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Understanding Technology Adoption

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CMU | Portugal

2025 Full professor - Department of Engineering and Management, IST, U. Lisbon

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Habilitation at the Department of Engineering and Management, IST, U. Lisbon

2021 President – National Innovation Agency-ANI (www.ani.pt)

2020 Associate professor at the Department of Engineering and Management, IST, U. Lisbon

2017 Assistant professor at the Department of Engineering and Management, IST, U. Lisbon

Assistant to the Minister for Economy, for Innovation, Technology and Science

2013 Research Appointment, IN+, Instituto Superior Técnico, U. Lisbon, and IRGC

Deputy Director at Directorate for Education and Science Statistics, Ministry for Education and Science

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2009 PhD in Engineering and Industrial Management
Master in Engineering Policy and Management of Technology
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CENTER FOR INNOVATION, TECHNOLOGY AND POLICY RESEARCH IN+

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Areas of interest:

- Innovation
- Desing Thinking
- Co-creation
- Entrepreneurship
- Business Models
- Technology adoption

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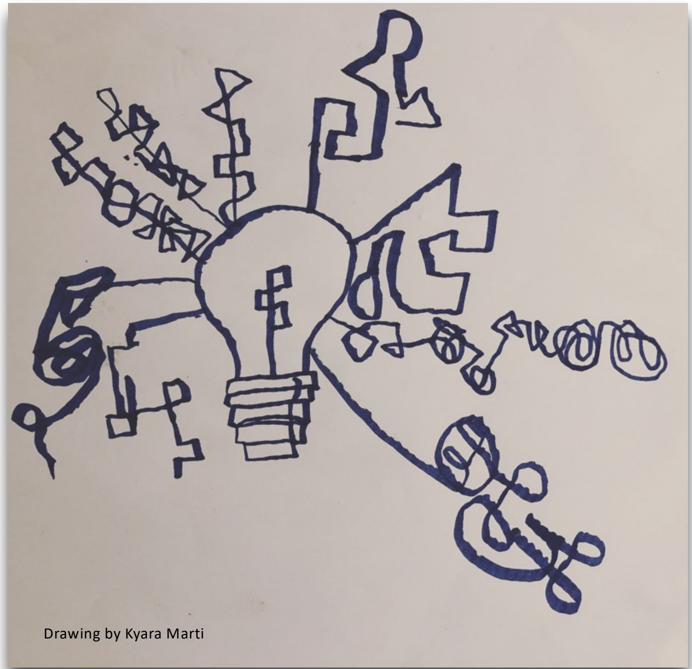
Outline

❖ Understanding on how technologies are adopted, commercialised and diffused in different contexts.

- Context
- Regulation and Technology adoption
- Incentives for consumer adoption
- Policy Implications for Europe



Drawing by Kyara Marti

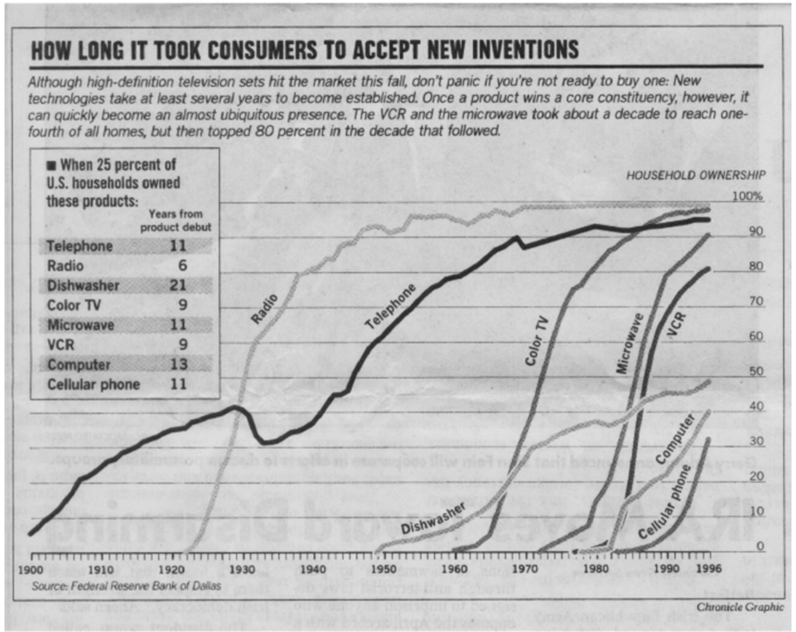
Context

- Countries, regions and firms and organisations differ in the way and extent to which they adopt new technologies

- Differences in technology levels of countries explains in part the differences in countries' GDP. Accounting for these differences may contribute significantly to our understanding of inequality (Foster & Rosenzweig, 2010).

- The diffusion of a new technology is usually a slow and complex process, given the existence of large amounts of technical and market uncertainty

- Factors that determine diffusion rates may vary across technologies (Hall, 2004; Mansfield, 1961; Marinakis, 2012; Rosenberg, 1972).



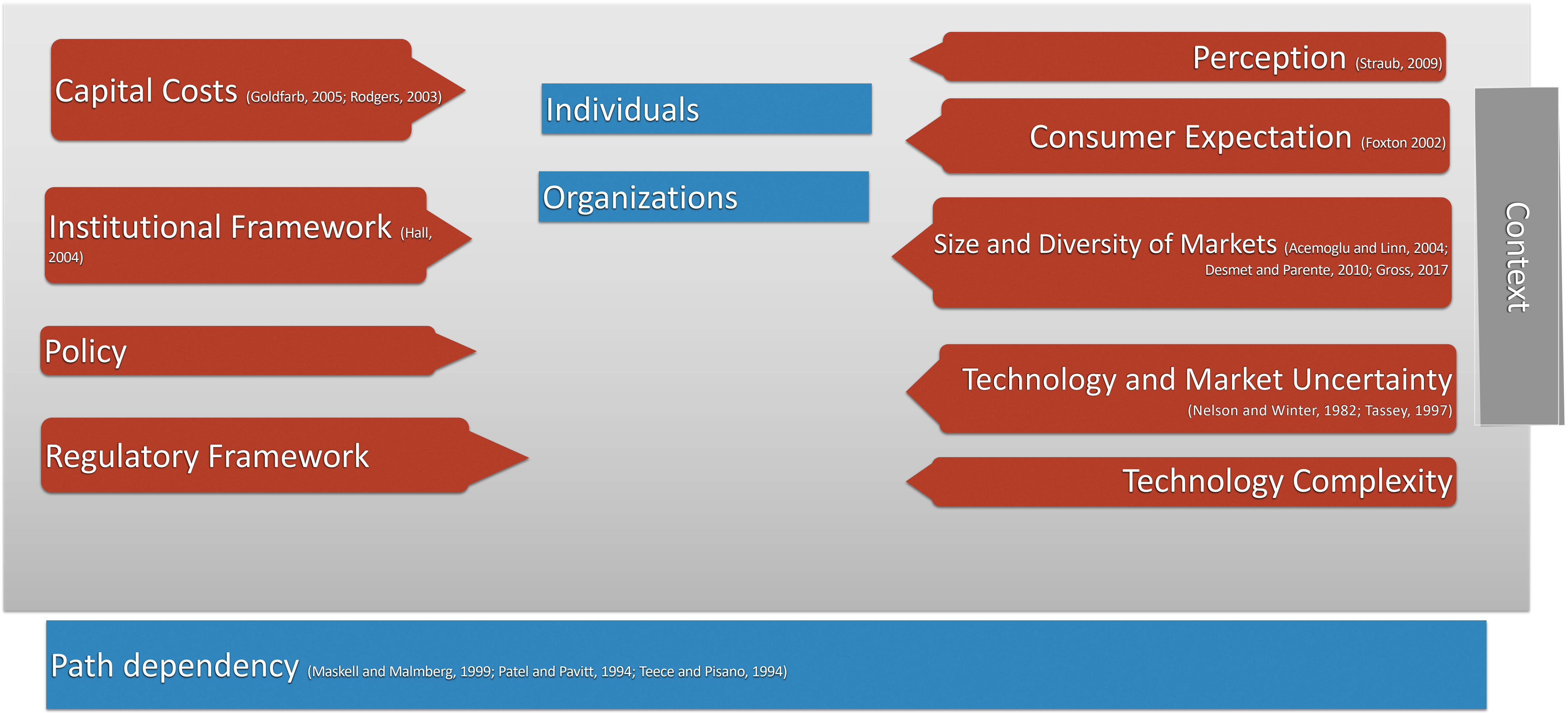
The role of Public Policy

Public support can play an important role in supplementing private investment in innovative activities, creating organizations and fostering networks for the generation of new knowledge, and supplementing additional funding for private R&D (Lerner, 1996; Lynn et al., 1996; Martin and Scott, 2000)

Government can foster the creation of consortia to develop sectorial roadmaps which decrease risks in disruptive technologies by increasing coordination among public and private stakeholders (Tierney et al., 2013; Walsh, 2004).

Public support for adoption may be done through financial incentives: capital subsidies, tax credits or hypothecated revenues (Foxon, 2002).

