

size and patterns of international trade such as the geographical and sectoral distribution. First, changes in sectoral productivity as a result of digitalization of the economy. Second, the development of e-commerce. E-commerce will reduce trade costs and raise productivity in retail sectors. We model these trends and evaluate their potential impacts. Third, robotization and artificial intelligence (AI). Robotization is expected to make production more capital intensive. We will project the capital intensity of production based on historical trends and examine the impact on the patterns of international specialization and reshoring. AI can be a form of automation which, instead of machine power substituting for manual labor, involves substituting the computing ability of machines for human intelligence and expertise. This is likely to increase the capital intensity of production as AI is likely to also be complementary to capital. The use of AI started out in the technology sector but is spreading to the non-technology sectors of the economy. As it does, this might mean increasing capital intensity of much of the economy as well. Fourth, the emergence of additive technology (3D printing). Additive technology could have large effects for the size and pattern of international trade, leading to a shift away from trade in physical goods to digital trade. We will use insights from the literature on 3D printing to quantify the expected impact on trade. Fifth, changes in production structures and servification. New technologies are expected to lead to a more intensive use of services inputs in other sectors. We will use historical trends in the service intensity of production and examine the impact on the patterns of specialization.

To summarize, the main mechanisms through which these digital trends are likely to affect trade are the reduction in trade costs, digitization of trade (shift from goods to services), increased use of digital inputs (services) in production, and a shift in comparative advantage towards more capital abundant countries.

The baseline simulations display three main characteristics. First, the included structural change has a considerable impact with production shares of services rising and of manufacturing and agriculture falling. The extraction sector also displays growth, because there is limited scope for productivity growth in this sector which is mainly using natural resources. Second, the geographic distribution of trade is changing with developing countries taking over the dominant position in global trade from the developed countries. The least-developed countries also raise their market share in global trade, although it remains small in 2030. Third, the sectoral distribution of trade follows the production pattern driven by structural change, featuring a rising share of services trade at the expense of manufacturing trade.

The simulations on the impact of new digital technologies show that ...

The structure of the paper is as follows. Section 2 describes the WTO GTM that will be used to project the future impacts of these technologies on global trade. Section 3 presents the baseline scenario for the world economy where using GDP, population and labor force projections from various international organizations we infer the productivity growth required to achieve the projected level of economic growth. In Section 4, we introduce the effect of digital technologies by applying the appropriate shocks to productivity and other economic variables and compares the result with the baseline scenario. The section examines three emerging digital trends and discusses their likely impact on trade. These include the growth of e-commerce platforms, robotization and the use of artificial intelligence, and additive manufacturing which is more commonly known as 3D printing. Section 5 concludes.

2 Global trade model

We employ the WTO Global Trade Model (GTM) for the baseline projections and policy simulations. The GTM is a recursive dynamic CGE model, based on the facelift version of the GTAP model (Version 7). This means that the model features multiple sectors, multiple factors of production, intermediate linkages, multiple types of demand (private demand, government demand, investment demand, and intermediate demand by firms), non-homothetic preferences for private households, a host of taxes, and a global transport sector. Each region features a representative agent collecting factor income and tax revenues and spending this under utility maximization on private consumption, government consumption, and savings. Firms display profit maximizing behavior, choosing the optimal mix of factor inputs and intermediate inputs. Savings are allocated to investment in different regions.

The model is calibrated to the current GTAP database, which has 141 regions and 57 sectors, implying that baseline shares are equal to actual shares.

Compared to the facelift GTAP model, the GTM contains a series of additional features. First, the model is recursive dynamic, thus featuring endogenous capital accumulation. The capital stock at the beginning of period t is equal to the capital stock at the end of period $t-1$ plus investment minus depreciation. Second, the model features isoelastic factor supply of land and natural resources. Third, it allows for changes in spending shares (for example changes in import shares or the share of labor income in total factor income) employing the twist-parameter approach developed by Dixon and Rimmer (2002). Under this approach spending shares can change under the condition that the aggregate price index stays constant (for example of the bundle of imported and domestic goods). Fourth, price and quantity indices in the model are defined using the "ideal" index approach. The ideal (or Fisher) price index is a geometric mean of the Laspeyres and and Paasche price indices. These price indices are used for example in the definition of the numeraire and of the GDP price and quantity indices. Fifth, the model contains various options for the allocation of global savings, in particular rate-of-return sensitive investment allocation, investment allocation based on initial capital shares, fixed foreign savings, and fixed relative foreign savings. In this paper we apply the rate-of-return sensitive investment allocation. The problem if implicitly accumulating foreign debt levels corresponding with non-converging current account imbalances is less pressing in our exercise given the fact that we project the economy only 15 years out in the future. In our experiments on the digitalization of the economy we want to take into account the effect of changes in the current account through savings and investment behavior. Therefore, we work with the rate-of-return sensitive investment allocation.

Sixth, the model allows for the integration of margin services in final consumption following the approach in Cardona et al. (2015). Seventh and finally, the model is flexible in its trade structure, allowing for a perfect competition setting with Armington preferences, but also for a setting with monopolistic competition, either with homogeneous firms (Ethier-Krugman) or with heterogeneous firms (Melitz). The model follows the approach in Bekkers and Francois (2018) to nest the different structures in a general model. This paper works with Armington preferences. In modelling the dynamics of the global economy the model contains a range of additional features relative to a business as usual scenario with only projections on GDP and population growth, as discussed in the next section.

3 Baseline projections

3.1 Standard features

We start with a baseline projection of the world economy until 2030. We use an aggregation with 15 sectors, 14 regions, and 5 factors of production, as displayed in Table 1. The sectoral aggregation includes the sectors of interest related to digitalization of the economy, such as telecommunications, business services, and electronic equipment. In order to shed light on the question how some of the newly emerging countries are affected by digitalization, we also include countries like Brazil and Nigeria in the aggregation.

