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Regulatory Impact Modeling for Emerging Digital Technologies

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ABSTRACT

Regulatory impact modelling (RIM) for emerging digital technologies requires methodologies that can quantify the costs and benefits of regulation across multiple dimensions -- compliance burden, innovation effects, consumer welfare, market structure, and societal outcomes -- under conditions of deep uncertainty about technology trajectories, market responses, and second-order social effects. This paper proposes the Regulatory Impact Modelling Framework for Digital Technologies (RIMFDT), a systematic methodology combining econometric estimation, computational simulation, and expert elicitation to quantify regulatory impacts across four emerging digital technology regulation domains: generative AI (EU AI Act), data governance (EU Data Act), digital platform competition (DMA), and cybersecurity (NIS2). RIMFDT extends and refines CRISF (Horvath, 2025) by integrating empirical econometric calibration with simulation dynamics and providing a structured impact decomposition methodology. Key results: EU AI Act produces net positive welfare impact (EUR +8.4 billion/year EU-27 by 2030) driven by trust and safety benefits exceeding compliance costs; EU Data Act consumer benefits exceed industry costs by 2.4x at current implementation parameters; DMA full compliance reduces consumer welfare loss from digital platform market power by EUR 12.4 billion/year. The framework provides impact modelling methodology and empirical calibration for digital technology regulators.

Keywords: regulatory impact modelling; digital regulation; EU AI Act; EU Data Act; DMA; NIS2; welfare analysis; innovation policy; econometrics

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1. Introduction

1.1 The RIM Methodology Gap for Digital Technologies

Regulatory impact assessments (RIA) for digital technology regulation face methodological challenges that conventional RIA for physical product regulation does not: network effects (regulation of one platform affects all platforms through interconnection); rapid technology evolution (baseline technology is different by the time regulation takes effect); data as a production input (regulation restricting data use affects downstream innovation in ways not captured by compliance cost estimates); and global regulatory arbitrage (firms can relocate data processing to avoid regulation in ways physical manufacturers cannot). The European Commission's Impact Assessments for the AI Act and Data Act acknowledge these challenges but use relatively simple models -- linear compliance cost estimates without dynamic market response modelling. RIMFDT provides the more comprehensive RIM methodology these assessments require, integrating empirical calibration (econometric estimates from the literature and natural experiments) with CRISF simulation dynamics (Horvath, 2025) and structured uncertainty quantification.

1.2 Contributions and Paper Structure

RIMFDT contributes: (1) a multi-method RIM methodology for digital regulation; (2) empirical impact estimates for 4 EU digital regulations; (3) net welfare positive finding for EU AI Act; (4) impact decomposition methodology. Section 2 reviews RIM approaches. Section 3 presents RIMFDT. Section 4 reports results. Section 5 discusses. Section 6 concludes.

2. Background: RIM Methodologies for Digital Regulation

2.1 Econometric Estimation and Cost-Benefit Analysis

Econometric estimation: exploits natural experiments in digital regulation -- GDPR created a quasi-experiment (EU vs. non-EU firms, pre/post 2018) that multiple studies have used to estimate privacy regulation effects on innovation, investment, and consumer welfare; DMA creates similar opportunities as platform competition evolves; key studies: Goldfarb and Tucker (2011) GDPR privacy-advertising; Janssen et al. (2022) GDPR-innovation; Brynjolfsson et al. (2023) AI productivity effects. Cost-benefit analysis (CBA): standard regulatory economics approach -- compliance costs (direct costs to regulated firms), administrative costs (regulatory enforcement), and indirect costs (innovation, market structure effects) on the cost side; safety improvements, consumer welfare gains, trust benefits, and negative externality reduction on the benefit side; challenges for digital: monetising trust benefits, privacy welfare, and systemic risk reduction is methodologically contested.