Factores influencing technology adoption



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1. Regulation and technology adoption

Bonnín Roca, J., Vaishnav J., Morgan, M.G., , P., Mendonça, and E. Fuchs, (2017) When risks cannot be seen: regulating uncertainty in emerging technologies, Research policy, 46: 1215-1233

Uncertainty and Regulation

We use metal additive manufacturing (MAM), an emerging technology with many sources of uncertainty;

Technological uncertainty creates regulatory challenges, particularly relevant in industries where technological risks directly impact safety such as aeronautics

The adoption of MAM on civil aviation promises many performance benefits

We use the adoption of MAM on civil aviation to analyze regulatory needs as a function of technological uncertainty, providing understanding on the role of regulation in technology adoption

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Methods

Our specific case is metal additive manufacturing in the context of the civil aviation industry.

We conduct inductive research to “(1) enable predication and explanation of behavior, and (2) be useful in theoretical advance” (Glaser and Strauss, 1967)

We use grounded theory-building methods to gain insight into technological uncertainty and the regulatory process in this immature technology in this safety-critical industry (Eisenhardt, 1989; Glaser and Strauss, 1967)

We triangulate archival data, 37 semi-structured interviews, and 80 hours of participant observations (Jick, 1979).

Private and public interest in promoting metal additive manufacturing in aviation

MAM Adoption in Aeronautics allows for optimised design

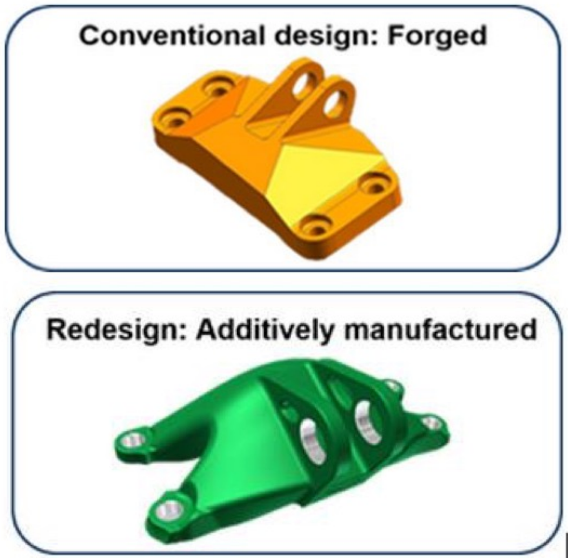
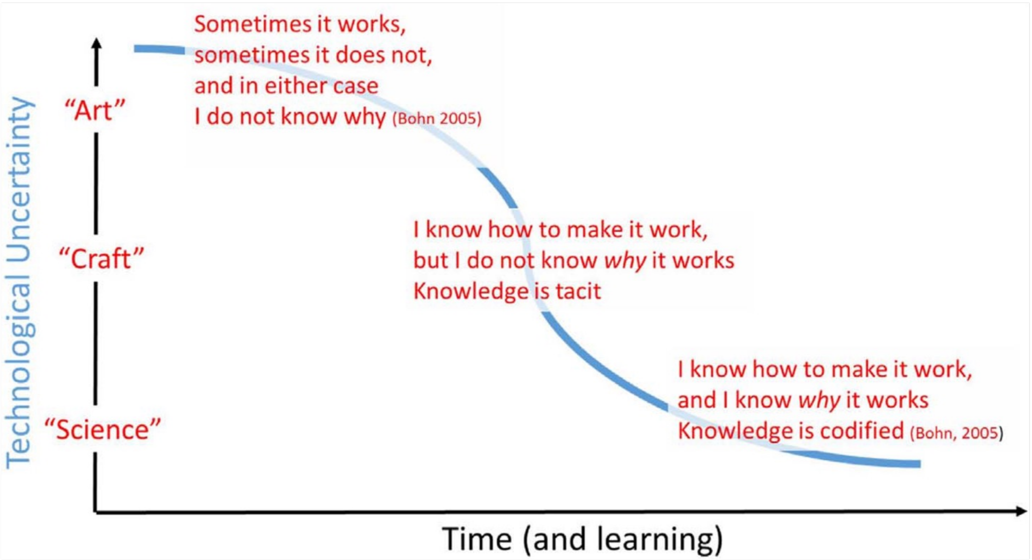


Image Source: https://grabcad.com/challenges/ge-jet-engine-bracket-challenge

- Designs obtained from GE Jet Engine Bracket Challenge
- Compliance with mechanical testing
- Additive Manufacturing design is 82% lighter
- Lower Mass leads to **Fuel Savings**
- AM also reduces the **time to market** and the need for inventory

Evolution of technological uncertainty



- Using the concepts of "Art" and "Science" introduced by Bohn (2005), we define a state, "Craft", which corresponds to an intermediate stage in the learning process where there have been important advances in terms of replicability, but the scientific understanding is still limited

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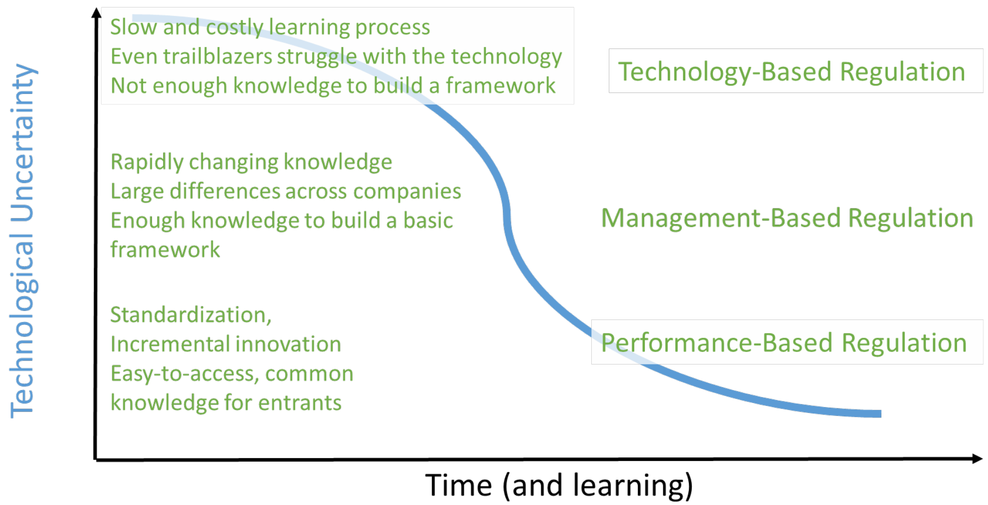
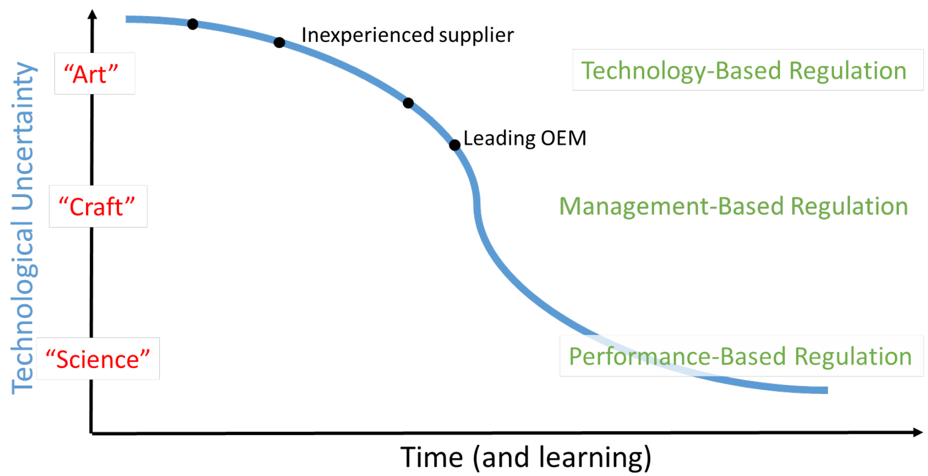
Planned adaptation of regulatory approach

The risk-benefit trade-offs of Technology-, Management-, or Performance-Based regulation depends on the level of technological uncertainty



Interpretation of difference of knowledge across players for the current state of MAM



Lessons from MAM for regulating emerging technologies in other industries

Different manufacturing processes have different sources of uncertainty and learning mechanisms which shape the optimal regulatory approach

	GENETIC ENGINEERING	PHARMACEUTICALS	SEMICONDUCTORS	MAM	BICYCLE ASSEMBLY
No. constituents	High	Low	High	High	Low
New measurement techniques required	Yes	No	Yes	Yes	No
Testability during intermediate phases of production	Not yet	Yes	Yes	Not yet	Yes
Learning by using	High	High	Low	High	Low