Table 1: Overview of regions, sectors, and production factors

Regions	Sectors	Production factors
Japan	Agriculture	Land
China	Mining and Extraction	Unskilled labor
India	Processed Food	Skilled labor
ASEAN	Chemicals and Petrochemicals	Capital
USA	Other Goods	Natural resources
Brazil	Metals	
Latin America	Electronic Equipment	
European Union (28)	Other Machinery and Motorvehicles	
Middle East and North Africa	Utilities and Construction	
Nigeria	Trade	
Sub-Saharan Africa	Transport	
Other developed countries	Communication	
Other Asian countries	Business Services	
Rest of World	Financial Services and Insurance	
	Other Services	

We start the simulations from 2011 based on the latest release of GTAP9, GTAP9.2. Following standard approaches, we use projections on growth in GDP per capita growth, population, labor force, and skills to discipline our trajectory of the world economy until 2030. The growth in population, labor force, and skills are imposed on the projections and GDP per capita growth is targeted by endogenizing labor productivity growth, while allowing for endogenous capital accumulation based on recursive dynamics. GDP per capita growth is based on actual IMF data and projections with the IMF Global Projection Model until 2018 (Carabenciov (2013)). For the later years we use the OECD Shared Socioeconomic Pathways projections, SSP2 (Dellink et al. (2017)). Population and labor force growth come from the UN population projections, medium variant for 2015 (UN (2015)). Changes in the number of skilled and unskilled workers are inferred from projections on education levels by IIASA (KC and Lutz (2017)). In particular, we have used the changes in the share of tertiary educated as a proxy for changes in the share skilled workers.

To allow for changes in the amount of land and natural resources employed, we work with isoelastic supply functions with supply elasticities equal to 1. All the other parameters are set at standard values provided by the GTAP9.2 database. All the details can be easily verified from the replication files available upon request.

3.2 Additional Features

Besides these standard sources we incorporated four other elements in the model. First, to account for structural change (a rising share of services output in total output and falling shares of agriculture and manufacturing), we allow for differential productivity growth across sectors based on historical data. In particular, we estimate the following equation to infer sectoral productivity growth:

$$gr_{i,j,w}^{MFP} - gr_{i,tot,w}^{MFP} = \beta + \gamma gr_{i,w}^{GDPpc} \tag{1}$$

With $gr_{i,j,w}^{MFP} - gr_{i,tot,w}^{MFP}$ the difference in multifactor productivity growth between sector j and the average productivity growth in period w and $gr_{i,w}^{GDPpc}$ GDP per capita growth. We relate the differential productivity growth to average economic growth to examine whether larger than average productivity growth in certain sectors occurs in particular for strongly growing countries. There is empirical work showing that the degree of technological catchup of developing countries is stronger in sectors where knowledge is easy to transfer, whereas this is harder in sectors where tacit knowledge plays a large role (Bekkers et al. (2018)). The equations are estimated both with EUKLEMS multifactor productivity data and with OECD-STAN data for 13 sectors, using 5 year averages (windows). Table 2 displays the regression results. We find support for our assertion that productivity growth is in particular larger in certain sectors such as manufacturing for countries displaying higher GDP growth.

Based on the estimates we allow for differential productivity growth varying with GDP per capita growth using the estimated coefficients with the EUKLEMS data if the coefficients display significance levels of 5% or more. This leads to the following differential productivity growth rates. Further details can be found in Sabbadini (2018).

Table 2: Structural change estimates

Dependent Variable: MFP Differential of the Sectors with respect to the Total Economy

EUKLEMS After 1994

	Agriculture	Agriculture	Mining	Mining	Manuf	Manuf	Construction	Construction	Electricity	Electricity	Wholesale	Wholesale	Transport.
Average of 5y Gr. Rate of GDP		-0.104		0.349		0.372*		0.377		-0.199		-0.0419	
		(-0.23)		(0.62)		(2.54)		(1.23)		(-0.53)		(-0.22)	
Constant KLEMS	0.0228***	0.0244*	-0.0126	-0.0179	0.0159***	0.0103**	-0.0124**	-0.0181**	-0.0125*	-0.00949	0.00682*	0.00745	-0.00625
	(3.64)	(2.64)	(-1.59)	(-1.54)	(7.32)	(3.39)	(-2.84)	(-2.84)	(-2.36)	(-1.22)	(2.51)	(1.87)	(-1.07)
Observations	60	60	60	60	60	60	60	60	60	60	60	60	60
R2	0	0.001	0	0.007	0	0.1	0	0.025	0	0.005	0	0.001	0

	Transport	Accomod.	Accomod.	Commun.	Commun.	Finance	Finance	RealEst.	RealEst.	ProfAct	ProfAct	CommServ	CommServ
Average of 5y Gr. Rate of GDP	-0.612		-0.427		-0.288		0.45		-0.808**		0.0325		0.0323
	(-1.49)		(-1.83)		(-0.98)		(1.69)		(-2.76)		(0.17)		(0.21)
Constant KLEMS	0.00297	-0.0130***	-0.00656	0.0134**	0.0177**	0.0115**	0.00472	-0.005	0.00717	-0.0144***	-0.0149***	-0.00619**	-0.00667*
	(0.35)	(-3.85)	(-1.36)	(3.22)	(2.91)	(3.01)	(0.86)	(-1.14)	(1.18)	(-5.42)	(-3.81)	(-2.92)	(-2.14)
Observations	60	60	60	60	60	60	60	60	60	60	60	60	60
R2	0.037	0	0.054	0	0.016	0	0.047	0	0.116	0	0.001	0	0.001

