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Paths of Robotization

Robotization according to Varieties of Capitalism

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This paper is dedicated to Albert Medina, Anton Hemerijck and Javier Arregui for their constant intellectual challenge. Without their support and trust this paper would have not been possible.

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Abstract

In this paper I analyse what factors explain the degree of robotization and why the effects of robotization on the labour force differ so much from country to country. This paper bears witness to the fact that robots do not necessarily lead to job losses, and that differences in national context are very relevant to fully understand both the degree and the effects of robotization. Robotization does not lead per se to destruction of jobs, if that is the case, the root can be traced to the functioning of a particular system of political economy. In fact, this paper finds that robotization, due to its productivity enhancing benefits is a source for job stability in many advanced countries and helps in remaining internationally competitive.

In this paper I discuss 4 case-studies of robotization according to the main Varieties of Capitalism, I analyse what are the social outcomes of robotization in each one and I make some specific public policy recommendations.

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Introduction

On the occasion of the last edition of the Premi Catalunya Europa Segle XXI, the Fundació Catalunya Europa awarded the work of Dr. Javier Arregui's on the issue of the winners and losers of the process of European integration and the lack of policies at the EU level to address it.

Dr. Arregui's valuable research showed that only a minority of the top 20% EU citizens felt the benefits of economic integration and identified with the EU project, while the remaining 80% did not feel tangible benefits from it (or only marginally) and did not identify with this process.

In his policy recommendations, Arregui stressed the importance of common social protection policies to generate more inclusive growth in Europe and reverse the trend of growing Euroscepticism, given that the lack of common social policies is the Achilles heel of the EU, and more specifically, of the Economic and Monetary Union.

I think the theme of this former research has a lot of relevance for the present edition, which is focused on work and training policies for the future; as these policies are of vital importance for inclusive economic growth and overall social protection. Moreover, for this edition, a special emphasis has been placed on the issues that robotization entails in terms of economic development and job loss.

Both robotization and social policy are subjects of special academic interest to me, and so I decided to take part in this year's edition and write this paper on these profoundly interesting subjects.

The time for writing on them could not have been better, as I had recently read two extremely interesting papers on robotization, one by Daron Acemoglu and Pascual Restrepo about the process of robotization in the USA and one by Wolfgang Dauth and others about the process of robotization in Germany.

In their analysis, Dauth et al. found that Germany is a country which has incorporated much more robots in its manufacturing sector than the USA and, at the same time, has had much fewer negative effects of robots on workers (less destruction of jobs and wage losses) than what Acemoglu found for the USA.

This counterintuitive finding immediately picked my interest, and I thought it was particularly relevant because, just as in the 90's globalization was seen by some authors as an irreversible extremely powerful process, swaying all nations into an inescapable liberalizing trend, robotization has been generally discussed in terms that make little distinction among the different national varieties of political economy.

As is the case with major economic trends, the analysis of cross-country differences and national path dependencies has proven to be of extreme importance when understanding how global economic trends translate into to the national context with success because - regardless of value judgments - States are still the most relevant political entities from an international standpoint and to me it seems very unlikely that this paradigm will change as a result of globalization or of robotization per se.

And so, I embarked onto an academic research to try and find out:

What can explain the degree of robotization?
Why the effects of robotization on the labour force differ so much from country to country?

To answer the first research question, in this paper I firstly construct a quantitative model of robotization (or robot density, understood as the number of robots per human workers) using empirical cross-country data to better understand how different variables explain robotization. And to answer the second research question, I construct a qualitative model to better understand the effects of robotization on the labour force according to different national contexts.

Once constructed these two models and using the typologies developed by the academic literature on national Varieties of Capitalism (VoC), I examine specific empirical cases representative of the most important models of Varieties of Capitalism in the world so as to check the plausibility of the two models. Hence, I examine 4 case studies representative of Liberal Market Economies (the USA) and Coordinated Market Economies (Germany), Mixed Market Economies (Spain) and State-permeated Market Economies (China).

Once I have analysed how robotization has developed there, I discuss the social outcomes of robotization in these political economies and what are their most noteworthy social challenges. The challenges differ, and so, the public policies to ensure inclusive growth should also be different and adapt to the specific needs. Hence, I suggest different policy guidelines for each variety of capitalism and I make some reflections on the role of social corporatism to ensure inclusive growth through robotization and I make some recommendations for the whole of the Eurozone.

The added value that this paper provides is not just two models to understand the different paths of robotization, but it also provides a better understanding of what are the social outcomes of robotization in different contexts and what public policies are the most pressing in each case.

It seems clear to me that, when discussing social policies for robotization, and more generally the future, it is necessary that national policymakers and social policy experts take into account not only the big trends in international economics, but also the more specific social needs. Through this paper I would ultimately like to contribute to a better public understanding of these nuances.

The underlying theoretical frameworks

The Theory of Real Competition

The first step to develop my arguments on robotization is to make explicit the basic underlying theoretical framework I use to understand the structural functioning of any capitalist market economy - which is Anwar Shaikh's Theory of Real Competition (TRC) (Shaikh, 2016) - so as to later on explain how different institutional varieties of capitalism moderate this basic functioning and generate different paths of robotization.

The choice of Real Competition is motivated because of the remarkable explanatory power of this theory to understand current issues about international competition of firms on goods and services, employment, and demand policies.

This framework, in the line of classical economists such as Adam Smith, David Ricardo, Karl Marx, etc. - and in contrast to the neoclassical theory where labour is considered as a mere input - understands that the process of production of goods and services is a labour process in which the labour force is an active subject, not a mere input like land, materials, machines and other forms of capital, and that this process therefore generates struggle over working conditions, over wages and over the social structure of production itself (Shaikh, 2016; pp. 130-135).

In Real Competition in a capitalist political economy firms compete for profits. Profitability is the ultimate goal of firms, they do not pursue productivity or investment as such if it is not expected to lead to higher profits and, contrary to neoclassical economics assumptions, firms are not guaranteed a minimum profit (Shaikh, 2016, pp. 259-290).

In Theory of Real Competition, the pursuit of profit by firms is the main driver of both demand (firms seeking profits hire workers in exchange of a certain wage) and supply (firms seeking profits sell goods and services) in a capitalist market economy, although they are channelled differently and this, far from the concept of equilibrium of Keynesian and neoclassical economics, creates mismatches to which firms and the State try to adapt through different cycles: the inventory cycle, the fixed capital cycle, and the long Kondratiev waves (Shaikh, 2016; pp. 542-546).

According to Shaik's Theory of Real Competition, competition between firms is governed by absolute cost advantages, not by classical Ricardian country comparative cost advantages (Shaikh, 2016; pp. 284-294).

Another key aspect of this theory is that in every capitalist market economy, there is a normal persistent rate of unemployment, which stems from competition itself between companies and their need for profits, and which is akin to the concept of the reserve army of labour (Shaikh, 2016; pp. 646-661).

The following table synthesizes what is the theory of unemployment according to the Theory of Real Competition and compares it with other two mainstream theories, namely, neoclassical and Keynesian theory.

TABLE 1. THREE THEORIES OF UNEMPLOYMENT

THEORETICAL PROPOSITION	ORTHODOX THEORY	KEYNESIAN THEORY	REAL COMPETITION THEORY
Persistent unemployment is a normal state of a capitalist system	Yes	Yes	Yes
The system has a particular normal rate of persistent unemployment	Yes	No (rate depends on aggregate demand)	Yes
Cause of persistent unemployment	Restrictions on competition	Demand insufficiencies	Competition between firms
Interpretation of persistent unemployment	Voluntary (Friedman) Involuntary (Phelps)	Involuntary	Involuntary
Unemployment can be eliminated in the long run	No (but it can be reduced by making labour markets more competitive)	Yes	No (but it can be reduced by weakening labour or by raising real wages and raising productivity even more)
Consequence of attempting to reduce unemployment at very low levels	Accelerated inflation	Modest inflation (Phillips curve)	Accelerated mechanization and automation

SOURCE: SHAIKH, 2016; P. 661.

Shaikh proposes a renewed Phillips curve in his theory where the relation between the growth of the wage share and unemployment intensity (unemployment and average time of unemployment) substitutes that of unemployment and inflation (Shaikh, 2016; pp. 646).

This new relation better explains the scenario that we see nowadays in many advanced countries of both very low unemployment, low wage growth and very low inflation (which the Keynesian and post-Keynesian frameworks cannot explain well). Through Shaikh's theory, very low unemployment and very low inflation are totally compatible because, despite the potential negotiating power that full employment may provide to the labour force, the labour force's demands for higher wages and better conditions can be effectively limited through the moderating effect of institutions (which vary from country to country). This is the reason which ultimately warrants the choice of this theoretical framework instead of the other theories.

The constraints on the wage share growth according the Shaik's revised Phillips curve, allow to have in a country at the same time, low unemployment and very competitive firms in a context of very open international trade. Shaikh does not develop very much the moderating effect of institutions (as he is interested in explaining the economic structure), so here I briefly outline how in the main varieties of capitalism labour demands are kept in check.

TABLE 2. MECHANISMS THAT KEEP THE DEMANDS OF THE LABOUR FORCE IN CHECK

IN LIBERAL MARKET ECONOMIES	IN COORDINATED MARKET ECONOMIES	IN MIXED MARKET ECONOMIES	IN STATE-PERMEATED MARKET ECONOMIES
External Competition	External Competition	External Competition	External Competition
Fragmentation of the labour force	Non-accommodative monetary policy	Non-accommodative monetary policy	Mock corporatism
Precarization of employment	Single currency (fixed exchange rates)	Single currency (fixed exchange rates) High structural unemployment	Precarization due to large informal economy

The theory of Varieties of Capitalism

The Implication of production of goods and services as a labour process entails struggle. This inherent struggle is managed differently in different political economies, sometimes more confrontationally, sometimes more consensually, depending on the relation of forces and the strategic management of firms in the generation and appropriation of surplus product.

The Varieties of Capitalism literature assumes, as the Theory of Real Competition does, and also as I do, that firms are the central economic actors in the economy (Hall, 2001; pp. 5-9). And in the case at hand, they orchestrate the robotization process, driven by their desire to increase profits through the capital deepening effect and through the substitution of labour.

Critics of the VoC literature have argued against its ad hoc nature to explain systems of political economy. But for the article at hand, this is actually useful, as what I am interested in are the different paths of robotization according to different political economies, and therefore, I give preference to literature that is more detailed in the explanation of different systems of political economy, even if it undermines to some extent a more systematic theory of the varieties of capitalism in the world.

Gathering from several authors (Hall, 2001), (Bohle, 2007), (Hancké, 2007), (Witt, 2014) and (Carney, 2016) I outline 7 varieties of capitalism as the general varieties which I think can explain sufficiently well all systems of political economy in the world, but the in-depth analysis will be focused on the 4 main varieties in the world today: The Liberal Market Economies, the Coordinated Economies, the Mixed Market Economies and the State-permeated Market Economies. In this table, I summarise the main characteristics of all 7 varieties.