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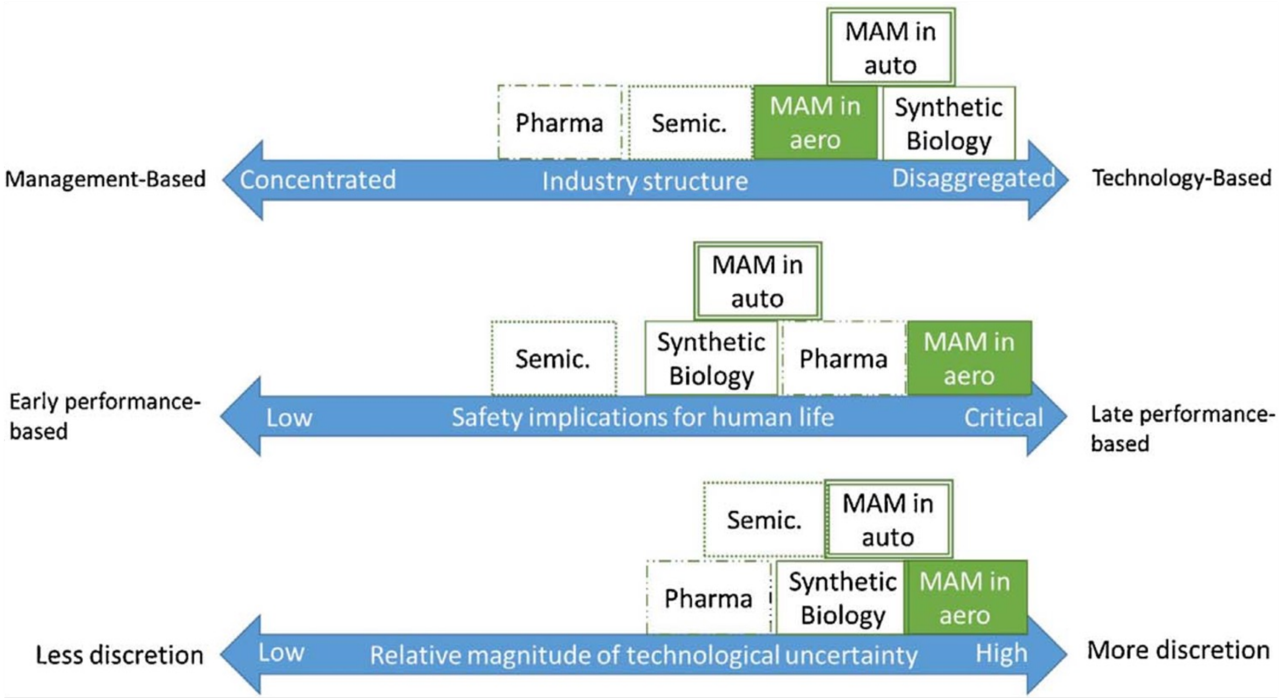
Regulatory approach for different industries and technologies

The appropriate regulatory approach depends on the structure of the industry, its safety implications and the relative magnitude of technological uncertainty, varies with technology and industrial context, and requires combining all three dimensions.



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Conclusion

Not all immature technologies should be regulated in the same way, because the sources of uncertainty can be different.

Sources of uncertainty across industry players come not only from differences in knowledge and technological capabilities, but also from financial interests, business traditions, position in the supply chain, and regulatory oversight.

Technology-based regulation, which has traditionally been reviled as an innovation-constraining approach, could serve as a useful tool both to control risks and to enhance the gathering of knowledge.

Our findings might be useful for "traditional" industries such as banking, which are undergoing large changes due to the emergence of technologies such as virtual currencies or blockchain.

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2. Leveraging domestic industry to enter nationally strategic markets & address technologically advanced product shortages

Part of this work was published on the following paper: • Amaral, A., Morgan, M. G., Mendonça, J., Fuchs, Erica R.H., (2023) , National core competencies and dynamic capabilities in times of crisis: Adaptive regulation of new entrants in advanced technology markets , Research Policy 52 https://doi.org/10.1016/j.respol.2022.104715

An overview

How can a nation leverage its domestic industry to enter markets deemed of national strategic interest?

How did EU member-states managed to incentivize their domestic manufacturers to address ongoing shortages of technologically advanced products?

Relevance of nations capabilities in the world's international competitiveness landscape

Extracting relevant insights for real-world policy making: National and International level

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National core competencies and dynamic capabilities in times of crisis: Adaptive regulation of new entrants in advanced technology markets

How can countries address product shortages in times of crisis?

Typically:

Reliance on
Market incumbents

Reliance on
domestic new entrants

Which **policy tools** can Nations leverage to **incentivize** domestic firms to **enter a nationally strategic** market?

What role **can national domestic competencies** play in **regulatory responses**, and the **emergence** of new entrants?

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Methods: Grounded theory building; Comparative case-study

Medical Devices and Vaccines of European Union markets:

- Government bodies, regulators, and agencies;
- New entrants (firms, research centres, and universities);
- Incumbent firms and associations;

Interview dataset:
115 Semi-structure interviews

		Location of production	
		Onshore	Offshore
Top-5 Global Market Share Home Country of Ownership	Yes	**Germany** (11 interviews)	**Netherlands** (20 interviews)
	No	**Spain** (25 interviews)	**Portugal** (32 interviews)

The case of Ventilators

Around 30% of COVID-19 cases require hospitalization[b]

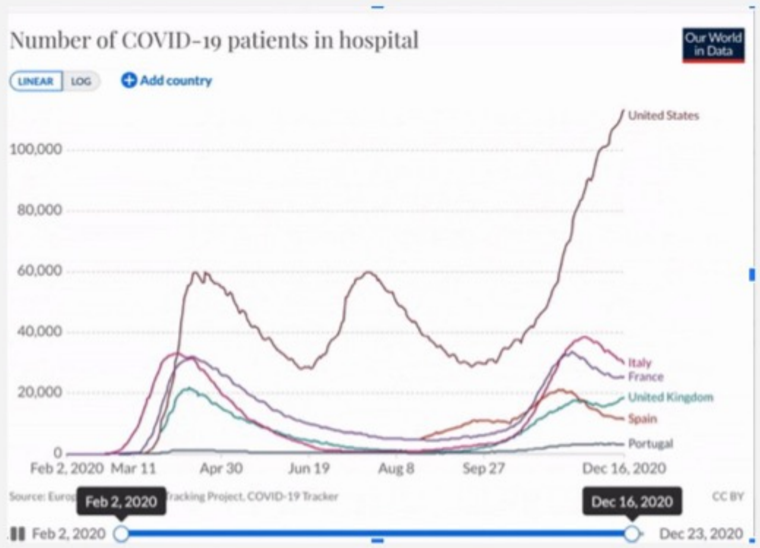
Around 3.2% of infected people require intubation[b]

↓ ↓

Roughly 10% of the hospitalizations might need mechanical ventilation assistance

Fulfilling world-wide demand of mechanical ventilators can save lifes

Progress of Number of COVID-19 hospitalizations in six different countries[a]



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The case of Ventilators

In 2019, the worldwide ventilator production was 77.000 units.

Country	People	Previous Nº ventilators	Nº ventilators to be acquired	Previous ratio (people per ventilator)	Intended ratio (people per ventilator)
United States	331M	200,000 units [a,b]	187,000 [e]	1 Ventilator for 1665 people	1 ventilator for 1170 people
United Kingdom	67.89M	8,000 units [c]	30,000 [c]	1 Ventilator for 8487 people	1 ventilator for 560 people
Portugal	10.3M	1,142 units [d]	900 [d]	1 Ventilator for 9020 people	1 ventilator for 5150 people

In 2020, the US alone wished to acquire 187.000 units

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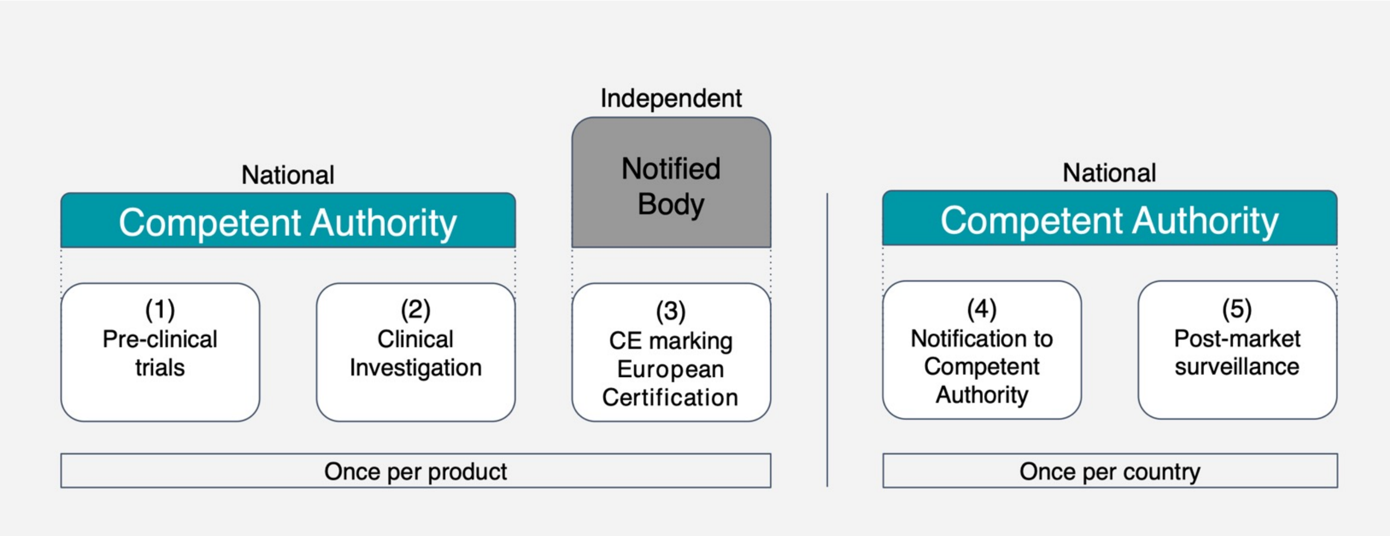
The case of Ventilators