OECD STAN After 1994

	Agriculture	Agriculture	Mining	Mining	Manuf	Manuf	Construction	Construction	Electricity	Electricity	Wholesale	Wholesale	Transport.
Average of 5y Gr. Rate of GDP		-0.502*		0.650*		0.224*		-0.146		0.041		-0.138	
		(-2.44)		(2.34)		(2.21)		(-1.06)		(0.21)		(-0.95)	
Constant OECD	0.0024	0.0130*	-0.00699	-0.0190*	0.0177***	0.0131***	-0.0106***	-0.00859*	-0.0119***	-0.0127*	0.000305	0.00351	-0.00842*
	(0.65)	(2.40)	(-1.38)	(-2.54)	(9.65)	(4.82)	(-4.37)	(-2.37)	(-3.40)	(-2.44)	(0.12)	(0.92)	(-2.33)
Observations	101	98	95	92	95	92	101	98	95	92	96	93	94
R2	0	0.058	0	0.057	0	0.052	0	0.012	0	0.001	0	0.01	0

	Transport	Accomod.	Accomod.	Commun.	Commun.	Finance	Finance	RealEst.	RealEst.	ProfAct	ProfAct	CommServ	CommServ
Average of 5y Gr. Rate of GDP	-0.456*		-0.457*		-0.202		0.367		-0.486***		-0.323*		-0.286***
	(-2.27)		(-2.61)		(-1.42)		(1.57)		(-4.07)		(-2.21)		(-5.38)
Constant OECD	0.000582	-0.0152***	-0.00567	0.0201***	0.0245***	0.00923*	0.0023	-0.00724**	0.00261	-0.0137***	-0.00743	-0.00855***	-0.00294*
	(0.11)	(-4.63)	(-1.22)	(8.03)	(6.62)	(2.28)	(0.38)	(-3.20)	(0.83)	(-5.27)	(-1.93)	(-8.19)	(-2.12)
Observations	91	94	91	100	97	100	97	96	93	96	93	100	97
R2	0.055	0	0.071	0	0.021	0	0.025	0	0.154	0	0.051	0	0.234

t statistics in parentheses

* $p < 0.05, **p < 0.01, ***p < 0.001$

Second, we allow for changes in the preference parameters as countries grow richer, such that income elasticities change over time with the level of income per capita of countries.

Third, we model changes in the trade to income ratio based on historical trends.

Fourth, the domestic savings rates are targeted to the projections of the CEPII macroeconomic model MaGE (Foure et al. (2013)). In this model saving rates are determined by demographic development in a life-cycle framework. Savings rates stay virtually constant in the basic model with savings a Cobb-Douglas share of national expenditures. Targeting the savings rates to the projections from a macroeconomic model makes the model more realistic and also helps the model to get closer to a steady state with converging rates of return, given that the base year (2011) savings rates are too large for a steady-state with constant rates of return, especially in countries like China.

3.3 Baseline projections: results

In this section we present the results of the baseline projection. Figure 1 displays the value added shares of agriculture, extraction, manufacturing, and services in both in the base year 2012 and in the final year 2030, as an indicator of structural change. The figure shows clearly that the services share rises, especially for the economies with strong growth. The share of manufacturing and agriculture falls in all economies. This is the result of the differential productivity growth across sectors with the manufacturing sectors displaying larger than average productivity growth and even more so for countries with large growth. The share of extraction instead rises in all economies. This is caused by the fact that the there is no productivity growth for the production factor natural resources (oil, gas, etc.), which is mainly used in extraction.

Figure 2 displays the development of the export shares of the 14 regions in the model over time.[2] The figure shows that the share of emerging countries is increasing. In particular China will gain, whereas both the EU and the USA are losing out global market share. Figure 3 shows the export shares of the three groups of countries, developed, developing, and least-developed. This figure shows that developing countries as a group will take over the dominant position of the developed economies.

Figure 4 displays the export share of different sectors in both 2012 and 2030 for the 14 regions. The figure reflects the impact of structural change with the share of manufacturing

[2] We have excluded intra-regional exports in these calculations, in particular important for composite regions such as the EU.