TABLE 3. THE MAIN VARIETIES OF CAPITALISM IN THE WORLD

INSTITUTION	LIBERAL MARKET ECONOMIES	COORDINATED MARKET ECONOMIES	MIXED MARKET ECONOMIES	STATE MARKET ECONOMIES	ENCOMPASSING FAMILY MARKET ECONOMIES	EXTRACTIVE FAMILY MARKET ECONOMIES	DEPENDENT MARKET ECONOMIES
Coordination mechanism	Competitive markets and formal contracts	Inter-firm networks and associations	Coordination failures, State regulates and mediates	Informal coordination via state elites	Informal coordination among firms in a family business group	Informal coordination among firms in a family business group	Intra Multinational corporations' hierarchies
Corporate ownership and governance	Outsider control/ Dispersed shareholders	Insider control and numerous stakeholders	Mixed; predominance of Insider control in medium and small firms	State ownership and party control or connivance with party	Family owned and controlled	Family owned and controlled	Headquarter control
Primary means of raising investment	Domestic and international capital markets	Domestic bank lending and internally generated funds	Domestic bank lending and internally generated funds	Bank lending, usually through State-owned banks	Bank lending, usually group affiliated	Bank lending through family-group banks	Foreign Direct Investment and internally generated funds
Employment relations	Decentralized, few collective agreements	Centralized. Corporatist, consensual; sector-wide and national agreements	Fragmented, conflictual industrial relations	Mock corporatism; State controlled	Group specific	Few collective labour protections	Paternalistic
Education and training systems	General skills, high R&D expenditures	Company or industry-specific skill, vocational training	General skills with high skill-mismatch and overeducation	General skills	General skills and education, group specific training offered	Poor generation of general skills	Inherited skills, low specific skill formation
Innovation and production	Radical innovation in technology and service sectors	Incremental innovation of capital goods	Weaker incremental innovation than in CMEs	Copycat and massive investment and distruptive innovation in sectors deemed important by the State	Incremental innovation and quick response to new market opportunities internationally	Weak innovation, natural resources extraction	Technology transfer by Multinational Corporations, standardized manufacturing

SOURCE: HALL, 2001; BOHLE, 2007; HANCKÉ, 2007; WITT, 2014; CARNEY, 2016.

The assumptions about robotization

Once stated the underlying theoretical framework, to explain the process of robotization it is necessary first of all to understand what essentially a robot is. And so, I will make explicit the assumptions about the economic nature of robots and the assumptions about their effects. This will be useful to construct the quantitative model of robotization (or robot density) and the qualitative model of the effects of robotization in relation to labour.

Assumptions about the economic nature of robots

First of all, I assume that robots can be capital or consumer goods. According to the Theory of Real Competition, what creates the distinction between capital and consumer goods are not the qualities of the things themselves, but rather their social use. Capital comprises all the things (including money, machines, tools, land, etc.) that are used in the production of goods and services in the process of making profit, and what is not used for this process (like goods to be enjoyed for personal satisfaction) are not considered capital (Shaikh, 2016; pp. 206-208).

In this work, I am interested in the role of robotization in the economy, that is to say, in the role of robots as capital, not as consumer goods to be mmenjoyed in themselves by consumers. For a more detailed and technical definition, I am interested in the role of robots as the International Federation of Robotics defines industrial robots: "Automatically controlled, reprogrammable multipurpose manipulators programmable in three or more axes" (IFR, 2012).

It naturally follows that, as capital goods, robots are susceptible to be owned and exchanged; to be held either as assets or liabilities. Additionally, they are perfectly disciplined for the needs of firms, owners, and/or customers. In other words, they are not active subjects in the labour process with free will autonomous of their owners or their customers, unlike the labour force. They do not demand better working conditions, and they do not require social security and other expenses for firms. They only have expenses related to the costs of other fixed assets, that is amortization and depreciation costs.

Plus, I assume that robots are especially well suited for Routine Task Intensive jobs (RTI), that is, jobs based on following different pre-set patterns of action according to the information they receive (Thewissen, 2016).

And finally, robots are not as well prepared for substituting professionals in jobs which demand more abstract thinking, interpersonal relations, leadership and overall, general skills. I think this assumption is a bit more debatable, since advances in Artificial Intelligence have narrowed somewhat the gap between humans and robots in these areas (Brynjolfsson, 2014), but nonetheless humans do have an intrinsic upper hand in cognitive processes and are more effective in abstract thinking and interpersonal skills (Kanero, 2018).

Assumptions about the economic effects of robots in relation to labour

Having stated my interest in robots as capital, I can consider what is the effect of robots as a form of capital in relation to labour.

In their relation to labour, and following the framework of Real Competition, I assume that robots can have both productivity enhancing effects and labour substitution effects (Acemoglu, 2017; p. 6). In other words, they can complement workers by improving their productivity and they can also substitute workers, replacing them fully or partially. This assumption is founded by several empirical and theoretical studies on the issue of robotization (Acemoglu, 2017), (Graetz, 2015), and is related with the effects of other kinds of technological introductions such as computerisation and automation (Frey, 2013).

Given robots are well suited for routine task-intensive jobs, I therefore assume that they have significant effects in terms of labour substitution in these kinds of jobs. RTI jobs are very predominant in manufacturing but also in some services (Thewissen, 2016; p. 12), (McKinsey, 2017), (Hawksworth, 2018), therefore we should expect to see an uneven speed of robotization among sectors, with manufacturing being the sector with the highest robot density (with more robots per human employees).

In jobs that demand more abstract thinking and interpersonal relations - which are general skills, more easily transferable between firms and sectors - I assume the effects of robots are mostly complementary (or productivity enhancing), (Thewissen, 2016; p. 5), (Oesch, 2013).

These two last assumptions could be summarised in that for intellectual workers robots have mainly productivity-enhancing complementary effects. For blue collar and white-collar workers complementary effects also exist but substitution effects should be relatively stronger.

Taking all these things into consideration, robotization is not an economic phenomenon intrinsically different to that of other sorts of increasing capital intensity, and consequently, its role and limitations can be conceptually clearly defined beforehand.

The model of robot density

Dependent variable

By now, I have presented a clearer picture about the nature of robots and their effects in relation to labour, but now, to answer my first research question (What can explain the degree of robotization?) In this segment I construct a quantitative theoretical model with robot density as the dependent variable. By robot density I understand the number of robots in the economy in relation to the number of human workers.

Independent variables

As I stated previously, robots outperform humans at routine task intensive jobs, therefore, I assume the maximum extent possible of robotization in a sector of activity or in the whole economy will vary according to the prevalence of RTI jobs.

Secondly, I expect that there should be an inverse relation between the normal rate of unemployment in an economy and the number of industrial robots (the lesser unemployment, the more robots). This can be due to three main reasons:

As is the conventional wisdom, low unemployment gives leverage to the labour force to demand higher wages and better working conditions than in a context of high unemployment. This raise in labour costs would certainly provide more incentives for firms to robotise if there are falling real prices of robots. However, as stated by Shaikh, low levels of unemployment and low levels of wage rise are compatible as long as labour demands for higher wages can be kept in check through institutions. This would reduce the incentive of firms for robotization, but, I argue -gathering from the Kaleckian tradition- that low unemployment helps keeping up the elasticity for the demand of goods and services (as people at the lower end of the income distribution have a higher propensity to consume) (Baccaro, 2016; pp. 181-186). Therefore, and in any case, full employment has a stimulating effect on demand, which incentivises firms to invest in robotization to mass-produce relatively cheaper consumer goods and services in order to obtain more profits.

The third reason I find is that, even if labour demands are kept in check, in very tight labour markets, firms may find robotization a good way to compensate located labour shortages without having to compete in attracting workers by raising wages.

So, to summarise, I expect very low unemployment should have a positive effect on the number of installed robots and, due to the nowadays situation in advanced countries, I think that the main reasons would be the second one and the third one.

Fourthly, as I have previously hinted to, besides the more structural variables, I suspect that the number of robots in an economy is determined by institutional arrangements, which differ among countries, in other words, it is determined by the Varieties of Capitalism (Hall, 2001), but I am not able to anticipate particular outcomes with this variable. Also, I expect that the growth model of a country (Baccaro, 2016) should at least partially explain the robotization process. The reason is that if firms in a country have a business strategy which seeks to increase their profits more competitively by exporting their goods and services, firms would have an appetite to invest more in robots in order to increase productivity and contain labour costs to outcompete external rivals. In other words, I expect that countries with aggressive internationally competitive models should install more robots than countries with growth models more geared by internal demand growth.

Sample

The aim of the quantitative model is to accurately explain robotization as a general process, in the whole world. To do this, I take as a sample a selection of 33 countries for which there is readily available data for the dependent variable and for all the independent variables.

The sample includes the following countries: Austria, Australia, Belgium, Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Greece, Indonesia, Italy, Japan, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Singapore, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Taiwan, Turkey, United Kingdom and United States of America.

Data for the dependent variable

I pick for the model the number of installed industrial robots per 10,000 human employees in the manufacturing industry. The manufacturing industry has been traditionally the industry most robotized and the best measured, which allows me to have sufficient good quality data to assess robotization. The data on installed industrial robots is provided by the International Robotics Federation, for the years 2017 and 2016 (IFR, 2018). This data is the most comprehensive and easily comparable for cross-country variation.

Data for the independent variables

For the prevalence of Routine Task Intensive jobs, I take as a proxy variable the percentage risk of automation in the manufacturing industry elaborated in 2018 by the consultancy firm PwC (Hawksworth, 2018; p. 19) which disaggregates the risk of automation in the previously selected countries. For Canada and some Asian countries I take the data from another report from Mckinsey of 2017 (McKinsey, 2017; p. 9).

For the normal rate of unemployment in an economy, I select as the main proxy variable the Non-Accelerating Wage Rate of Unemployment in 2017 estimated by AMECO. The data on

Australia, Canada, Mexico, New Zealand and South Korea is taken from the Non-Accelerating Inflation Rate of Unemployment estimates of CeSIFO for the year 2015 (DICE Database, 2015). For the Asian countries except South Korea, given the lack of recent estimations of structural unemployment, I take the unemployment rate of 2017 data of the World Bank (in this year inflation rates are at reasonably low levels for all these countries between 0,8% and 3,5%).

For the variable of the Varieties of Capitalism, I use a classification of countries built upon the work of different authors of the Varieties of Capitalism literature (Hall, 2001), (Bohle, 2007), (Hancké, 2007), (Witt, 2014), (Carney, 2016). I distinguish between Liberal Market Economies, Coordinated Market Economies, Mixed Market Economies, State-permeated Market Economies, Encompassing Familial Market Economies, Extractive Familial Market Economies and Dependent Market Economies. I think virtually all countries in the world can be classified quite well in these 7 categories.

For the growth model, I take as a proxy the Trade balance (% to GDP) data from the World Bank for 2017.