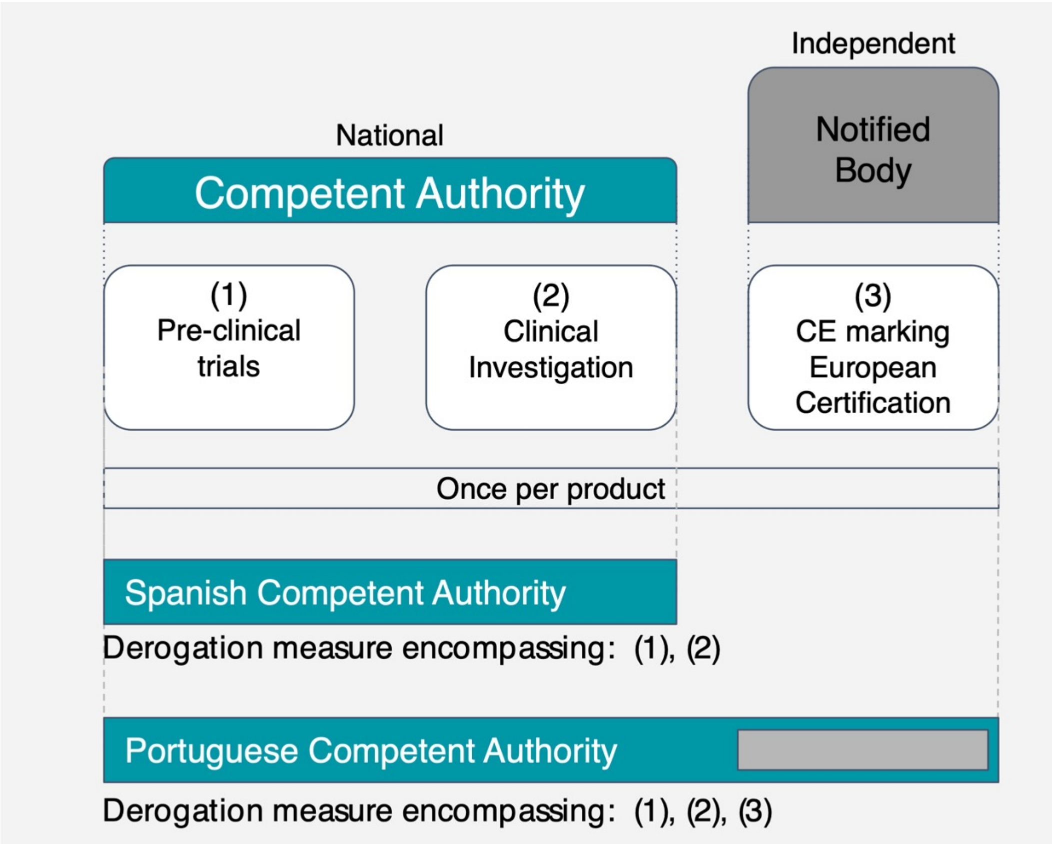


MDD (93)

MDR (2017)

A derogatory measure is a "special" authorization not to obey a certain rule, in this case the 5 steps described above.

The case of Portugal and Spain



Portugal followed standard EU requirements for non-crisis situations

Spain relied on its internal notified body to streamline the process

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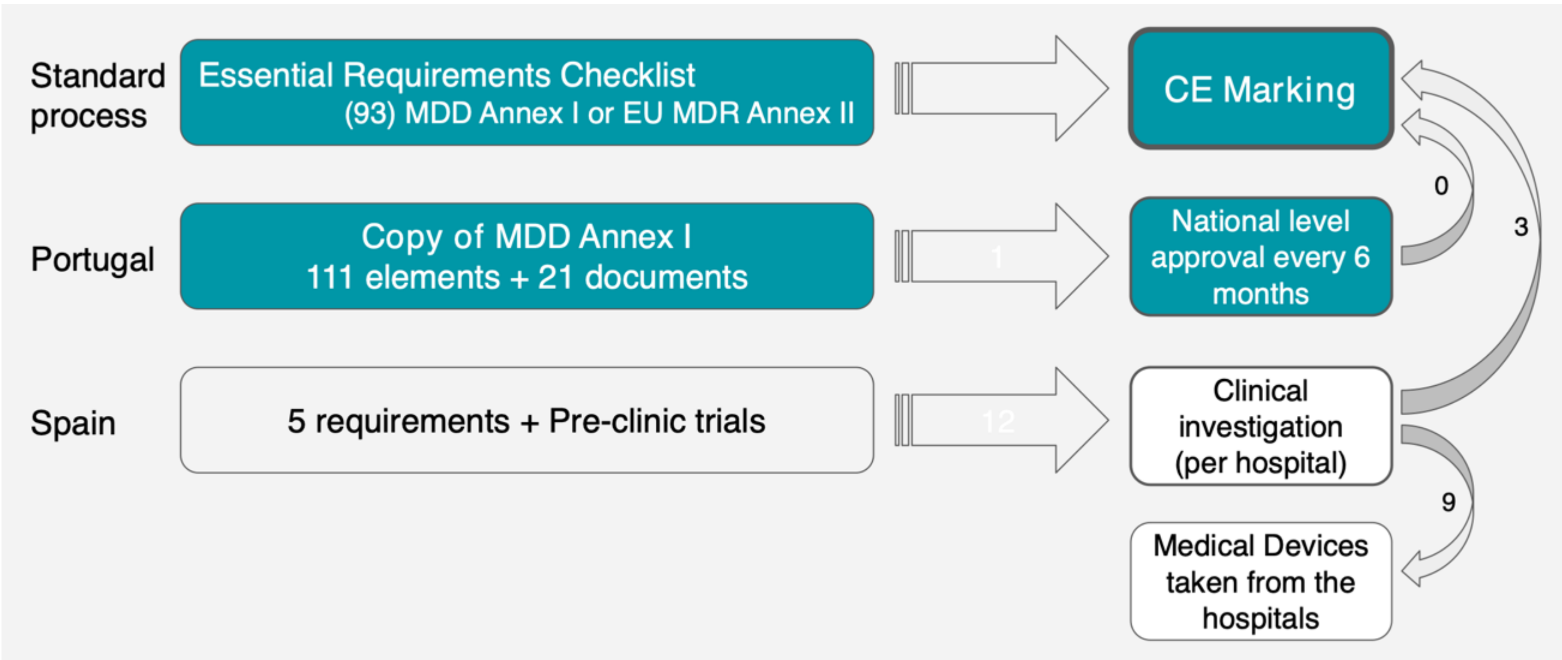
The case of Portugal and Spain

- The Portuguese derogation measure is a copy of the European directive, while Spain has reduced the number of requirements for approval



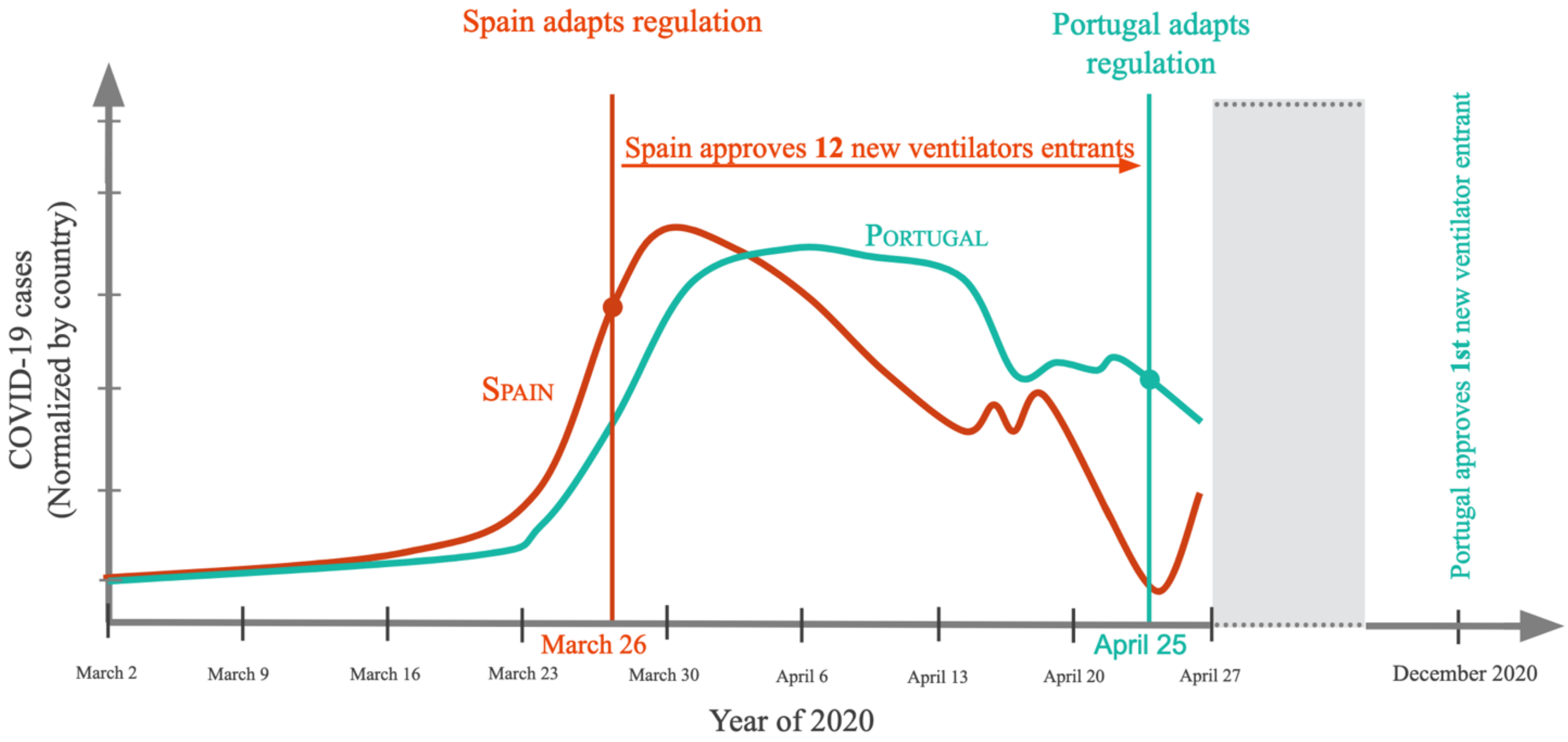
The Spanish derogation was quicker, simpler and more effective than the Portuguese one, without the need for external expertise