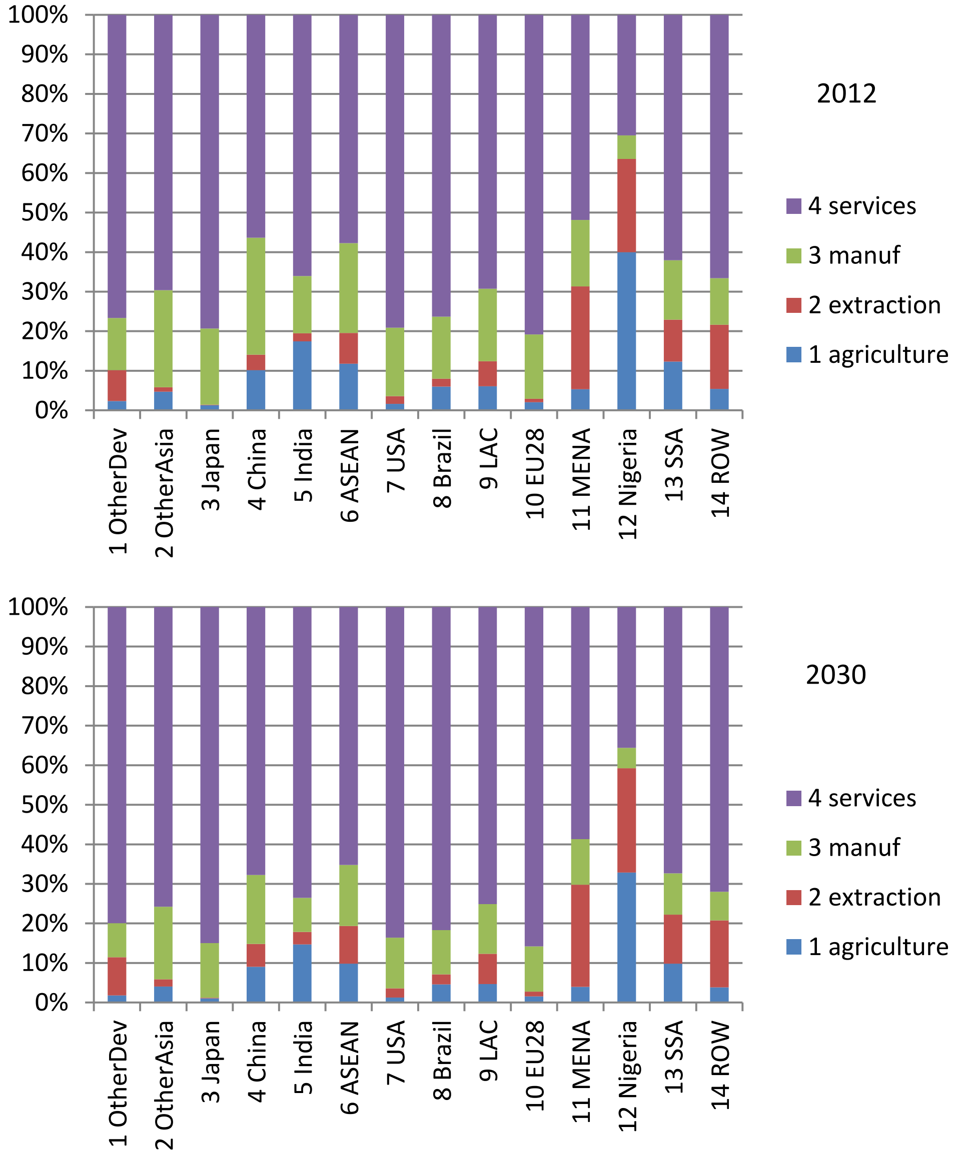

Figure 1: Value added shares of different sectors in 2012 and 2030

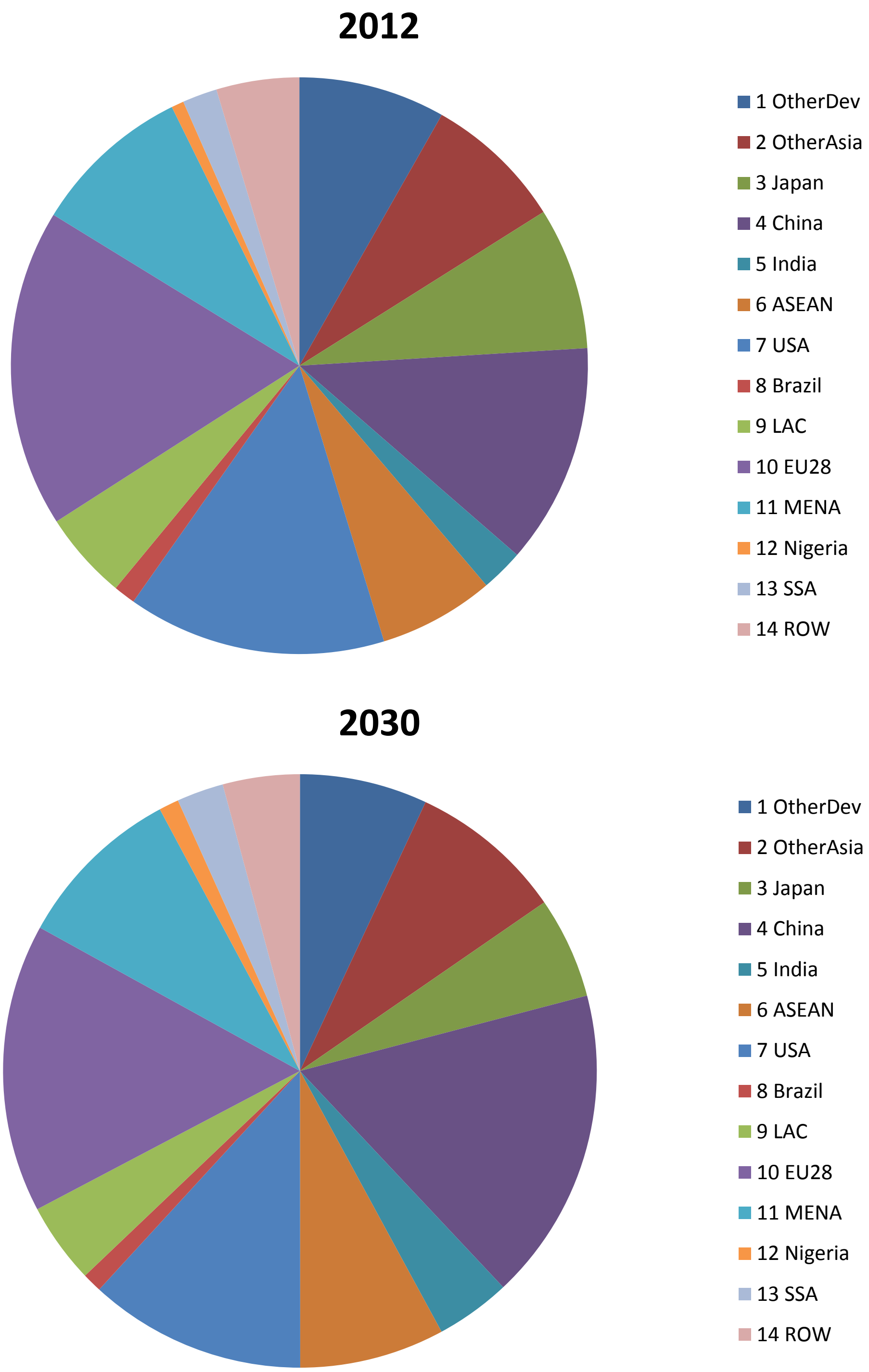

Figure 2: Export shares of different regions in global exports in 2012 and 2030 (excluding intra-regional trade)