TABLE 4. DATA FOR THE MODEL

COUNTRY	ROBOT DENSITY	RTI	NORMAL UNEMPLOYMENT	VARIETY OF CAPITALISM	TRADE BALANCE
Austria	167	48	5,1	CME	3,164992056
Australia	83	44	5,3	LME	0,647737194
Belgium	192	45	7,1	CME	0,70388178
Brazil	10	50	13,3	ExtractiveFME	1,015391793
Canada	161	61	7,1	LME	-2,274598245
China	97	50	4	SME	1,711360608
Czech Republic	119	55	3	DME	7,212675634
Denmark	230	46	5	CME	7,058195558
Finland	139	41	7,2	CME	0,45901522
France	137	53	9,3	MME	-1,102323379
Germany	322	49	3,7	CME	7,573965404
Greece	17	35	13,8	MME	-1,076385048
Indonesia	5	50	5,4	ExtractiveFME	1,205394757
Italy	190	55	9,7	MME	3,078463031
Japan	308	32	3	CME	0,971722688
Malaysia	34	50	3,4	SME	6,941952741
Mexico	31	52	4,8	ExtractiveFME	-1,805021078
Netherlands	172	46	5	CME	11,6810881
New Zealand	49	36	6,3	LME	0,312598836
Norway	51	33	3,3	1)CME(Norway)	2,420517702
Philippines	3	48	7,7	ExtractiveFME	-9,927759436
Poland	32	50	6	DME	4,022113504
Singapore	658	33	2,1	SME	24,26228555
Slovakia	151	58	8,6	DME	3,426475756
Slovenia	144	57	6,4	DME	9,657558523
South Korea	710	31	3,2	EncompassingFME	5,402732376
Spain	157	45	16,3	MME	2,666753748
Sweden	240	45	6	CME	4,207118264
Switzerland	129	47	4	CME	11,04926124
Taiwan	197		3,8	EncompassingFME	14,7
Turkey	23	45	9,2	ExtractiveFME	-4,513550233
UK	71	45	5,5	LME	-1,404567445
USA	200	53	5	LME	-2,798677547

Simple linear regression analyses

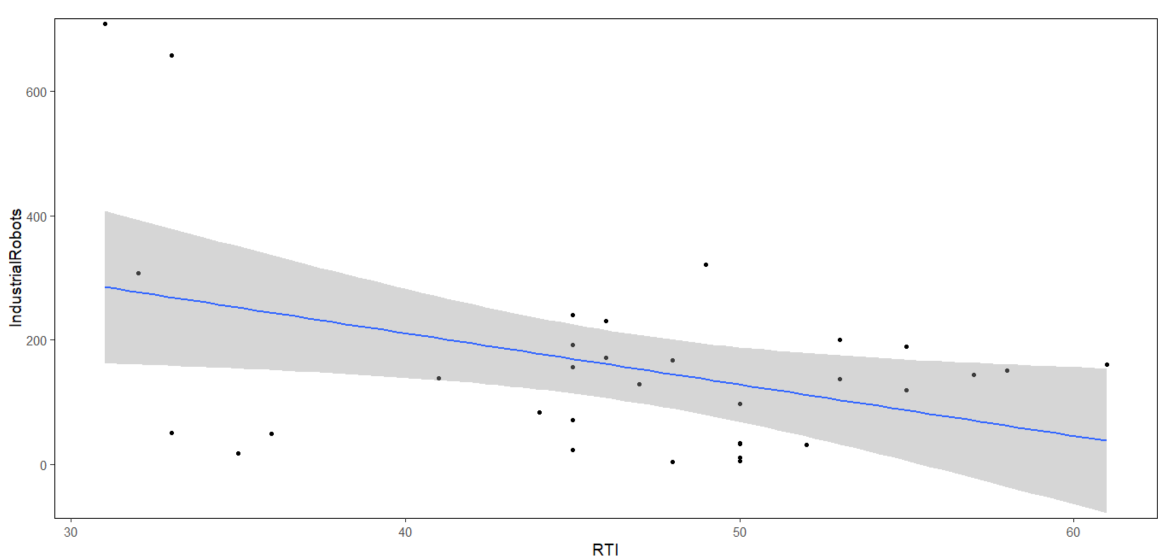
A separate regression analysis of the different variables allows to find what independent variables show higher correlation with the density of robots and the higher statistical significance.

TABLE 5. LINEAR REGRESSION WITH ROUTINE TASK INTENSIVENESS

lm(formula = RobotDensity ~ RTI, data = Dataset)				
RESIDUALS:				
MIN	**1Q**	**MEDIAN**	**3Q**	**MAX**
-235,37	-96,89	-1,02	71,16	424,55
COEFFICIENTS:	**ESTIMATE**	**STD. ERROR**	**T VALUE**	**PR(>|T|)**
(Intercept)	541,847	164,343	3,297	0,00252**
RTI	-8,271	3,487	-2,372	0,02431*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 151.6 on 30 degrees of freedom
(1 observation deleted due to missingness)
Multiple R-squared: 0.1579, Adjusted R-squared: 0.1299
F-statistic: 5.626 on 1 and 30 DF, p-value: 0.02431

GRAPH 1. SCATTERPLOT OF RTI REGRESSION



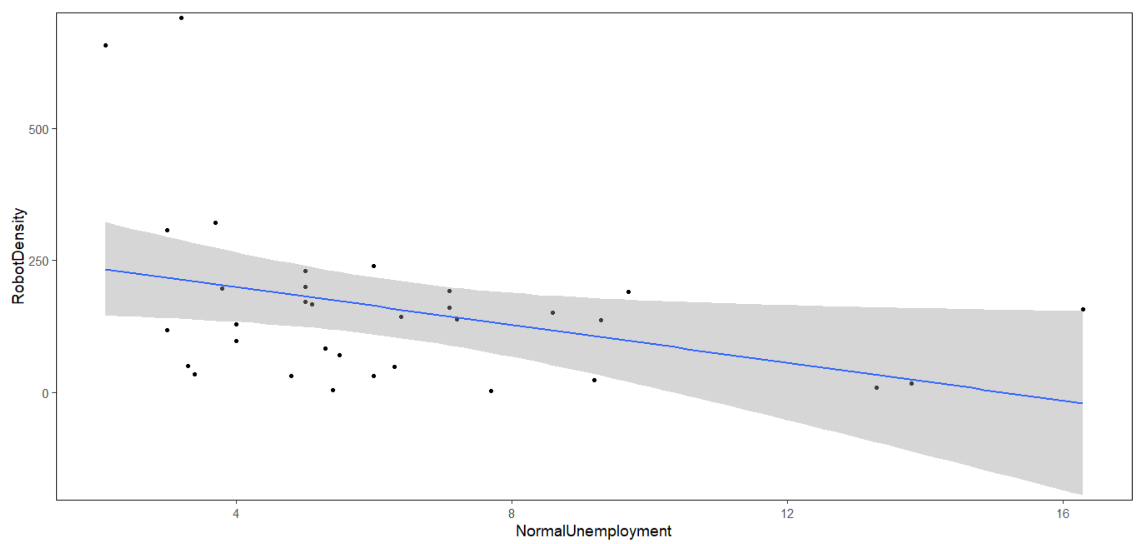
Routine Task Intensiveness is negatively associated with robot density, this would mean that, the more Routine Task Intensiveness, the less installation of robots has been undertaken at a given period in time, therefore there is more scope for future robotization. It is a statistical significant relation with a relatively low coefficient of determination.

TABLE 6. LINEAR REGRESSION WITH NORMAL UNEMPLOYMENT

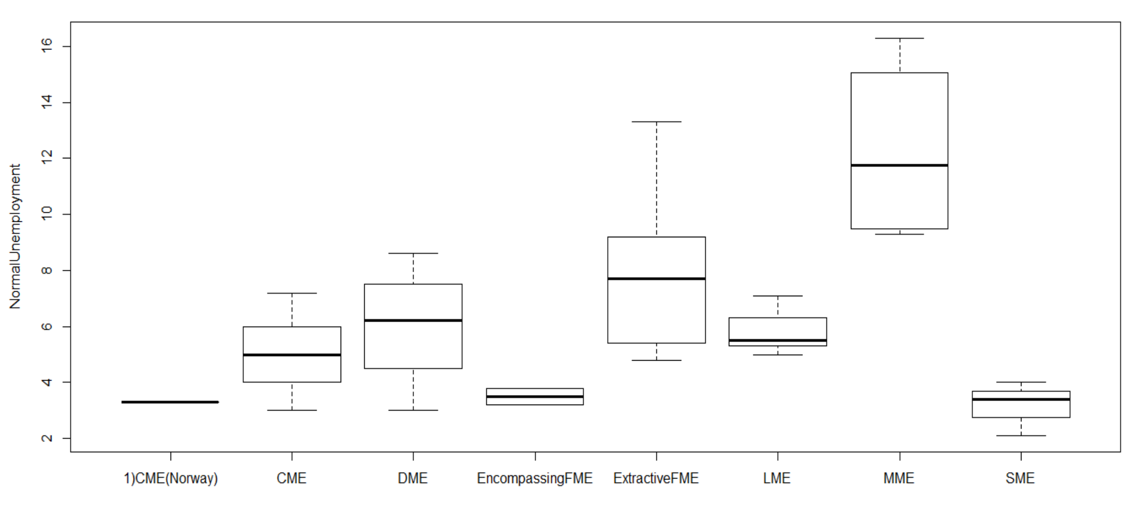
lm(formula = RobotDensity ~ NormalUnemployment, data =				
RESIDUALS:				
MIN	**1Q**	**MEDIAN**	**3Q**	**MAX**
-176,76	-102,16	-10,11	47,49	495,66
COEFFICIENTS:	**ESTIMATE**	**STD. ERROR**	**T VALUE**	**PR(>|T|)**
(Intercept)	271,631	57,838	4,696	0,0000512***
NormalUnemployment	-17,904	8,146	-2,198	0,0356*

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 151.3 on 31 degrees of freedom
Multiple R-squared: 0.1348, Adjusted R-squared: 0.1069
F-statistic: 4.831 on 1 and 31 DF, p-value: 0.03555

GRAPH 2. SCATTERPLOT OF NORMAL UNEMPLOYMENT REGRESSION



GRAPH 3. BOX PLOT OF NORMAL UNEMPLOYMENT BY VOC



By plotting a box plot with the Varieties of Capitalism as a stratum variable it is easy to observe that the varieties with lower rates of normal unemployment are Encompassing Family Market Economies, State-permeated Market Economies and Coordinated market Economies. In stark opposition, Mixed Market Economies and Extractive Family Economies have the highest rates of normal unemployment.

Interestingly, the relation between the rate of Normal unemployment and the robot density seems to follow a logarithmic function: very low levels of unemployment seem to increase proportionally more the number of installed robots. By performing a logarithmic transformation of the data on normal unemployment it is possible to observe how both the coefficient of determination and the statistical significance of the regression substantially increase.

TABLE 7. LINEAR REGRESSION WITH LOGNORMALUNEMPLOYMENT

lm(formula = RobotDensity ~ logNormalUnemployment, data				
RESIDUALS:				
MIN	**1Q**	**MEDIAN**	**3Q**	**MAX**
-206,65	-91,66	-6,12	59,5	459,52
COEFFICIENTS:	**ESTIMATE**	**STD. ERROR**	**T VALUE**	**PR(>|T|)**
(Intercept)	439,07	57,838	4,696	0,00000649***
logNormal Unemployment	-162,14	53,09	-3,054	0,00461**

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 142.6 on 31 degrees of freedom
Multiple R-squared: 0.2313, Adjusted R-squared: 0.2065
F-statistic: 9.327 on 1 and 31 DF, p-value: 0.00461