	Spanish Competent Authority	Portuguese Competent Authority	
Type of Action	Clinical Investigation (per hospital)	Exceptional authorization (Nationwide)	Portuguese derogation measure more holistic and
Longevity	March 27th 2020 during 3 month	Since April 24th 2020 (every 6 months)	Speed and brevity in the Spanish derogation action
Approvals	12 approvals	1 approval	Spain was 12 times more effective
Complexity	Simplified (considering MHRA)	Copied from the Directive (MDD)	Spanish derogation simplicity might justify its effectiveness
Competencies	Only internal	Internal & External (Task-Force)	Portuguese Competent Authority required external competencies

The Case of Portugal and Spain

Spanish derogation measure available for 3 months

The Spanish regulatory adaptation was simpler and more effective than the Portuguese one

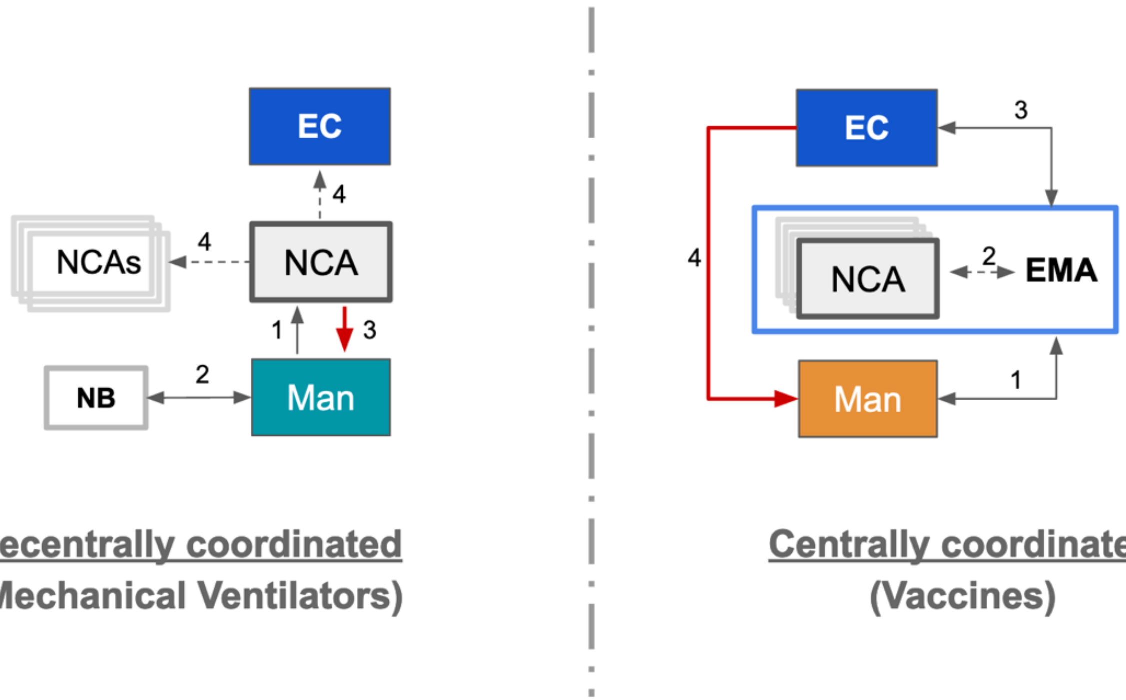


Theory building

The importance of dynamic regulatory capabilities in addressing national product shortages

Addressing shortage of:		Product Safety Relevance	
		Non-critical	**Safety-critical**
Product Complexity	**Complex**	International trade E.g. Wind turbines, solar	Dynamic Regulatory Capabilities needed E.g. ventilators
	Simple	International trade E.g. potato chips	Access might be Sufficient E.g. masks

Extending our work: The case of the covid-Vaccine



NCA - National Competent Authority; **NB** - Notified Body; **EMA** - European Medical Agency; **Man** - Manufacturers; **EC** - European Commission

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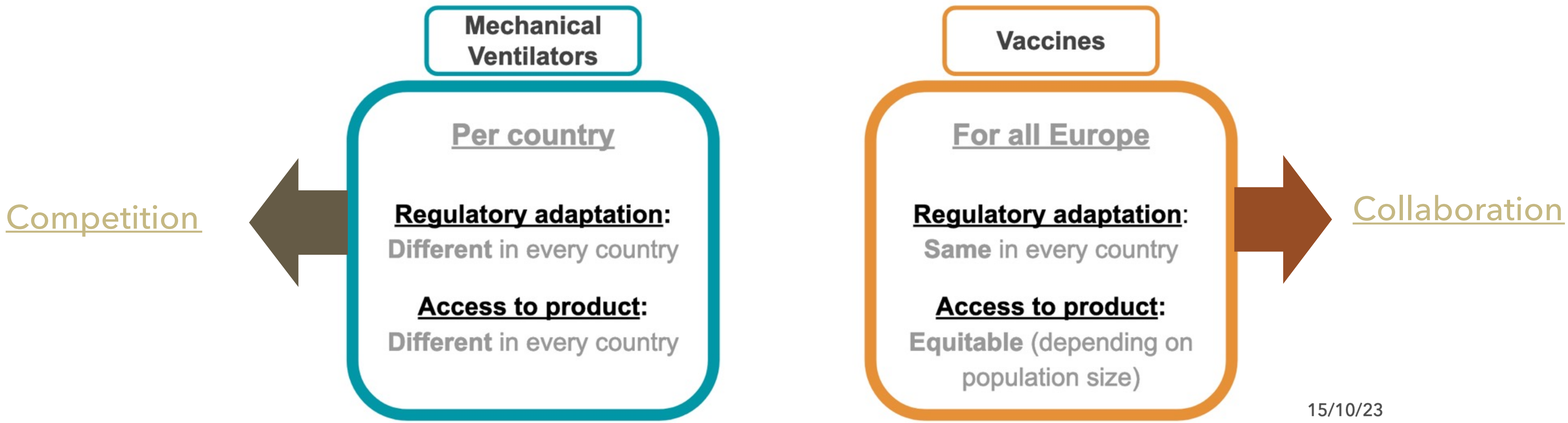
THE CASE OF THE COVID-VACCINE

- Centralization encourages collaboration between local institutions in their own silos:
- Regulatory adaptation receives input from all local institutions within teams established throughout the adaptation process;



THEORY BUILDING: DOMESTIC CAPABILITIES – NECESSARY BUT NOT SUFICIENT

		Locus of Manufacturing		
		Onshore	Offshore	Doesn't exist
	Contextualization:	DRC Exists	DRC don't exist	
Types of Safety-critical products in shortage	Complex	Reliable access (Incumbent firms or New entrants)	Access not ensured	
	Simple	Ensured access (Incumbent firms or New entrants)	Not reliable access (New entrants)	

DRC - Dynamic Regulatory Capabilities

4. Incentives for consumer adoption: The case of EV

Part of this work was published on the following paper: Santarromana R., Mendonça J., Dias A.M., (2020) The effectiveness of decarbonizing the passenger transport sector through monetary incentives, Transportation Research Part A 138 - 442–462

The role of incentives

The sector where CO_2 emissions reduction has been more difficult is in the mobility, because it requires changes of behaviour of individuals and consumers

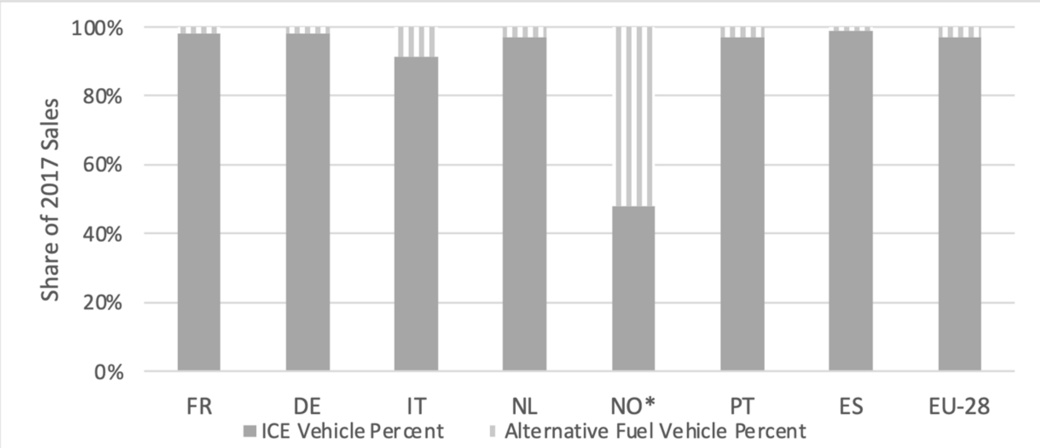
Passenger cars account for most road transportation emissions, and almost half of overall transport sector emissions in the EU.