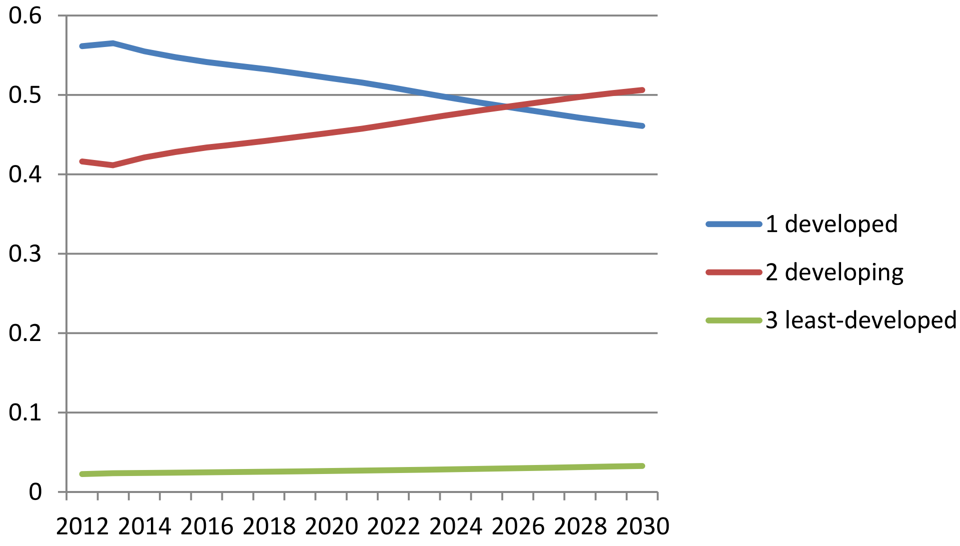

Figure 3: Export shares of aggregate regions in global exports over time

falling and the share of services in exports rising. Finally, Figure 5 shows the change in the export ratio (value of exports over value of GDP) for the 14 regions. We see that for most regions the export ratio is slightly falling. This can be explained with the structural change of economic activity from manufacturing to services, since export shares are smaller for services. These numbers do not include any changes yet in iceberg trade costs.

4 The impact of new technologies on trade

To study the impact of digitalization on global trade, we explore five expected trends quantitatively. For each of the trends we discuss the economic rationale for the trend, the way we introduce the trend in our model, and the impact on global trade. In particular, we report the impact on the sectoral and geographic distribution of international trade. Moreover, we report how some value chain measures are affected.

4.1 Digitalization and sectoral productivity growth

We start with the impact of digitalization on sectoral productivity growth. Based on the German study by Bitkom and Fraunhofer (2014) on Industry 4.0, De Backer and Flaig (2017) define scenarios for the differential impact of digitalization on productivity growth across sectors. Moreover, these authors classify countries in terms of their "digital readiness and aptitude" based on work by consultancy firms. Together this leads to the sectoral productivity growth

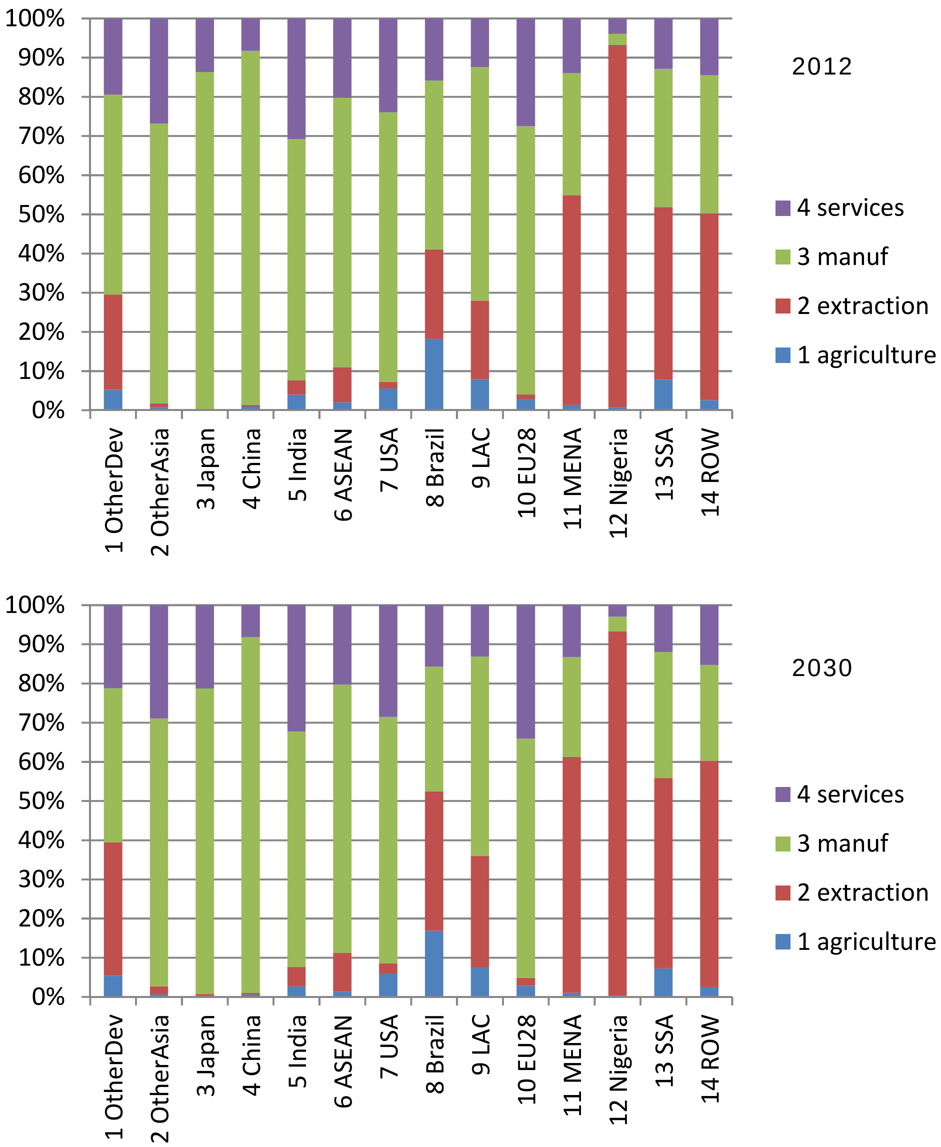

Figure 4: Export shares of aggregate sectors in 2012 and 2030 in different regions