GRAPH 4. SCATTERPLOT OF LOGNORMALUNEMPLOYMENT REGRESSION

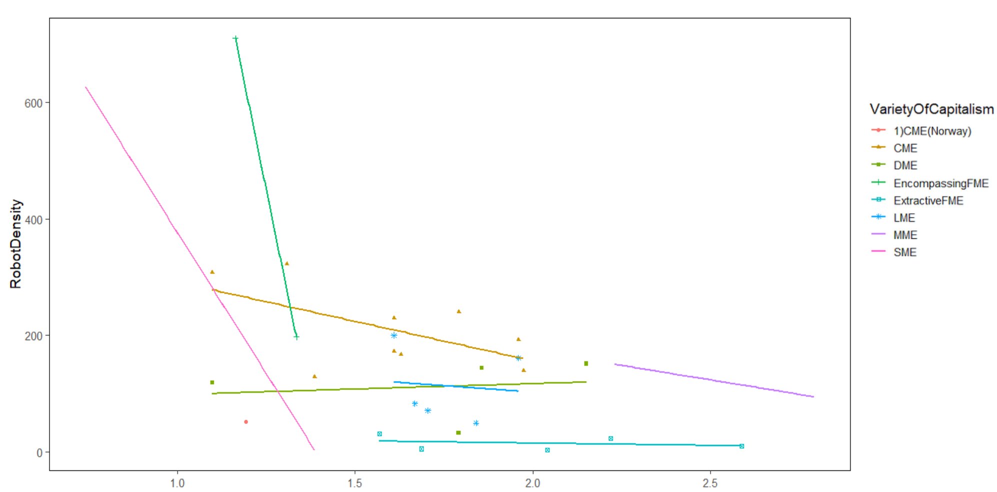


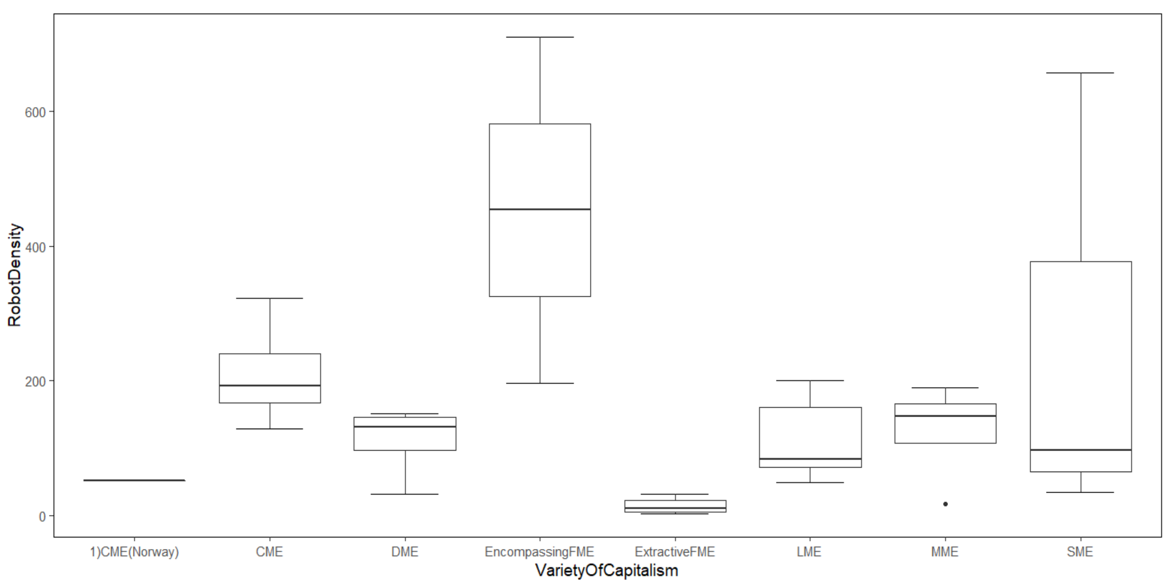
TABLE 8. LINEAR REGRESSION WITH VARIETIES OF CAPITALISM

lm(formula = RobotDensity ~ logNormalUnemployment, data = Dataset)				
RESIDUALS:				
MIN	**1Q**	**MEDIAN**	**3Q**	**MAX**
-256,5	-44	0	32,5	395
COEFFICIENTS:	**ESTIMATE**	**STD. ERROR**	**T VALUE**	**PR(>|T|)**
(Intercept)	51	134,09	0,38	0,7069
VarietyOfCapitalism[T.CME]	160	141,35	1,132	0,2684
VarietyOfCapitalism[T.DME]	60,5	149,92	0,404	0,69
VarietyOfCapitalism[T.Encom-passingFME]	402,5	164,23	2,451	0,0216*
VarietyOfCapitalism[T.Extrac-tiveFME]	-36,6	146,89	-0,249	0,8053
VarietyOfCapitalism[T.LME]	61,8	146,89	0,421	0,6776
VarietyOfCapitalism[T.MME]	74,25	149,92	0,495	0,6247
VarietyOfCapitalism[T.SME]	212	154,84	1,369	0,1831

—

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 134.1 on 25 degrees of freedom
Multiple R-squared: 0.4519, Adjusted R-squared: 0.2985
F-statistic: 2.945 on 7 and 25 DF, p-value: 0.02153

GRAPH 5 BOX PLOT OF ROBOT DENSITY ACCORDING TO THE VARIETIES OF CAPITALISM



By observing the regression of Varieties of Capitalism on the robot density and a box plot of the two variables we can observe how the varieties which show on average higher robotization are Encompassing Family Market Economies, Coordinated Market Economies and Mixed Market Economies. The variable Varieties of Capitalism seems to be the one which could explain the best the density of robots in a country according to the adjusted coefficient of determination of 0.2985 and a p-value of 0.02153.

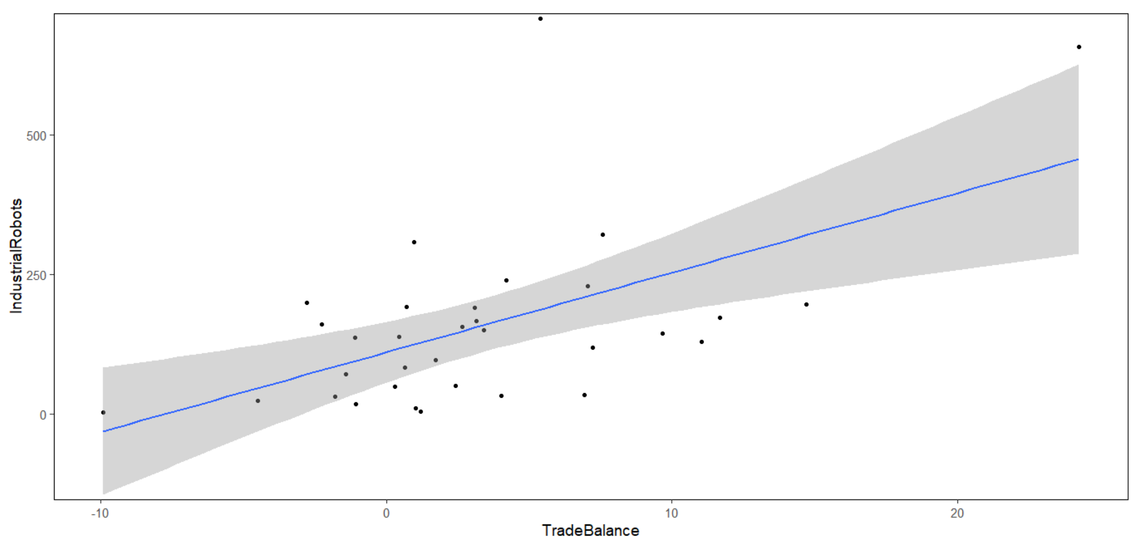
TABLE 9. LINEAR REGRESSION WITH EXTERNAL BALANCE

lm(formula = RobotDensity ~ TradeBalance, data = Dataset)				
RESIDUALS:				
MIN	**1Q**	**MEDIAN**	**3Q**	**MAX**
-175,73	-94,6	-19,48	42,2	522,26
COEFFICIENTS:	**ESTIMATE**	**STD. ERROR**	**T VALUE**	**PR(>|T|)**
(Intercept)	110,547	26,783	4,127	0,000256***
TradeBalance	14,288	3,825	3,736	0,000757***

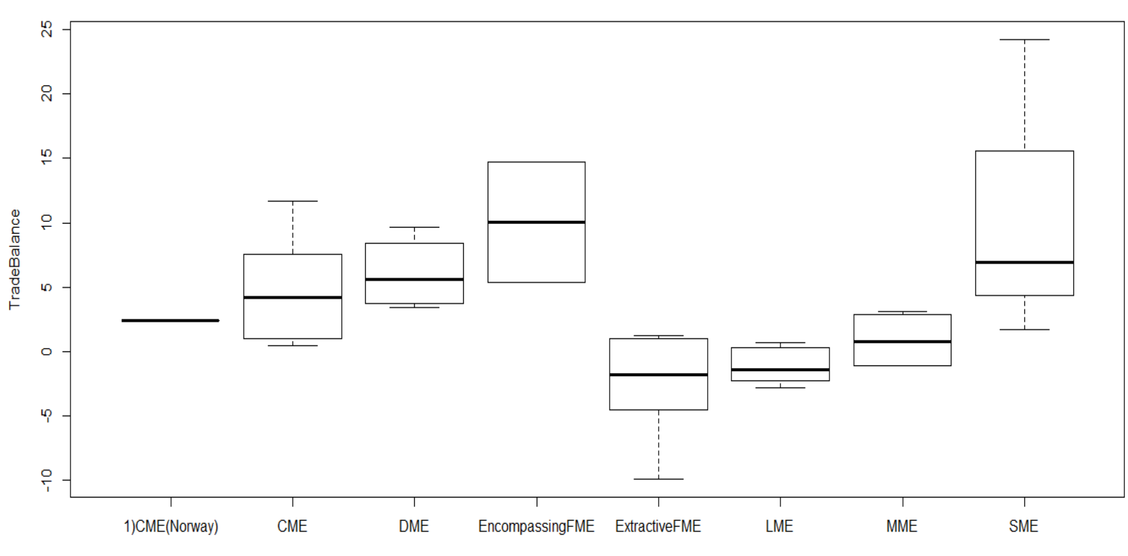
—

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 135.1 on 31 degrees of freedom
Multiple R-squared: 0.3104, Adjusted R-squared: 0.2882
F-statistic: 13.96 on 1 and 31 DF, p-value: 0.000757

GRAPH 6. EXTERNAL BALANCE REGRESSION



GRAPH 7. BOX PLOT EXTERNAL BALANCE ACCORDING TO VOC



By observing the regression of the growth model (using as a proxy the trade balance) on the robot density and a box plot of the two variables we can observe how the varieties which have on average more export-led growth models are Encompassing FMEs, SMEs, DMEs and CMEs. One additional percentage change in the trade balance is correlated with an increase in robot density of 14. The growth model to the robot density seems to be highly correlated of the robot density in an economy with an adjusted coefficient of determination of 0.2882 and a p-value of 0.000757.

Even more interestingly, when I generate an interaction between the variety of capitalism and the growth model (using as a proxy the trade balance as a % of GDP) to explain the robot density, the coefficient of determination jumps to extremely high levels and the statistical significance is extremely strong.

TABLE 10. INTERACTION VOC EXTERNAL BALANCE

lm(formula = RobotDensity VarietyOfCapitalism*TradeBalance, data				
RESIDUALS:				
MIN	**1Q**	**MEDIAN**	**3Q**	**MAX**
-117,49	-23,73	0	26,64	116,58
COEFFICIENTS:	**ESTIMATE**	**STD. ERROR**	**T VALUE**	**PR(>|T|)**
(Intercept)	-15,976	67,804	-0,236	0,816386
VarietyOfCapitalism[T.CME]	239,261	76,853	3,113	0,006003
VarietyOfCapitalism[T.DME]	83,468	110,844	0,753	0,461172
VarietyOfCapitalism[T.Encom-passingFME]	1024,085	131,812	7,769	0,000000371***
VarietyOfCapitalism[T.Extrac-tiveFME]	31,316	76,897	0,407	0,688627
VarietyOfCapitalism[T.LME]	89,574	77,979	1,149	0,265718
VarietyOfCapitalism[T.MME]	119,33	77,136	1,547	0,139259
VarietyOfCapitalism[T.SME]	-24,617	84,766	-0,29	0,774819
TradeBalance	27,67	4,02	6,883	0,000001945***
VarietyOfCapitalism[T.CME]: TradeBalance	-30,029	6,781	-4,429	0,000324
VarietyOfCapitalism[T.DME]: TradeBalance	-20,432	13,919	-1,468	0,159376
VarietyOfCapitalism[T. EncompassingFME]:TradeBalance	-82,848	10,97	-7,552	0,000000551***
VarietyOfCapitalism[T. ExtractiveFME]:TradeBalance	-27,335	8,302	-3,292	0,004048
VarietyOfCapitalism[T.LME]: TradeBalance	-63,195	22,243	-2,841	0,010838*
VarietyOfCapitalism[T.MME]: TradeBalance	-3,113	17,363	-0,179	0,859708
VarietyOfCapitalism[T.SME]: TradeBalance	NA	NA	NA	NA

—

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 67.1 on 18 degrees of freedom
Multiple R-squared: 0.9012, Adjusted R-squared: 0.8243
F-statistic: 11.73 on 14 and 18 DF, p-value: 0.000002574

Multivariate regression analysis

After having run regression analyses for the separate variables, I am now interested in checking how well the model of robot density I had envisioned fares when analysing the variables and the empiric data I have selected.