Different countries in Europe have established policies to achieve emissions reductions in the transport sector by incentivizing the acquisition of fuel-efficient vehicles.

As incentives have been identified as an important way to foster technology adoption at different levels, the goal of this study is to analyze the impact of incentives for the adoption of electric vehicles.

Government policy and fiscal mechanisms aimed at vehicle electrification for decarbonization of the transport sector have proven to be effective, but businesses have been slower to implement mechanisms to incentivize sustainable operation behaviours by consumers.

Shares of passenger vehicle sales between ICEVs and AFVs



Passenger Vehicle Market Context

Country	*Plug-in Electric Vehicles*			*Public Charging Infrastructure*			
	Current Vehicle Stock	*2020 Target*	*2020 Share of PEVs (%)*	*Existing Recharging Stations*	*2020 Target*	*Vehicles per Charger*	*Projected Vehicles per Charger in 2020*
France	*118,663*	*960,000*	*2.2*	*16,081*	*35,000*	*7.4*	*27.4*
Germany	*87,914*	*1,000,000*	*2.1*	*18,078*	*43,000*	*4.9*	*23.3*
Italy	*11,663*	*45,000-130,000*	*0.1-0.3*	*2,205*	*6,500-19,000*	*5.3*	*6.9*
Netherlands	*115,502*	*140,000*	*1.5*	*10,400*	*17,844*	*6.5*	*7.9*
Norway	*212,705*			*11,195*		*19*	
Portugal	*2,258*	*14,000*	*0.2*	*1,126*	*2,394*	*2.0*	*5.9*
Spain	*12,883*	*38,000-150,000*	*0.1-0.5*	*1,754*	*-*	*7.3*	

Source: European Commission, 2017

Social Factors affecting demand for EV

- Key uncertainties facing consumers include: price uncertainty, range anxiety, travel need uncertainty, and social influence.
- Demand is usually negatively affected by price;
- Range anxiety and a perceived lack of infrastructure for refueling are barriers toward the acquisition of EVs and influence the charging decision by users, identified as the largest barriers to purchasing an AFV
- Social influence is tied to the influence of behaviors: when individuals are provided messages about the sustainable transportation behaviors of others, the individuals improve their behaviors more effectively than those who are asked to improve transportation behaviors, but are not provided with messages about how others have done with the same task (Kormos et al., 2015)

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Data and Methods

Vehicle Pair Choice Criteria

Pair-wise comparison to compare the differences across vehicle segments and country markets (following Lévay, Drossinos and Thiel, 2017).

EV Vehicle		*ICEV Vehicle*		*Vehicle Segment*
Vehicle Name	***Fuel Consumption [kWh/100 km]***	***Vehicle Name***	***Fuel Consumption [l/100 km]***	
Renault Zoe (BEV)	*14.1*	*Renault Clio (Petrol)*	*5.5*	*Small*
Volkswagen e-Golf (BEV)	*14.5*	*Volkswagen Golf (Diesel)*	*4.5 (Diesel)*	*Medium*
Nissan Leaf (BEV)	*14.4*	*Honda Civic (Petrol)*	*5.9*	*Medium*
Mitsubishi Outlander PHEV (Petrol/Electric)	*14.7 + 4.3 l Petrol/100 km*	*Mitsubishi Outlander (Petrol)*	*6.2*	*Large*

Sources: Beckwith, 2017; EEA, 2017b; Cars-of-europe, 2020; Electric Vehicle Database, 2020

Data and Methods

- Vehicle Data Collection

Country	VAT, % (EV/ICEV)	Subsidy	Registration Duties		Ownership/Circulation Duties	
			EV	ICEV	EV	ICEV
France	20/20	€6000 (1000)	-	CO_2, kW	-[b]	CO_2
Germany	19/19	€4000 (3000)	€26 fee	€26 fee	-[b]	CO_2, engine cm^3
Italy	22/22	-	kW	kW	-	kW
Netherlands	21/21	-	-[b]	CO_2	-[b]	region, CO_2, wt
Norway	0[b]/25	-	-	wt, CO_2, NOx,	-[b]	fuel type
Portugal	23/23	€1125 (562.50)	€100 fee	€100 fee	-[b]	CO_2, engine cm^3
Spain	21/21	€5500 (5500)	-	CO_2	kW	kW, fuel type

The vehicle total cost of ownership (TCO) and incentives were calculated for each vehicle; The total cost of ownership summarizes all present and future costs and revenues (from resale) of an investment over its lifetime.

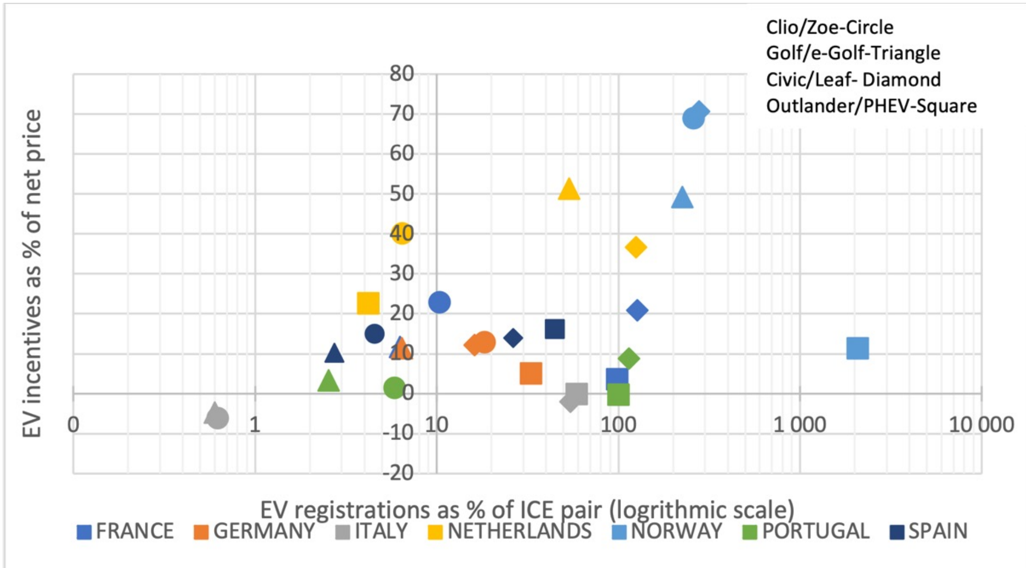
$$TCO = P + VAT + T_r - S + PV(T_c) + PV(F) - R$$

$$Incentive = S + (VAT_{ICEV} - VAT_{EV}) + (T_{r,ICEV} - T_{r,EV}) + (PV(T_{c,ICEV}) - PV(T_{c,EV}))$$

Results and Discussion

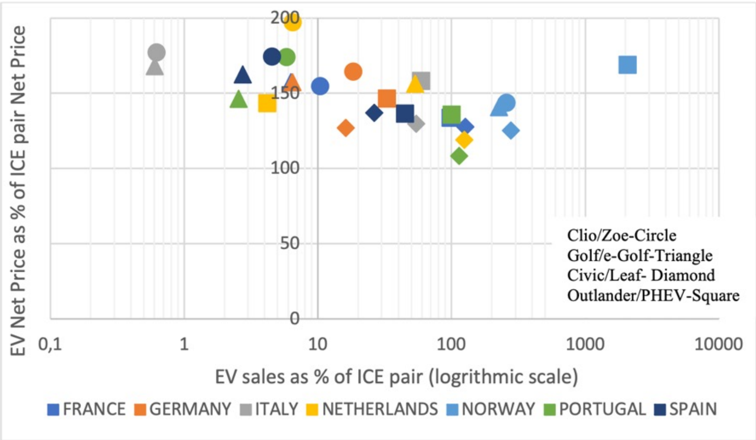
- Italy and Portugal are the only countries which have negative incentives for certain pairs- economic incentive favor the acquisition of an ICEV as opposed to its EV pair.
- Direct relationship between incentives and sales: as incentives (or benefits) increase, so do the sales
- The market responds to fiscal incentives for vehicle acquisition