rates and scaling factors for countries displayed in Table 3.[3] In Figure 6 we display the impact of the digital productivity shocks on the value of trade by region, comparing the predicted value of trade in 2030 with and without sectoral productivity shocks. Surprisingly, the value of trade falls with digitalization. In Figure 7 we examine whether this is due to changes in the sectoral distribution of exports, as a result of differential sectoral productivity shocks. The figure depicting the export shares in 2030 for the baseline and the experiment shows that export shares across sectors are very similar. In Figure 8 the export to GDP ratio is displayed, showing that this ratio falls considerably for one country, the USA. This is due to the fact that the OECD-digitalization scenario assumes a 150% productivity shock relative to the benchmark country,

[3]We thank De Backer and Flaig (2017) for sharing these scenarios with us.

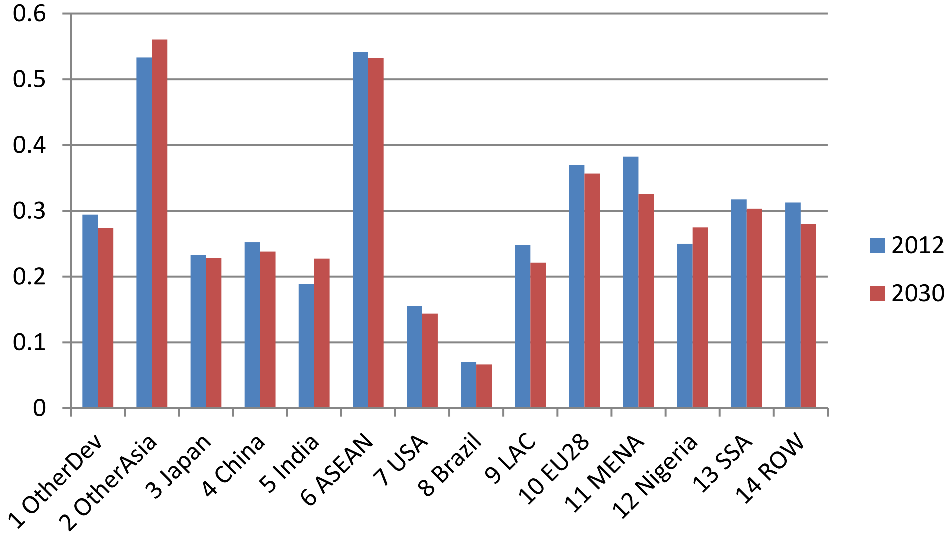

Figure 5: The ratio of exports to GDP in 2012 and 2030 in different regions

Germany, whereas for most other countries the productivity shock is scaled down to 66% or less. As a result the US attracts a considerable amount of global capital, raising its trade deficit, and focusing more on its domestic economy. Figure 9 confirms the described pattern, showing that the trade deficit in the US rises substantially.

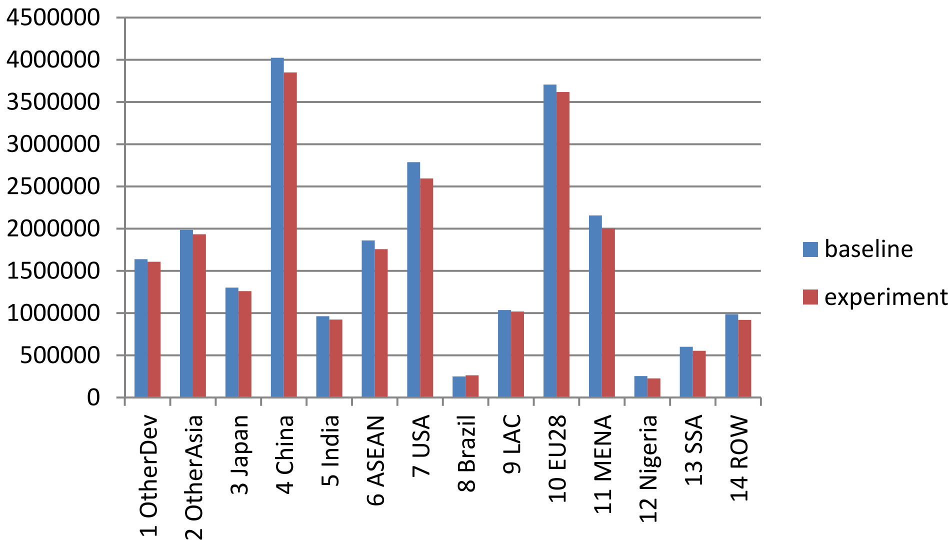

Figure 6: The value of exports in different regions in 2030 in the baseline and with differential productivity growth because of digitalization

Table 3: Productivity growth scenarios as a result of digitalization from OECD

Sectors	Productivity shock	Regions	Scaling factor
Agriculture	1.17	OtherDev	0.66
Extraction	1.15	OtherAsia	0.73
ProcFood	1.15	Japan	0.66
Chemicals	2.10	China	0.73
OtherGoods	1.15	India	0.33
Metals	1.15	ASEAN	0.33
ElectrMach	2.21	USA	1.50
OtherMach	1.33	Brazil	0.33
Utilities	1.15	LAC	0.33
Trade	1.53	EU28	0.60
Transport	1.17	MENA	0.21
Comm	2.21	Nigeria	0.10
BusServices	1.15	SSA	0.10
FinanceInsur	2.21	ROW	0.17
OthServices	1.15		

Source: De Backer and Flaig (2017)

4.2 E-commerce and falling trade costs

More and more consumers and firms are turning to online markets and platforms to make their purchases. It is estimated that global e-commerce transactions in 2016 amounted to about $28 trillion, up 44 percent from 2012 (USITC, 2017). E-commerce transactions between businesses (B2B) are estimated to be six times larger than e-commerce purchases of consumers from businesses (B2C). While cross-border e-commerce transactions are only about 15% of the total e-commerce market, they are expected to grow rapidly by about 25% annually until 2020 – nearly twice the growth rate of domestic e-commerce (DHL, 2017).