The model can be expressed through this formulation:

Robot density= Prevalence of RTI + logNormal rate of unemployment + Variety of Capitalism*Trade Balance

TABLE 11. MULTIVARIATE REGRESSION

lm(formula = RobotDensity RTI + logNormalUnemployment + VarietyOfCapitalism*TradeBalance, data = Dataset)				
RESIDUALS:				
MIN	**1Q**	**MEDIAN**	**3Q**	**MAX**
-122,707	-29,611	0,396	26,958	97,064
COEFFICIENTS:	**(2 NOT DEFINED BECAUSE OF SINGULARITIES)**			
	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-14,088	133,473	-1,06	0,917251
RTI	1,987	2,868	0,693	0,49838
logNormalUnemployment	-56,51	46,48	-1,216	0,241703
VarietyOfCapitalism[T.CME]	252,776	81,555	3,099	0,006888**
VarietyOfCapitalism[T.DME]	94,735	110,844	0,742	0,468901
VarietyOfCapitalism[T.Encom-passingFME]	578,695	95,914	6,033	0,0000174***
VarietyOfCapitalism[T.Extrac-tiveFME]	44,436	94,381	0,471	0,644126
VarietyOfCapitalism[T.LME]	102,817	83,982	1,224	0,238571
VarietyOfCapitalism[T.MME]	166,059	99,603	1,667	0,114924
VarietyOfCapitalism[T.SME]	-51,522	100,012	-0,515	0,613484
TradeBalance	27,677	4,819	5,743	0,0000302***
VarietyOfCapitalism[T.CME]: TradeBalance	-32,585	7,978	-4,084	0,000864***
VarietyOfCapitalism[T.DME]: TradeBalance	-24,546	14,44	-1,7	0,108524
VarietyOfCapitalism[T. EncompassingFME]:TradeBalance	NA	NA	NA	NA
VarietyOfCapitalism[T. ExtractiveFME]:TradeBalance	-27,993	8,978	-3,118	0,006626**
VarietyOfCapitalism[T.LME]: TradeBalance	-53,38	25,338	-2,107	0,051278
VarietyOfCapitalism[T.MME]: TradeBalance	-5,227	18,861	-0,277	0,785232
VarietyOfCapitalism[T.SME]: TradeBalance	NA	NA	NA	NA

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error: 67.26 on 16 degrees of freedom
(1 observation deleted due to missingness)
Multiple R-squared: 0.9116, Adjusted R-squared: 0.8287
F-statistic: 11 on 15 and 16 DF, p-value: 0.000009746

The separate linear regressions and the model of robot density confirm the effects that I had previously expected with regard to the relation between normal unemployment and robot density, and the growth model and robot density, but somewhat surprisingly the Routine Task Intensiveness has flipped the sign when doing the multivariate regression; it is difficult to pin down the actual effect of this variable and its actual significance in explaining robotization. Moreover, and remarkably, the Varieties of Capitalism is the variable that determines the most the robot density in an economy.

With an adjusted coefficient of determination of 0,8287 and a p-value of 0.000009746 this general quantitative model is extremely statistically significant and accurate to explain the degree of robotization in the world.

To assess the statistical power of the study I perform a post-hoc power study; given that the robot density in countries drops to 3 industrial robots per 10,000 employees in manufacturing after the Philippines (which ranks 43rd according to the IFR data), it seems to me a conservative estimate to suppose that the average of industrial robots for the remaining 148 countries in the whole world recognised by the UN not taken into account into the IFR data is 2 and the standard deviation is close to 0.

Through this estimation, the mean of industrial robots per 10,000 employees for the world (193 countries) falls to 30,06 and the standard deviation to 87,977. The mean for my sample of 33 countries is 158,4545 and the standard deviation is 160,1. Taking into account this figures and a very conservative alpha of 0,0001, the post-hoc power of the study is close to 100%.

I think it is important to acknowledge as a limitation of the model, that it does not seek to explain qualitative differences of the robots installed. Of course not all robots installed in the same countries perform the same functions as capital nor do they cost the same, but I think the variables and the empirical data used compensate the limitation on the qualitative issues of robots, as it has been centred around manufacturing, in which we could expect less heterogeneity of robot quality than in the overall economy (in which robotization is less frequent to start with).

The qualitative model of the effects of robots in relation to labour

Now, to answer my second research question (Why the effects of robotization on the labour force differ so much from country to country?) my aim is to understand the effects of robots in relation to labour depending on the institutional features of the different varieties of capitalism. According to the framework of the Theory of Real Competition the seeking of profits by firms drives the supply and demand of the economy, but institutions moderate their strategies to achieve them, so it seems logical that they should also moderate the effect that institutions have in the relation between firms and the labour force when facing the issue of robotization.

To better grasp the effect, I construct a qualitative model of the effect of robots in relation to labour by taking some qualitative variables. The variables I select concern the growth model and the strength of labour when negotiating with employers in different areas, namely: employment protection, flexibility in working conditions, the role of work councils in the strategic management of firms and the level of union membership. This is how the different Varieties of capitalism fare in these variables:

TABLE 11. VARIABLES OF THE EFFECT OF ROBOTS IN RELATION TO WORKERS ACCORDING TO VOC LITERATURE

VARIABLES	LIBERAL MARKET ECONOMIES	COORDINATED MARKET ECONOMIES	MIXED MARKET ECONOMIES	STATE-PERMEATED MARKET ECONOMIES	ENCOMPASSING FAMILY MARKET ECONOMIES	EXTRACTIVE FAMILY MARKET ECONOMIES	DEPENDENT MARKET ECONOMIES
Employment protection	Low	High	High	High	Medium	High	Medium
Flexibility in working conditions	High	High	Low	Low	Low	Low	Medium
Role of work councils in strategic management	Weak	Strong	Weak	Weak	Weak	Weak	Medium
Union membership	Low	High	Medium	High	Low	Low	Low
Growth model	Internal demand	Export-led	Internal demand	Export-led	Export-led	Internal demand	Export-led
Effects of robots on labour	Destructive	Benign	Relatively Benign	Benign	Relatively benign	Relatively benign	Relatively benign

SOURCE: HALL, 2001; CARNEY, 2016; BOHLE, 2007; OECD; ICTWSS.

High Employment protection, low flexibility in working conditions, a strong role of work councils in the strategic management of firms, high union membership and an export-led growth model would make robotization a more benign process for workers and limit the ability of firms to use robots as a means to substitute current jobs and reduce wages.

And, on the contrary, low employment protection, high flexibility in working conditions, a weak role of work councils in the strategic management of firms, low union membership and a growth model oriented towards internal demand would entail a scenario much more destructive for the labour force, as firms would have very low hurdles to reduce wages and displace workers through robotization.

The reason why the growth model would influence the effect of robots on labour is that a strategic focus of firms on internal demand to gain profits, facing less external competition than exporting to world markets, would entail a higher tendency to use robots to substitute domestic jobs and high salaries. In contrast, countries with export-led models where firms seek to actively gain profits through exports to world markets, robotization is a long-term investment to increase productivity of the labour force to maintain cost-competitiveness.

According to this simple model, we would expect to see more adverse consequences for workers in LMEs with more destruction of existing jobs and more reductions of salaries than in other varieties of capitalism. All characteristics of LMEs point to a significantly destructive role of robots in this setting.

In CMEs we would expect to see both less firings and less wage cuts due to higher employment protection, a stronger role of unions in corporate management and higher union membership. The key here is that unions in CMEs are strong but accommodative, they value more full employment and job security than inflexible working hours and high wage rises. Through their strong position in work councils, workers could ensure that these preferences are taken into account and that management strategies look at robotization as a way to keep existing jobs and cost-competitiveness in world markets.

In SMEs and MMEs the effects of robotization should also be relatively benign as firms facing high employment protection, low flexibility of working conditions and higher union membership than in other varieties of capitalism (except CMEs) would tend to adopt strategies of robotization with less firings and less wage cuts, although I expect that the combination of both high employment protection and rigid working conditions would limit the extent of robotization and suppose a trade-off, more so than in CMEs.

Empirical cases of robotization

Now that the quantitative model of robot density and the qualitative model of the effect of robots in relation to labour have been set out, the analysis of empirical cases can shed more light on the validity of the models.

A qualitative analysis is warranted for two reasons, one is that there is not enough adequate cross-country data available to test the qualitative model of the effect of robots in relation to workers in a meaningful way, and the second, and most important, is that the interest of understanding the degree of robotization and the effects of robots in relation to labour resides in the strategic decisions of firms and unions, which can be better grasped by qualitative case studies.

For these two reasons, I want to examine some cases which I think illustrate well the main Varieties of Capitalism: Liberal Market Economies (for which I select the USA), Coordinated Market Economies (Germany), State-permeated Market Economy (China) and Mixed Market Economies (Spain) to see how robotization has unfolded up to the present day in these systems.

United States of America

The United States, with 200 industrial robots per 10,000 employees in the manufacturing industry ranked 7th in the world in terms of industrial robotization in 2017. The effects of robotization have been quite well documented in the manufacturing sector of this country, and probably the most relevant empirical study of robotization at a national scale is a recent study by Daron Acemoglu and Pascual Restrepo (Acemoglu, 2017).

In this paper, they study the US labour market for the period 1990-2007 and analyse the employment rates in different areas and industries while controlling for other variables such as imports from China and the offshoring of jobs.

The results they came across showed that, in the overall US economy, between 3 and 5.6 workers lost their jobs as a result of the introduction of one additional robot and wages experimented a reduction of between 0.25% and 0.5% as a result of one additional robot per thousand employees (Acemoglu, 2017; pg. 35).

Another study by Georg Graetz and Guy Michaels shows that during this period in the United States robotization has translated into increases in productivity (Graetz, 2015; p. 28) but it has also destroyed jobs and reduced salaries in a quite substantial way as found in Acemoglu's study; hence generating a decline in the labour income share.

All these findings are in line with the qualitative model of the effects of robots in relation to labour in Liberal Market Economies, as I expect that robotization has the most destructive impact in countries with this Variety of Capitalism.

Germany

Germany with 322 industrial robots per 10,000 employees in the manufacturing industry ranks 7th in the world in terms of industrial robotization in 2017. The effects of robotization have been quite well documented in the manufacturing sector of this country, and particularly in its strong and robotized automotive sector, in which Germany has been a world leader for many decades. In 2017 the automotive industry in Germany (accounting for related activities and distribution) represented roughly 14% of GDP (Saberi, 2018) and 78% of the production of the car industry was destined to exports to other countries (GTAI, 2019).

The most relevant empirical paper on the subject of robotization in Germany is a recent study by Wolfgang Dauth, Sebastian Findeisen et al. (Dauth, 2017)., which looks at the impact of rising robot exposure on the careers of individual manufacturing workers, and the equilibrium impact across different industries (not only in the automotive sector) and local labour markets in Germany.

In this study, the authors start by stating how robot density in Germany is way higher than in the US in the manufacturing industry, and not only that, they find that between 1994 and 2014 Germany has adopted robots in the manufacturing sector at a faster rate than both the US and Europe overall (Dauth, 2017; pp. 6-7).