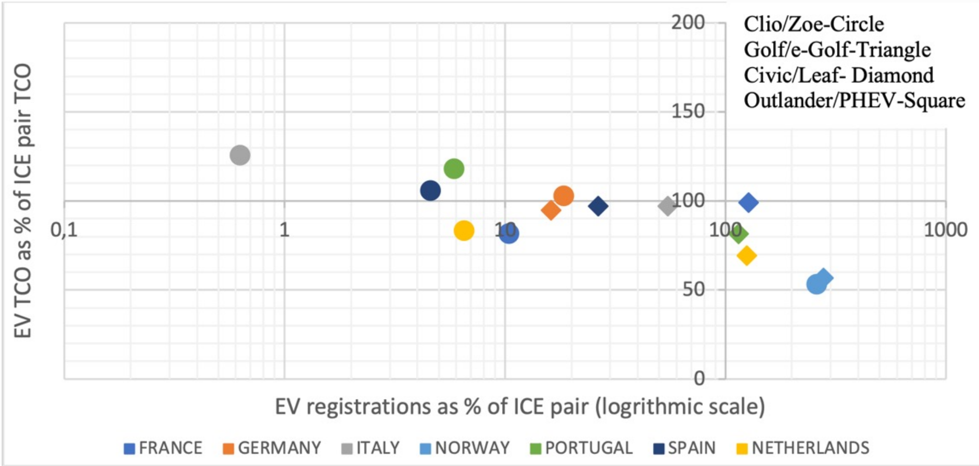
EV Incentives as % of Net Price- Incentives vs. 2017 sales



Results and Discussion

EV net price vs. sales





- ❖The higher the relative net price of the EV with respect to its pair, the less popular this model is.
- ❖TCO and net price depict a negative correlation indicating that the market responds to both net price and TCO
- ❖The expected negative relationship between price and quantity is visible.
- ❖Financial incentives realized at purchase and in operation are good drivers of market behaviors.

Conclusions

Acquisition of EVs instead of a similar ICEV realizes immediate benefits and reductions in GHG emissions.

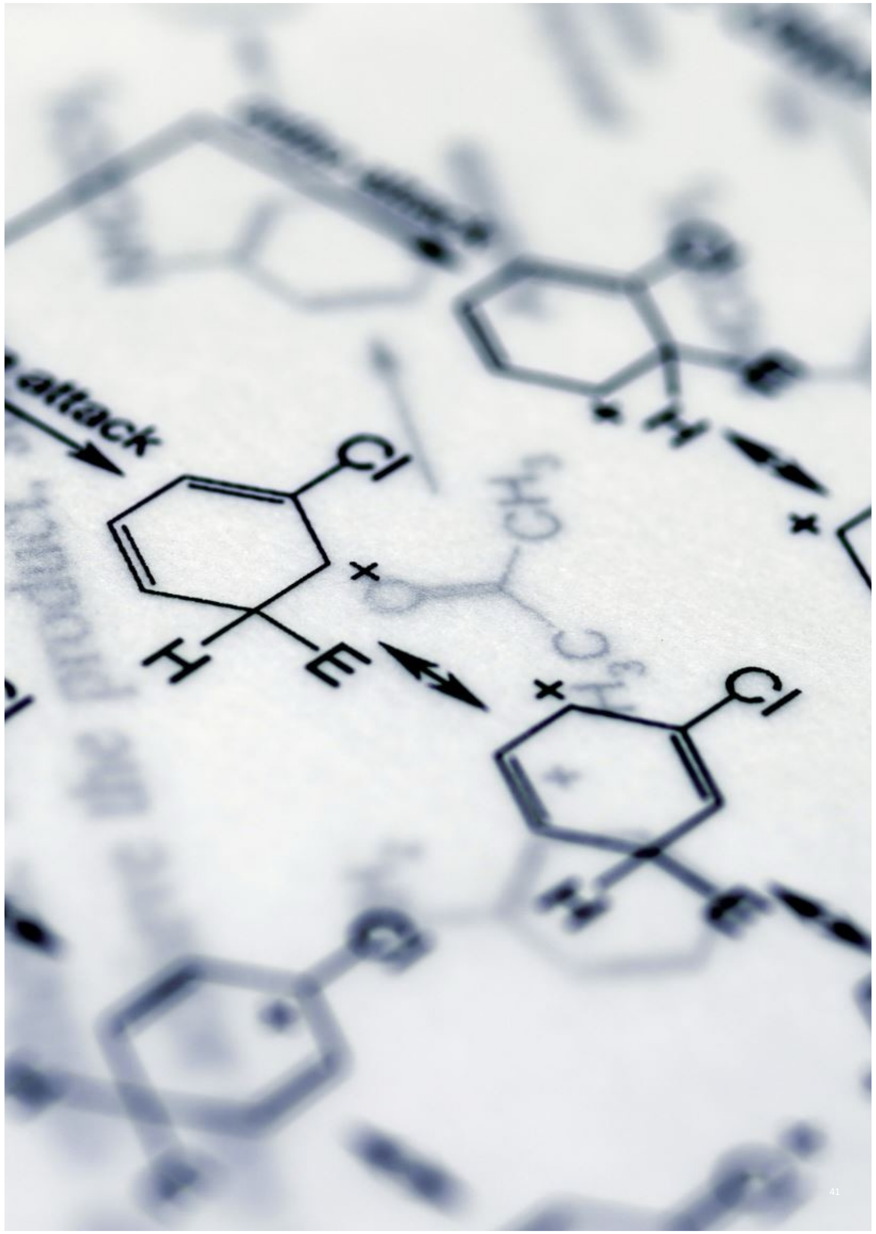
Using a method from a previous pair-wise study allowed for the reproduction of similar results and relationships between EV uptake and incentives with newer data, reinforcing conclusions made.

A review of incentives and costs shows that the market effectively responds to price signals that aim to achieve increased EV uptake.

Consumer acquisition behavior in choosing an EV over an ICEV results in large emissions reductions of the passenger transport sector, and consumer operation behavior in choosing when to charge can provide further reductions.

Additional work

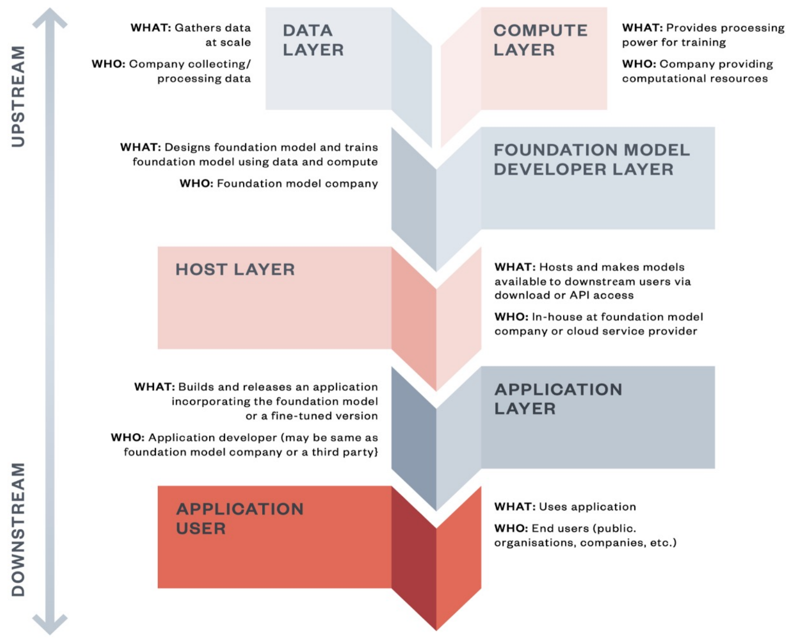
- **Cost**:
  - Gonçalo Cardeal, Diogo Sequeira Joana Mendonça Marco Leite, Inês Ribeiro, (2021) Additive manufacturing in the process industry: A process-based cost model to study life cycle cost and the viability of additive manufacturing spare parts, Procedia CIRP 98 (2021) 211–216
  - Bonnín Roca J, Vaishnav P, Laureijs RE, Mendonça J, Fuchs ERH, (2019) Technology cost drivers for a potential transition to decentralized manufacturing, Additive Manufacturing, https://doi.org/10.1016/j.addma.2019.04.010
- **Regulation**:
  - Bonnín Roca, J., Vaishnav J., Morgan, M.G., , P., Mendonça, and E. Fuchs, (2017) When risks cannot be seen: regulating uncertainty in emerging technologies, Research policy, 46: 1215-1233
  - Amaral, A. Morgan, M.G., , P., Mendonça, and E. Fuchs, (2017) National core competencies and dynamic capabilities in times of crisis: Adaptive regulation of new entrants in advanced technology markets, in submission



AI Supply Chain

- Data
    - Open Source datasets (Common Crawl, The Pile)
    - Propietary
- Compute
    - Nvidia for GPUs
- Foundation Model
    - OpenAI, Anthropic, Meta
- Host
    - BigTech compute infrastructure
    - AWS, Google Cloud, Microsoft
- Application

Foundation model supply chain



https://www.adalovelaceinstitute.org/resource/foundation-models-explainer/

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Foundation Model Landscape

Foundation Model Developers

"A foundation model is any model that is trained on broad data that can be adapted to a wide range of downstream tasks" [1]

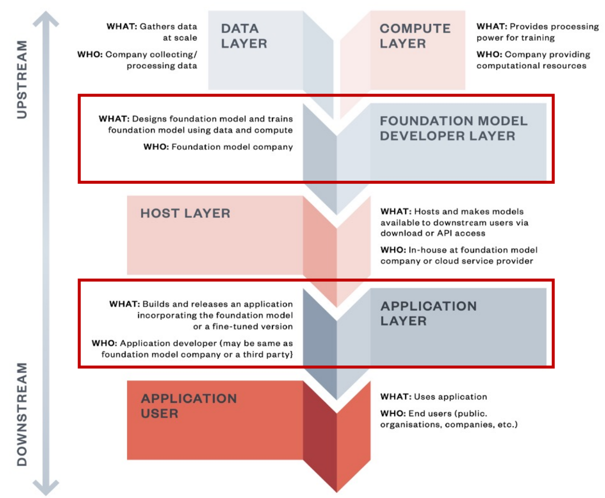
Created by OpenAI, Meta, Google, etc.