By reducing search costs, the Internet and e-commerce platforms can facilitate market transactions including cross-border trade (see e.g. Cairncross (2001), Borenstein and Saloner (2001)). This is borne out by the empirical literature which finds that e-commerce reduces distance-related trade costs (Freund and Weinhold (2004); Clark (2008); Hortacsu (2009); Ahn et al. (2011); and Lendle et al. (2016)). E-commerce shrinks the distance between buyer and seller — by nearly a third according to Lendle et al. (2016) — facilitating more exchange.

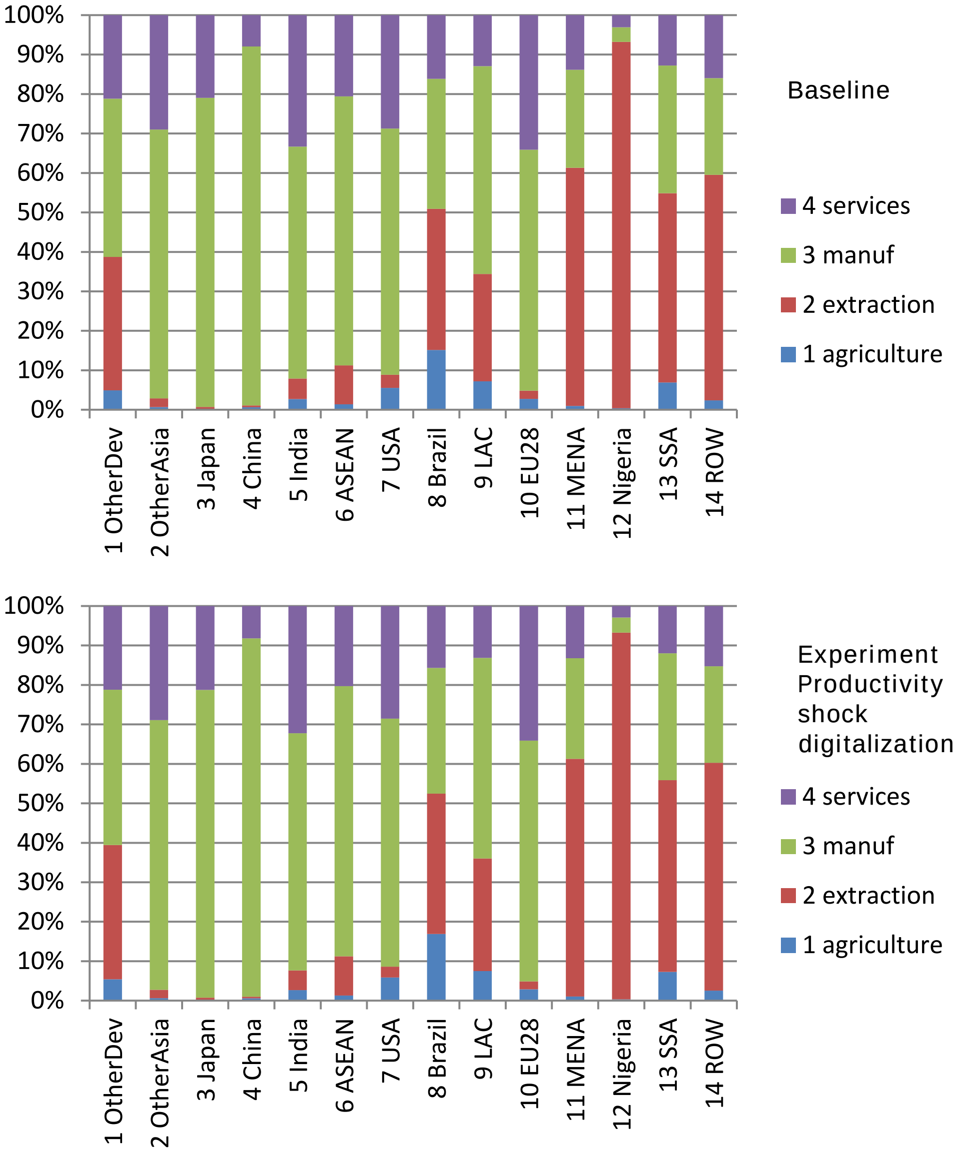

Figure 7: The value of exports in aggregate sectors in different regions in 2030 in the baseline and with differential productivity growth because of digitalization

4.3 Robotization and artificial intelligence

The automation or robotization of production is accelerating around the world. According to the International Federation of Robotics, there are now 74 robot units per 10,000 employees globally in the manufacturing industries compared to the average global density of 66 units just two years ago.[4] By regions, the average robot density in Europe is 99 units, in the Americas 84 and in Asia 63 units.

Robotization is expected to make production more capital intensive. There is also a growing number of studies which support the idea that robots lift productivity. For trade, the impli-

[4] https://ifr.org/ifr-press-releases/news/robot-density-rises-globally.