Back in 1994, Germany had installed 2 industrial robots per thousand workers (in the whole economy, not just manufacturing sector), Europe close to 1 and the USA 0.5. Between 1994 and 2014, robot density increased almost four-fold in Germany and in 2014 stood at 7.6 industrial robots per thousand workers compared to only 2.7 in Europe and 1.6 in the US.

Europe's manufacturing powerhouse has quadrupled the amount of industrial robots installed in the last 20 years, but despite such rapid robotization, the authors find that paradoxically -when compared to the USA- robotization has not generated negative total employment effects, or in other words, there has been no significant job destruction in Germany, and that the employment share in manufacturing is still very high, at around 25% of the whole worker population in 2014 (compared to less than 9% in the USA) (Dauth, 2018; p. 7).

According to their findings, the substitution effect of robots on labour has been channelled in Germany differently than in the USA. Rather than destroying existing jobs, the introduction of more robots has translated into changes in the tasks of existing workers and less job creation in manufacturing for new entrants into the labour market. Between 1994 and 2014, in Germany, roughly 275,000 full-time manufacturing jobs were not created because of rapid robot introduction (Dauth, 2017, pp. 8 and 41).

When it comes to wages, the study finds considerable heterogeneity at the individual level. Robotization caused gains in earnings for high-skilled workers (average of 7% increase for each additional robot per 1,000 workers), especially in scientific and management positions, but for medium and low- skilled manufacturing workers, it was accompanied by wage cuts (averages of -5% and -2.5% for each additional robot per 1,000 workers). (Dauth, 2017, pp. 34-38).

Moreover, robots increased productivity per worker, and this increase in productivity translated into higher profits for firms, but not higher wages, as previously stated; hence creating a decrease in the labour income share (Dauth, 2017, p. 40).

The authors argue that corporate industrial relations and the role of unions and work councils, which have a strong say in the management decisions of Germany's manufacturing companies, in view of the threat posed by offshoring to other countries, struck deals with employers and accepted lower wages in return for job security and full employment (Dauth, 2017, p. 41).

These findings are consistent with the expectations of the model of the effects of robots, as robotization indeed seems overall a benign process for the labour force in Germany, an archetypical Coordinated Market Economy.

Spain

Spain with 157 industrial robots per 10,000 employees in the manufacturing industry ranks 14th in the world in terms of industrial robotization in 2017. The relatively high robotization in manufacturing for Spain can be traced to the automotive sector and the sector of automobile components, which represents the largest sector in Spanish manufacturing. If we account for related activities and distribution it represented in 2017 10% of Spain's GDP, more than 9% of the total employment and 22% of the Spanish exports to the world (CCOO, 2018).

The robotization of Spain, though not having the same extent as in Germany and for different reasons of political economy, has some parallels with this Coordinated Market Economy, as the automotive industry represents the most export-oriented sector of the Spanish economy in spite of being a country with traditionally an internal demand growth model, contrary to Germany.

Overall, the institutional setting and the tendency to favour other economic sectors (tourism, construction, banking) limits the extent of the robotization process in Spain according to OECD data on sectoral productivity growth. As Rueda points out in *Origins of Dualism* (Rueda, 2015; pp. 91-97), in MMEs, as a legacy of their traditionally closed economy to international competition, there is dualization in the employment protection and working conditions, with some sectors (industrial workers and public servants) where there is job security and high wage raises at the expense of segments of the population in very precarious labour situations or outside the formal economy.

In countries with closed economies, industrial labour and capital tend to reach a pact to ensure very high employment protection and high wages for industrial workers and translate the costs to the rest of society. Capital prefers labour peace to avoid strikes (as manufacturing is one of the highest added-value generating sectors of the national economy) and industrial labour unites to improve their working conditions and to keep entry barriers for the rest of the labour force into the industrial economy, hindering overall economic development (Rueda, 2015; pp. 102-107).

I would argue following the Theory of Real Competition that this creates high dualization, but it also creates incentives for firms to invest in improving productivity of industrial labour, through raising capital intensity and the training of specific skills for industrial labour.

Strong unions in the automotive industry and high employment protection encourage robotization because of productivity-enhancing effects, albeit these effects have been less intense than in Germany.

Additionally, robotization in Spain is less strategically agreed than in Germany, as work councils are less relevant in the strategic management and they do not have as much codetermination rights as in CMEs (Visser, 2015). This is a plausible explanation of why Spain has also had more offshoring of industrial production than other Coordinated Market Economies as documented by a report prepared for the European Commission in 2015 by the Fraunhofer research organization (Fraunhofer, 2015; p. 42), in which it was also found that firms that used more industrial robots were less likely to relocate production outside the EU (Fraunhofer, 2015; p. 62). The benignity of robotization is further analysed in page 57 of the report, in which no negative effect of robotization is found in the employment of the Spanish manufacturing sector (Fraunhofer, 2015; p. 57).

According to a report of 2015 from the Boston Consulting Group (Sirkin, 2015; p. 17), Spain presents a pattern of slow adoption of robotization, slower than that of Germany, Sweden, the USA and China. This is despite relatively higher labour costs when adjusted to productivity.

The report points to the presence of regulations in working conditions in the countries with patterns of slow adoption that pose barriers to the maximum extent of robotization that the firms in these countries are willing to adopt, giving credit to my expectation that low flexibility in working conditions makes robotization a more benign process in relation to labour but there is also some trade-off with the degree of robotization, which Germany, with its high flexibility in working conditions, resolves in favour of more robotization.

China

China with 97 industrial robots per 10,000 employees in the manufacturing industry ranks 21st in the world in terms of industrial robotization in 2017. The process of robotization has not been analysed in the People's Republic so much in terms of potential harmful impact on workers, but rather on the strategy of robotization pursued by Chinese firms and the Chinese State, and the fast-rising market of robotics, which since 2013 has become the biggest robot market in the world with a continued dynamic growth according to the International Federation of Robotics. Since 2013, China has significantly expanded its leading position as the biggest market with a share of 36% of the total supply of industrial robots in 2017, an increase from 30% in 2016. Moreover, about 137,900 industrial robots were sold in China in 2017, 59% more than in 2016 (IFR, 2018a; p. 2).

The meteoric economic rise of China since the Deng Xiaoping's reforms in 1978 and subsequent reforms towards an export-led and public investment-led State Market Economy has transformed China into the world's industrial powerhouse (and the greatest beneficiary of Western industrial relocation) and in 2018 China presented, by far, the largest industrial output in the world, representing more than a third of the global industrial output according to the World Bank data.

Nonetheless, the 2009 global recession and the subsequent slowing down of demand for Chinese manufactured goods evidenced the limits of a growth model so focused on manufacturing exports and public investment in fixed capital assets (World Economic Forum, 2018; p. 6), (Wolf, 2018).

The new situation made the government change the focus of growth from less reliance on export-led growth and investment towards more domestic demand, and to accelerate the revamp of manufacturing to keep gaining productivity and avoid falling into the middle-income trap (Woo, 2012), (Zhang, 2013). The adoption of a macroeconomic strategy towards productivity enhancement is especially warranted since the ratio of working age to total population peaked in 2012 (ending the boost of a demographic dividend) and wages have outstripped productivity growth in the last years, which has declined outside of ICT intensive sectors (Wu, 2014) and, I would argue, as a natural consequence of this transition towards domestic consumption.

In this new age, to keep developing China and catching up to high income countries, the Chinese State and firms seek productivity enhancing technologies to compete in higher added value markets, and one of the fundamental elements is robotization and artificial intelligence, as evidenced by the government's "Made in China 2025" 10-year plan (Institute for Security and Development Policy, 2018).

According to a Boston Consulting Group report of 2015 (Sirkin, 2015; p. 17) China has a fast pattern of robotization, evidenced by the fact that it increased the number of industrial robots per 10,000 employees in manufacturing from 68 in 2016 to 97 in 2017. The report states that companies in China are installing robots in new factories even though wages in most of China remain relatively low. In this report the authors argue that this may be due to companies anticipating that the rapid rise in Chinese wages over the past decade will continue for the foreseeable future or they could also be anticipating that skill shortages in several provinces will worsen (Sirkin, 2015; p. 18).

These considerations are accurate, but I think they neglect the main reason behind the managerial strategies for such rapid robotization, which I argue is the Chinese variety of capitalism. To understand robotics and Artificial Intelligence development in a State-permeated Market Economy I think it is important to realize that it has different characteristics than in other market-based economies.

In China, the State with its enterprises is the main economic agent, and the informal coordination between Communist Party elites – which hold positions of power in both major public and private firms - is the most relevant coordination mechanism at a national level (Witt, 2014; pp. 6-8). Labour in this system does not have an effective autonomous representation outside the Communist Party, as the party is supposed to already represent the interests of workers, which makes industrial relations a sort of mock corporatism in which the coordination between party members in different positions of power (as firms and as labour's representatives) is the main mechanism (Witt, 2014; p. 9-10).

Robotization, in this institutional setting, is not only used as a means for private companies to increase profits through new products, higher productivity and containing labour costs; it is also employed by the State as a means to increase the State's own power and influence in the world through its firms.

The influence of the Communist Party and the State is not confined to the sphere of the State-owned firms, especially when understanding robotization and economic development; because in order to effectively compete at a large scale, connivance between the Chinese party elites and the entrepreneurs of China's rising technological sector (Lucas, 2018) is necessary for these private firms in order to access vital finance from public banks and other advantages (Witt, 2014; pp. 5-6).

Following Witt's line of argument, and contrary to mainstream belief, I would say the Communist

Party is a rather inclusive political institution (at least in terms of economic elites), as it continually co-opts rising entrepreneurs into the party, turning them from potential political opposition to allies making them align their interests with those of the party and the State, much more than in other varieties of capitalism. Moreover, I would argue that this is a crucial reason in understanding why the Chinese system is so resilient to domestic and external political opposition.

Robotization in this variety of capitalism is not simply a way to increase profits for private firms, but it is also subordinated to the State's economic and political objectives which also entails, security, military and external influence, further evidenced by the ongoing technological race with the USA for the future technological hegemony (Hille, 2018).

Social outcomes and public policy recommendations in LMEs

The social outcomes of robotization

As a political economy, the USA is an archetypical Liberal Market Economy, characterised by competitive markets and formal contracts as the main coordination mechanisms, very low levels of employment protection, an orientation of the education and training system towards general skills and with a system of corporate governance where outsider control and dispersed shareholders are predominant (Hall, 2001, pp. 27-44). In this political economy, employment relations are very decentralised and unions are small.

The characteristics of its political economy combined with its process of robotization and the strong offshoring process it has endured reinforce the plausibility of the models I have previously presented.

According to the qualitative model, American firms face high industrial labour costs from an international perspective, low employment protection, a corporate governance characterised by outsider and disperse control, and weak unions. In this setting, they would arguably prefer to fire existing workers and reduce wages either through offshoring or through robotization if it generates higher profits.

Between 1998 and 2006, the USA endured severe offshoring (Milberg, 2010). According to the model of robotization, I could predict that the USA's growth model not focused on strong international cost-competition of its manufacturing, the high industrial labour costs and the weakness of unions lead to a preference by firms in the manufacturing sector for offshoring over robotization, a tendency which could plausibly explain the relative slower pace of the USA in industrial robotization compared to CMEs and South Korea and Singapore since the 1990's.

All these previous factors can plausibly explain through a theoretical model why robotization in the USA has been less extensive than in Germany but it has been more socially damaging at the same time.