Application Developers

Use API or fine-tune upstream models

Who: Businesses using these models e.g. Microsoft, Duolingo, Slack, etc.

Foundation model supply chain



https://www.adalovelaceinstitute.org/resource/foundation-models-explainer/

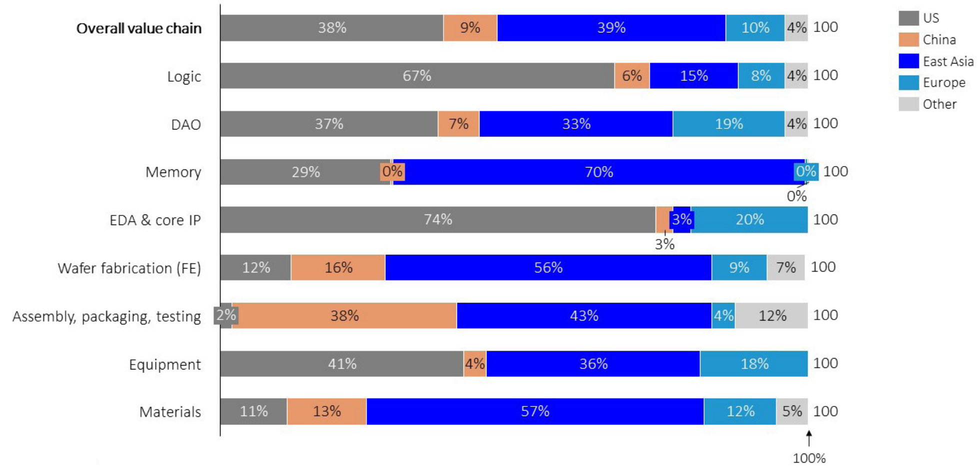
[1] R. Bommasani, D. A. Hudson, E. A. R. Altman, and S. Arora, 'On the Opportunities and Risks of Foundation Models'.

Critical technologies

- The EU relies on foreign countries for over 80% of digital products, services, infrastructure and intellectual property.
- Dependencies are acute for semi-conductors, dominated by a small number of large players. The US has specialised in chips design, Korea, Taiwan and China in chips manufacturing, and Japan and some EU Member States in key materials and equipment – optics, chemistry and machinery.
- Europe has little domestic capacity in many parts of the supply chain.

Share in semiconductor value chain by country

% of worldwide total, 2019



Source: SIA, 2021.

National Critical Technologies Assessment

Strategic Approach

The assessment evaluates technologies through national security and economic prosperity lenses.

Comprehensive Framework

Evaluation includes current capabilities, development potential, and risk factors.

Ongoing Evaluation

The framework enables continuous monitoring of Australia's technology position.

Global Digital Dependencies

80%

Foreign Dependency

Australia and EU rely on foreign sources for digital products and services.

5

Key Players

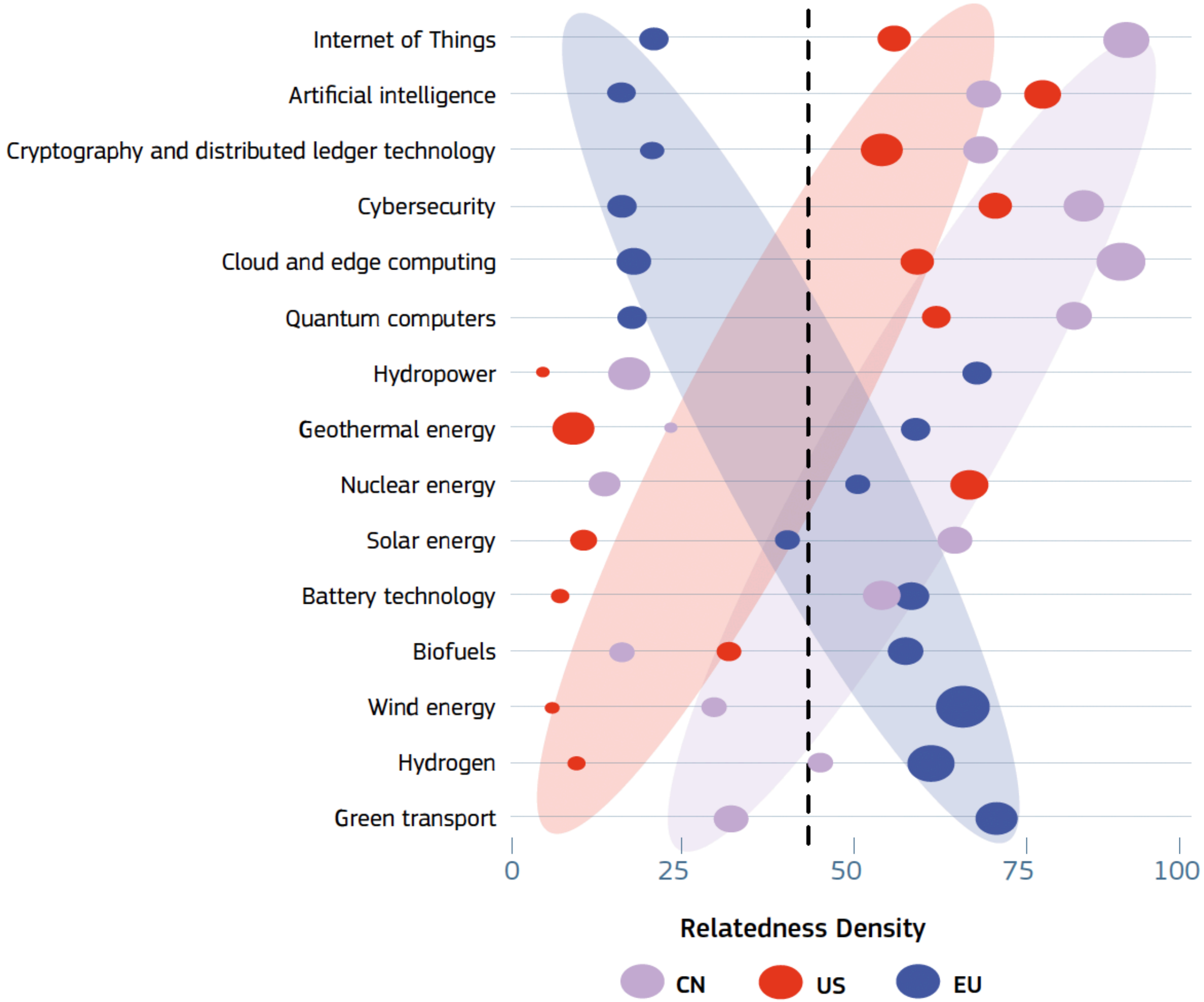
The semiconductor industry is dominated by a handful of global powers.

3

Supply Chain Segments

US designs chips, East Asia manufactures, EU and Japan provide materials.

EU Position in complex technologies



EU Position in Complex Technologies

Strong Research Base

Excellence in fundamental research across universities

Limited Manufacturing

Insufficient domestic production capacity

High Dependencies

Reliance on foreign technologies and components

2021 List of Critical Technologies in the National Interest - Australia

“Alongside the List, government has also published a series of 29 Critical Technology Profiles, which each provide a readily accessible snapshot of Australia’s comparative strengths and the applications of the technology, as well as the opportunities and risks. The Profiles include detailed scientometric analysis examining Australia’s international ranking for research impact, as well as venture capital investment metrics and patent family data.”

- Advanced materials and manufacturing
- AI, computing and communications
- Biotechnology, gene technology and vaccines
- Energy and environment
- Quantum
- Sensing, timing and navigation
- Transportation, robotics and space

Fonte: industry.gov.au

2021 Critical Technologies

National Interest

Australia identified key technologies vital for economic prosperity and national security.

Technology Profiles

29 detailed profiles provide snapshots of Australia's comparative strengths in critical technologies.

Analysis Components

Profiles include research impact rankings, venture capital metrics, and patent family data.

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Mission

We aim to build the intellectual foundations, data, and analytic tools to inform U.S. National Technology Strategy so as to advance security, prosperity, and social-well being of all citizens.

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