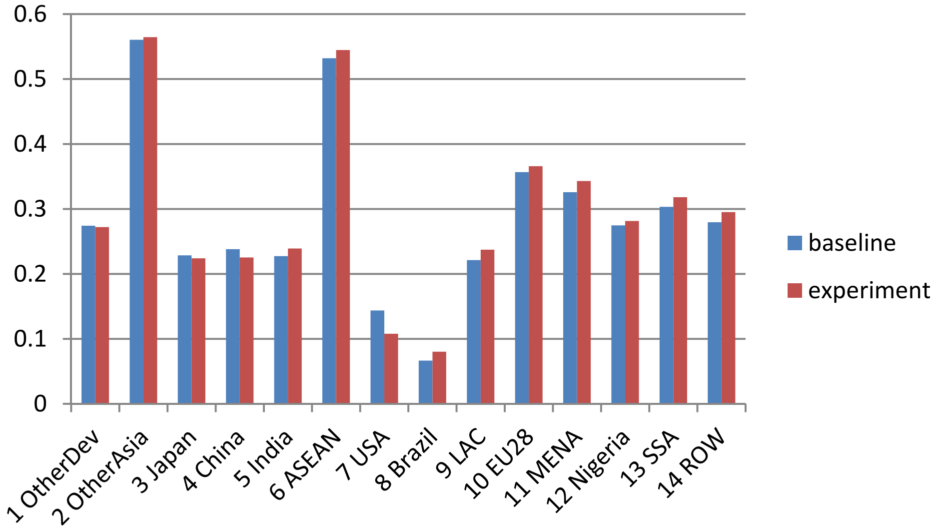

Figure 8: The ratio of exports to GDP in different regions in 2030 in the baseline and with differential productivity growth because of digitalization

cation is that more capital abundant countries are likely to reap these productivity benefits in manufacturing encouraging reshoring of manufacturing activity from emerging economies. We will project the capital intensity of production based on historical trends and examine the impact on the patterns of in international specialization and reshoring.

Artificial intelligence (AI) can be defined as the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with humans, such as the ability to reason, discover meaning, generalize, or learn from past experience.[5] Important branches of AI, such as machine learning, rely on computing power to sift through big data to recognize patterns and make predictions without being explicitly programmed to do so. It can be seen as a form of automation in which the computing ability of machines is substituted for human intelligence and expertise (Aghion et al. (2017)). Like robotization, it is likely to increase the capital intensity of production.

4.4 3D printing

Additive manufacturing, more popularly known as 3D printing, is a process of making a three-dimensional solid object of virtually any shape from a digital model. It is achieved using an additive process, where successive layers of material are laid down in different shapes. It is being used for an enormous range of applications, such as fabricating spare and new parts for planes, trains and automobiles and thousands of items in between (Garrett (2014)). Additive

[5] https://www.britannica.com/technology/artificial-intelligence.

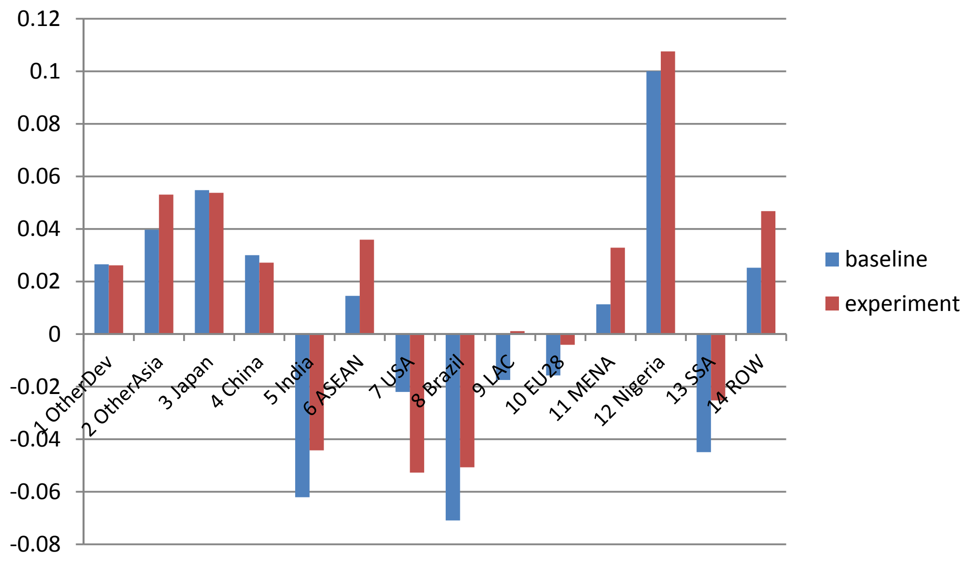

Figure 9: The trade balance in different regions in 2030 in the baseline and with differential productivity growth because of digitalization

technology could have large effects for the size and pattern of international trade. First, it could lead to a shift away from trade in physical goods to digital trade. Second, it lowers the cost of producing goods for markets with low volumes, or customized and high-value production chains as aerospace and medical component manufacturing (Gebler (2014)). Third, additive manufacturing is also expected to lead to more localized supply chains which can result in a shift of manufacturing production away from emerging economies.

4.5 Digitalization of production process (servicification)

5 Concluding remarks

In this paper we examined the expected impact of new digital technologies on international trade in the next 15 years until 2030. We employed a dynamic CGE model to generate a baseline trajectory of the world economy based on GDP, population, labor force, and skill projections of various international agencies, complemented by our own empirically underpinned predictions on differential productivity changes by sector (structural change), changes in preferences, and the evolution of trade relative to output. The baseline displays significant structural change towards the services sectors away from manufacturing and agriculture. Developing countries will take over the dominant position of developed countries in global exports and reflecting structural change services trade will gain importance relative to manufacturing trade.

Simulations on the impact of digitalization on productivity growth differing across sectors and regions indicate that the USA will attract more international capital flows and diminish their integration into the world economy, thus concentrating more on their domestic economy. Obviously, this result is driven by the assumption that the USA is the country best prepared for the digital transformation of the economy. The other simulation experiments show ... .

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Appendix A