Given that in the USA, robotization generates job destruction and wage cuts for low and medium skilled workers (which are predominant in manufacturing), robotization tends to reinforce an ongoing process of social bifurcation, through which the biggest losers of robotization are medium skilled workers with high Routine Task Intensive jobs, which are displaced in favour of jobs that require either high education or low education.

If we look at the risk of automation of different sectors and professions outside of manufacturing, as we expect robotization to get more common in the future through the decrease in the real cost of robots, the professions more at risk are jobs which require medium level of education and to somewhat lesser degree, low levels of education (McKinsey, 2017), (Hawksworth, 2018, p.1).

The most pressing problem for the USA is that the education system is very dualized, reinforcing class rigidities and hampering equality of opportunities (Gamoran, 2017). Although it has an emphasis on generating general skills, which should guard off the job destruction potential of robots in LMEs, it is very unequal as top education is reserved to elites.

The public policy recommendations

In the case of a Liberal Market Economy like the USA, my main public policy recommendation to ensure that robotization generates more inclusive growth would be to reduce the dualization in the education system.

If the main features of the LME typology were to remain in place (market and formal contracts as the main coordination mechanism, low employment protection, decentralized employment relations and outsider control of firms) the federal government and the States should facilitate the access to higher education as much as possible and ensure that the acquisition of high-level general skills is much more widely available through different social classes in order to guarantee equality of opportunities.

This would require a lot of public investment in public high schools and State universities and policies that financially support full time dedication of students to their studies to reduce the currently high dropout rates in higher education (Martini, 2015; p. 9).

Social outcomes and public policy recommendations in CMEs

The social outcomes of robotization

Germany embodies the conventional Coordinated Market Economy characterised by coordination through interfirm networks, relatively high levels of employment protection, an orientation of the education and training system towards industry and company-specific skills and with a system of corporate governance where insider control is prevalent (Hall, 2001, pp. 21-28). In this political economy, employment relations are very centralised, they follow a consensual corporatist fashion and unions are very big.

The characteristics of this political economy, combined with its rapid process of robotization and the relatively mild offshoring effect on employment (Becker, 2014) reinforce the plausibility of the robotization model I have previously presented.

According to the qualitative model, German firms, faced with existing high industrial labour costs from an international perspective, but also high employment protection and a corporate governance characterised by insider control and consensual decision-making with big unions, would prefer to reach agreements that are less socially destructive.

Firms would prefer to increase profits not by firing existing workers, but by increasing productivity through more robotization, and containing Unit Labour Costs in order to retain or gain international competitiveness.

An unforeseen effect by the model and which has been argued in Dauth's study, would be that the substitution effect of robots on labour would take the form of less job creation for new entrants into the labour market (Dauth, 2017).

Given that in Germany robotization limits the creation of new jobs for new entrants and generates wage cuts for low and medium skilled workers (which are predominant in manufacturing), my argument is that robotization will likely generate a gradual mismatch between the education and vocational training system and the needs of the economy.

As previously said, robotization is less socially damaging even at a much faster rate of adoption than in LMEs. Social corporatism through codetermination mechanisms and the role of work councils and unions have a positive effect in generating more inclusive growth through robotization than in liberal economies.

The public policy recommendations

In the case of a Coordinated Market Economy like Germany, my main social policy recommendation to ensure that robotization generates more inclusive growth would be to reorient the education system towards the acquisition of more general skills and less industry and company-specific skills. And furthermore, professionalize social reproduction functions; and reorient their Welfare States towards a Social Investment paradigm of social policy, with special emphasis on the care and education of children (Hemerijck, 2017; pp. 118-128).

If the main features of the CME typology were to remain in place (interfirm networks as the main coordination mechanism, high employment protection, centralized employment relations and insider control of firms), robotization would accentuate the weakness that the relative lack of disruptive innovation characteristic of CMEs have in the creation of new goods, services and the creation of employment for young people.

As seen in the case of Germany, robotization leads to lesser job creation for young people in the industries concerned. Therefore, as robotization becomes more widespread, it becomes necessary to reorient the education and vocational training system from industry and company-specific skills to more general skills, where the highest employment creation is bound to happen in the future in these most advanced economies, the ones at the forefront of the technological frontier.

Sweden is an example of a Coordinated Market Economy with an education system oriented towards generals skills (Goergen, 2012; p. 503) and although the level of robotization in manufacturing has not been as extensive as in Germany, it is one of the most cutting-edge countries in the knowledge economy and one of the most inclusive, as reflected by the knowledge Economy Index of the World Bank, in which Sweden is consistently ranked at the top.

Moreover, the Swedish system of education and vocational training and its social investment policies generate a more inclusive economic growth (Iversen, 2015) and a more balanced growth model than that of Germany (Hope, 2016). Therefore, I argue that for CMEs in general, more investment in general skills and favouring disruptive innovation is the way to keep being the technological leaders, and for this, a more active role of the government is needed in the aforementioned areas.

Besides, given that according to OECD data, CMEs are some of the societies in the world most rapidly ageing and with some of the lowest fertility rates, it becomes pressing for these countries to invest in social policies aimed at improving the cognitive abilities of children since a young age (Hemerijck, 2017; pp. 118-128). The rationale is to make sure that the future increases on productivity related to such policies can counteract the adverse consequences of more rapid ageing when compared to LMEs.

Furthermore, the increase in the professionalization of social reproduction functions through social investment policies would increase employment in activities relatively difficult to substitute through robotization and overall, increase the productivity of workers who would not need to dedicate as much effort, resources and time to social reproduction tasks.

Social outcomes and public policy recommendations in MMEs

The social outcomes of robotization

As I have showed, Spain, as a good representation of an Mixed Market Economy, is a country where robotization is overall a benign process in relation to workers, but factors such as an orientation towards tourism, construction and banking and rigid working conditions suppose limits to the extent of robotization that firms pursue and its productivity enhancing benefits. These sectors in which Spain has based its economic development have less scope for productivity increases through robotics and digitalization and if the model of economic development and of industrial relations is not changed, I argue that high structural unemployment is likely to continue to be the main macroeconomic problem.

Therefore, I argue that the social outcome of robotization in MMEs is of social benignity but lost development, which is direly needed in countries with this variety of capitalism as productivity has staggered for the last 20 years (with France as the most notable exception according to OECD data) and international competitiveness of goods and services was achieved through socially destructive internal devaluation after the sovereign debt crisis.

In this context, I think the question is not simply how to make robotization more socially inclusive but rather how to adequately stimulate it so Spain and other MMEs do not miss the benefits of robotization and they do not lag behind other varieties of capitalism where it is more actively pursued.

A lack of robotization can actually have negative effects for the labour force in the long term for Spain and the other Mixed Market Economies through offshoring, as being in a monetary union with Coordinated Market Economies puts higher pressure to be competitive internationally. I think that if this problem is not addressed, these countries will keep being an economic periphery of other more advanced European economies.

Furthermore, higher productivity is very badly needed for sustaining these Welfare States as they traditionally do not integrate well young people into the labour market because of underdeveloped education-to-work transition policies for young people (Chevalier, 2016) and spending in social policies is disproportionately oriented towards the elder and labour market insiders (Rueda, 2005).

The public policy recommendations

In order to make possible investment in robotization and ICT technologies to accelerate productivity I think Spain should institutionally change and adopt the social corporatism of Coordinated Market Economies to adopt more robotization and to both increase productivity and make it socially inclusive.

As the cases of this paper have illustrated, in countries where there is high employment protection, high flexibility of working conditions, and where labour codecides the management of firms, firms are much more likely to make long term investments not only in robots to improve productivity, but also in other programmes that increase the productivity of human workers. Therefore, a change towards social corporatism should be coupled with a change in the education and vocational training system towards more industry and company-specific skills.

Following the framework of the Theory of Real Competition I argue that -in order to be more competitive internationally- Spain and the other MMEs should adopt the institutions that allow CMEs to have both low inflation and low unemployment. This argument is based on the evidence that nowadays MMEs and CMEs have similar constraints on the demands of the labour force, namely: high external competition, non-accommodative monetary policy (very low inflation targeting by Central Banks), fixed exchange rates, and in the case of MMEs, also high normal unemployment.

These similar constraints have already made possible a change in the preferences of labour unions in Mixed Market Economies in the aftermath of the crisis: from high wage raises for insiders of the labour market to less unemployment; which makes possible a transition towards inclusive economic institutions similar to that of CMEs and reducing labour market dualization.

So, to both withstand the competitiveness of the CMEs with whom Spain and the other MMEs share currency and to lead to higher investment, less unemployment and higher social equality, I argue there should be a new social pact in southern countries to end the harmful divides in the labour market.

Through this new social pact I propose, labour unions would accede to wage restraint and higher flexibility of working conditions for the insiders of the labour market but in return:

1. Work councils would be conceded the same codetermination rights as in CMEs.
2. The government would set a higher level of minimum wage, following the example of CMEs.
3. The government would invest much more in Active Labour Market Policies, as CMEs do, including policies of Employer of Last Resort (Tcherneva, 2012), and of work sharing.

I argue these measures aimed at generating higher union membership and creating a broader safety net for income security would substantially reduce dualism, as through this much more comprehensive safety net the large majority of the labour force would be benefited in the long term, instead of just the insiders.

Low end services like tourism will keep be present in MMEs (so they will still generate a more demand-led growth model than Germany for example), but my argument is that they should be restrained in favour of sectors with more potential for productivity growth, be it through robotization or other complementary means.

Social outcomes and public policy recommendations in SMEs

The social outcomes of robotization

Taking China as a reference for a modern State Market Economy, we can observe that in this political economy the main coordination mechanism is the party elites' informal coordination in different positions of power: either as government officials, representatives of public and private firms or workers' representatives. The education and vocational training system are geared towards general skills, and the public financial institutions play a key role in raising funds for investment, which gives to this system a comparative advantage to quickly mobilize resources towards governmental priorities.

Due to the relatively small penetration of robots in China up to 2015 and to the recent change of governmental orientation towards robotization it is still to be seen empirically what this large robotization will generate in relation to Chinese labour, but using the models I have presented and looking at the economic trends in China I can derive a plausible theoretical explanation of the social outcomes of the Chinese big push for robotization.

First, gathering from the qualitative model of the effects of robots on labour, I think it is safe to expect that complementary effects and relatively benign robotization for the workers involved will be the trend, with profit-led growth in employment and a reduction of the labour income share in high ICT sectors.

Nonetheless, I think that such a rapid process of robotization as the present one could well increase income inequality, which had been in a decreasing trend since 2009 after reaching a peak Gini score of 0,49, and which for the year 2015 stood at 0,462 according to the data from the National Bureau Statistics of China; as one of the highest in the world.

The reason for this is that robotization is a process that will be most likely complementary for urban industrial workers, and especially enhancing for workers on ICT intensive sectors, which are already some of the main workers and economic activities with the highest productivity (Wu, 2014). These increases in productivity in conjunction with a governmental priority of re-balancing the growth model towards more domestic demand will likely generate substantial wage gains in these sectors, more than in other sectors of the economy.

This push in a context of very rapid development will accentuate income inequality because in China there is high dualization in the education and vocational training system between the rural and urban schools as a result of gargantuan economic growth localised in several urban areas (Zhang, 2015), and there is at the same time high employment dualization (Zhang, 2013), as formal employment protection is high but the levels of the informal economy have skyrocketed as a side effect of the opening of a highly centralized economy and the gargantuan growth of the last decades without sufficient institutional capability to deal in a timely manner with the social challenges it has generated.

To grasp the extent of the number of people employed in the informal economy: In 2006 it was estimated that 168 million people worked in the informal urban economy (Huang, 2009; p. 406), and from 2007 to 2013 the proportion of formal employees overall dropped from 65% to 43% (Liang, 2016; p. 8).

Regarding the inequality in the education system although in recent years there have been efforts by the Chinese government to bridge the gap in the education system between rural and urban areas (OECD, 2016), dualization is still very prevalent (Zhang, 2015), and not only in education, but also in the access to important basic services like healthcare.

These problems of dualization in education and employment will mean that students in the most advanced urban areas and the urban workers in the formal economy will experience much higher benefits from robotization than the rest of society if no institutional reforms are made to reduce dualization in these two fronts.

The public policy recommendations

The path for development in China is no longer a quest for massive GDP growth through an extreme export-led growth and disproportionate investment in fixed capital and infrastructure as it was during the 2000s. The Chinese government has already realized that the path for sustainable growth is gradually becoming more reliant on productivity increases and to make them possible inclusive and efficient allocation of human resources becomes essential.

As I have previously discussed, SMEs are good at mobilising a lot of resources to certain economic and social goals deemed politically important but this often comes at a trade-off in terms of large inequalities and subprime efficiency in the allocation of these resources, as evidenced by Wu when examining the period between 1981 and 2012 (Wu, 2014). And I argue that the potential inequality and misallocation due to an aggressive process of robotization could be soothed in the Chinese case by making a transition in the education system towards industry and firm-specific skills similar to that of Germany.

China is still a very large and developing country with massive regional differences and divides and far from being at the forefront of the technological frontier; hence, I would argue it is not at a point where it requires something like a Swedish variety of capitalism to generate inclusive growth; as it requires much more focus on more basic institutional mechanisms to improve productivity.

Given that the State has the capacity to mobilize vast resources but with not the best efficiency in their allocation and that employment protection is high, I think it becomes necessary to make an institutional reform that provides incentives for public and private firms to invest in the education of their prospective workers. High employment protection is costly for enterprises to readapt; consequently, they should be able to develop a vocational training system that provides them with incentives to invest in human capital for specific skills and mould it to changing circumstances.

A reorientation of the education and vocational training system towards industry and firm-specific skills coupled with its high employment protection would have multiple benefits in China. It would give more leeway and incentives to companies to cooperate and jointly improve the allocation and productivity of human resources. At the same time, it would reduce dualization in the labour market by reducing the informal economy through the provision of more targeted education-to-work transitions to workers. And lastly, provided this institutional reform is undertaken at a national level, it would reduce the regional inequality in the education system.

To summarise, in order to offset the inequality effects of rapid robotization in China, the focus should be placed on improving the current problems of allocation and training of human resources by developing an industry and firm-specific vocational training system orchestrated by firms and sponsored by the State.

The role of social corporatism on robotization beyond manufacturing

In the construction of the models and in the selection of the case studies - and in the explanations of the degree and the effects of robotization - the focus has been placed on industrial robotization, particularly concerning manufacturing. This choice has been made on grounds that it is the best documented and more richly treated, nonetheless, robotization is already being felt in services and in tasks of social reproduction (International Federation of Robotics, 2018b).

From the comparisons between different varieties of capitalism, Coordinated Market Economies have come out as the systems that overall best generate a compromise between high robotization and social inclusiveness but I think it is important to acknowledge that the initial Varieties of Capitalism devised by Peter Hall and David Soskice represented more comprehensively the case of Coordinated Market Economies (specifically Germany) and their corporatist systems in the 1990's than in 2018 (Heeg, pp. 150-154). This can be partly due to new activities in services, a higher presence of companies where workers have little say in the management of firms and an increase in the number of jobs with low employment protection not covered by more comprehensive collective agreements, but as Heeg shows, this is due mainly to legislative governmental reform (Heeg, 2014; pp. 150-154; 157).

This is why I argue the case of robotization of CMEs is transferable to the new services and to the new sectors of the economy susceptible to robotization. Basically, what is needed in any country for ensuring that robotization is an inclusive process of economic development is an inclusive form of industrial democracy. With this goal in mind, it becomes necessary in several countries to reform labour law and corporate law to facilitate unionization and the co-determination of management of firms in the overall economy.

In summation, it becomes necessary to readapt social corporatism to new contexts and not just let its potential as an inclusive institution vanish, as the social corporatist model of industrial relations ensures a consensual resolution of the inherent struggle in capitalism between the labour force and capital, not only when addressing robotization, but also any major process in economic development.

The Euro Area's political economy and the policy recommendations for it

So far, I have commented on the different paths of robotization, the social outcomes of robotization in different political economies and the social policy recommendations specific for each case, but I think the recommendations would fall somewhat short if I didn't take into account the specific dynamic of the Euro Area. In this section I would like to comment on some EU laws and policies which I think point in the direction of my recommendations but have not been very developed up to the present day and would require more impetus at a European level.

As its been widely established, the Economic and Monetary Union, mixes different national Varieties of Capitalism and the crisis of the Euro has put severe strains on the relation of these different national varieties sharing the same currency (Hall, 2014).

Given the limitations of the EU budget to deal with macroeconomic differences between countries, and in accordance to my previous positions on how to manage robotization in different national political economies, I am of the opinion that the EU should mainly use its regulatory capabilities to increase the codetermination in industrial relations and provide fiscal incentives for institutional change in Member States.

The case of the 2009 revision of the EU directive of European Work Councils should serve as a first step towards expanding codetermination rights of work councils and industrial democracy at a EU-wide level, especially since, with the departure of the UK and only the remain of Ireland in the EU as a Liberal Market Economy, it would be easier to agree on EU legislation that reinforces social corporatism at a European level.

Besides that, and on the front of social investment policies, the creation in 2013 of the Social Investment Package (European Commission, 2013) and the European Youth Guarantee coordinated through the European Employment Strategy and with EU funding (Andor, 2016), represent strategies with a lot of potential for improving active labour market policies for the youth in the direction I pointed to, especially for the case of Mixed Market Economies, which have traditionally lagged behind on social investment policies.

Lastly, and very specifically related to robotization, there has been quite some debate at a European level on the possibility of introducing robot taxes in the future, or in other words, taxes specifically targeted at the use of robots as capital. I think this kind of tax in the European context would have more negative impact than what its benefits in terms of redistribution would imply.

As I have argued when discussing the cases of the Coordinated and Mixed Market Economies, robotization is an overall benign process of economic development which helps in providing higher productivity increases and safeguarding jobs in industries very oriented towards international competition. So, as social corporatism serves to greatly moderate the negative social effects of robotization, I would say these kinds of taxes on robot usege are unfounded and would gratuitously limit robotization. Furthermore, other kinds of taxes already in existence could palliate potential increases in inequality derived from robots by targeting labour and capital income.

Only in the case of Liberal Market Economies such as the USA and the UK I would consider the introduction of such robot taxes, although I think the recommendations I have made in this paper in the case of LMEs would more appropriately address the crux of technological inequality in these countries.

Conclusions

In this paper I have treated what variables explain the degree of robotization and why the effects of robotization on the labour force fundamentally differ between models of political economy. Departing from a novel theoretical structural framework and a well-established institutional literature, I have constructed and presented a quantitative model of robotization (or robot density) to explain its degree and a qualitative model to understand the effects of robotization in relation to labour in different contexts.

After developing and testing the quantitative model of the robot density with empirical data, I have developed the qualitative model of the effects of robotization on labour and - to assess the validity of the two models- I have discussed 4 different national cases of robotization: the USA as a Liberal Market Economy, Germany as a Coordinated Market Economy, Spain as a Mixed Market Economy and China as a State-permeated Market Economy.

Subsequently, I have assessed for each variety of capitalism what are the social outcomes of robotization and what specific policy recommendations I propose for each case.

In a Liberal Market Economy such as the USA -due to its institutions- robotization is both less extensive and more socially damaging in terms of job destruction and reduction of wages. Nonetheless, the important finding by Acemoglu and Restrepo of the negative effects of robotization should not dominate academic and public discussion of robotization because - as it has been shown in this paper - other forms of political economy such a Coordinated Market Economy like Germany are able to incorporate much more robots into their economy without any significant job destruction, concentrating the displacing effects of robots on wage moderation and on lesser creation of new entry jobs for young people.

In Liberal Market Economies such as the USA, I argue that the main outcome is a reinforcement of an ongoing process of social bifurcation. Therefore, if the main institutional arrangements are kept in place without major changes, the most pressing social investment policy is reducing the dualization in the education system by improving access and finance to higher education. The government should concentrate its efforts in directing more resources to high schools and universities and policies that financially support full dedication of students to their studies.

On the other hand, in Coordinated Market Economies such as Germany, the outcome of robotization is socially more inclusive but it accentuates the relative weakness to disruptive innovation that some CMEs have in the creation of new goods, services and the creation of employment for young people. Therefore, I argue that in CMEs there should be a gradual reorientation of the education and vocational training system from company and industry-specific skills towards more general skills and an increase in the professionalization of social reproduction following a Swedish model, so as to make sure that in the future young people have the adequate skills and easily find employment in the emerging sectors of the knowledge economy.

These changes in public policy would ensure that the education system does not gradually generate a mismatch between the supply of labour and the needs for economic development, ensuring high employment for young people and, at the same time, higher standards in social services.

In the case of Mixed Market Economies such as Spain robotization is overall a benign process in relation to workers, but factors such as an orientation towards tourism, construction and banking and rigid working conditions suppose limits to the extent of robotization that firms pursue and its productivity-enhancing benefits.

My argument is that in order to make possible investment in robotization and ICT technologies to accelerate productivity, MMEs should institutionally change and adopt the social corporatism of Coordinated Market Economies. There should be a new social pact in southern countries to end the harmful divides in the labour market. Through this new social pact I propose, labour unions would accede to wage restraint and high flexibility of working conditions for the insiders of the labour market but in return: 1) Work councils should be conceded the same codetermination rights as in CMEs. 2) The government should set a higher level of minimum wage, following the example of CMEs. 3) The government should invest much more in Active Labour Market Policies, as CMEs do, including policies of Employer of Last Resort, and of work sharing.

In the case of State-permeated Market Economies, the very rapid robotization that is currently taking place will accentuate income inequality because in China there is high dualization both in the education and vocational training system (between rural and localized urban areas) and in the labour market (with increasing shares of employment in the informal economy).

In order to offset the inequality effects of rapid robotization in China, the focus should be placed on improving the current problems of allocation and training of human resources by developing an industry and firm-specific vocational training system orchestrated by firms and sponsored by the State. The aim is to bridge regional differences and to sooth the trade-off between large mobilisation of resources towards governmental goals and the efficiency of human resources.

After my public policy recommendations, I have reflected on how social corporatism is an institution that guarantees economic development and consensual resolution of the inherent struggle in capitalism between the labour force and the capitalists, not only when addressing robotization, but also any major trend in economic development.

Finally, I have looked at the special situation of the Eurozone, in which different varieties of capitalism coexist in a monetary union. My policy recommendations in this sui generis scenario are to use the regulatory powers of the EU to strengthen codetermination rights of work councils in the European Union, to invest more in policies of social investment such as the European Youth Guarantee and finally refrain from introducing taxes such as a "robot tax".

These actions at the EU level should complement and reinforce the policy recommendations I've made at the level of national varieties of capitalism and ensure an inclusive economic development for the overall benefit of Europeans.

As a closing note, this paper bears witness to the fact that robots do not necessarily lead to job losses, and that differences in national context are very relevant to fully understand both the degree and the effects of robotization. In fact, this paper finds that robotization, due to its productivity enhancing benefits is a source for job stability in many advanced countries and helps in remaining internationally competitive. In summation, robotization does not lead per se to destruction of jobs, if that is the case, the root can be traced to the functioning of a particular system of political economy.

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