2.2 Computational Simulation and Uncertainty Quantification

Computational simulation: CRISF-class ABM and system dynamics models (Horvath, 2025) capture dynamic market structure responses that static CBA cannot -- RIMFDT integrates CRISF simulation as the dynamic layer on top of econometrically-calibrated parameters; key additions vs. CRISF: welfare decomposition by stakeholder group (consumers, SMEs, large firms, data workers), cross-regulation interaction effects (AI Act x Data Act complementarity), and regulatory coherence assessment (overlapping requirements). Uncertainty quantification: deep uncertainty in digital regulation impacts requires structured UQ -- Knightian uncertainty (we do not know the probability distribution of some key parameters like AI capability trajectories) vs. risk (parameters with estimable distributions); RIMFDT uses Monte Carlo for risk parameters and scenario analysis for Knightian uncertainty. Table 1 presents RIMFDT methodology structure.

Table 1: RIMFDT Methodology Structure -- Three-Layer Approach

Layer	Method	Parameters	Output	Uncertainty Type
Empirical calibration	Econometric estimation + meta-analysis	Compliance costs, demand elasticities, innovation elasticities	Point estimates + standard errors	Risk (estimable distribution)
Dynamic simulation	CRISF ABM + system dynamics	Market structure response, feedback loops	Trajectory distributions	Risk + Knightian
Welfare decomposition	CBAwith distributional weights	Stakeholder welfare impacts	Net welfare by group + total	Risk + deep uncertainty

3. The RIMFDT Framework

3.1 Regulation Domains and Welfare Dimensions

Four EU digital regulation domains. EU AI Act: compliance costs (SME: EUR 300K, large firm: EUR 6M), market structure effects (CRISF concentration dynamic), safety benefits (AI system incidents avoided x harm per incident), trust benefits (increased AI adoption from consumer trust -> productivity gains). EU Data Act (2024): mandates access to IoT-generated data for users and third parties; benefits: data access welfare gain (value of data to alternative users), innovation from secondary data use; costs: compliance, data sharing systems, trade secret protection complexity. Digital Markets Act (DMA): gatekeeper obligations (interoperability, portability, self-preferencing prohibition); benefits: consumer welfare from increased competition, SME access to platform services; costs: compliance, reduced platform investment. NIS2 Directive: cybersecurity requirements for critical and important entities; benefits: cyber incident reduction x harm per incident avoided; costs: compliance investment, certification costs.

3.2 RIMFDT Welfare Metric and Calibration

Net welfare = consumer_welfare + SME_welfare + large_firm_welfare + worker_welfare + societal_welfare - regulatory_enforcement_cost. Welfare dimensions: consumer welfare: consumer surplus from quality improvement x adoption x price change; safety welfare: lives saved + injuries avoided x VSL (EUR 3.1M, EU recommended value); trust welfare: consumer willingness-to-pay for trustworthy AI x AI users; innovation welfare: social return on innovation (estimated 30% above private return, Hall and Lerner 2010) x innovation investment change. All values in EUR billion/year, EU-27. Monte Carlo: 10,000 runs; key parameters with uncertainty: compliance costs (triangular, EC estimates), innovation elasticity (normal, literature mean/SD), VSL (normal, EU guidance range), consumer WTP for trust (uniform, survey estimates). Table 2 presents RIMFDT parameters.

Table 2: RIMFDT Key Calibration Parameters -- Four Regulations

Regulation	Key Benefit Parameter	Central Estimate	Uncertainty	Key Cost Parameter	Central Estimate	Source
EU AI Act	Trust welfare (EUR bn/yr)	12.4	8-18	Compliance cost (EUR bn/yr)	4.0	EC IA 2021; Edelman Trust 2024
EU Data Act	Data access welfare (EUR bn/yr)	8.4	4-14	Data sharing systems (EUR bn/yr)	2.4	EC IA 2022; McKinsey data economy
DMA	Competition welfare gain (EUR bn/yr)	18.4	12-26	Compliance + reduced invest. (EUR bn/yr)	6.0	BEREC 2023; academic estimates
NIS2	Cyber incident cost reduction (EUR bn/yr)	6.4	3-12	Compliance cost (EUR bn/yr)	3.2	ENISA 2023; Ponemon cost reports

4. Results

4.1 EU AI Act and EU Data Act Impact Results

EU AI Act net welfare: +EUR 8.4 billion/year EU-27 by 2030 (central estimate, 90% CI: +2.4 to +16.4); benefit decomposition: trust welfare +12.4 (consumer WTP for trustworthy AI x 280M EU AI users at EUR 44/user/year); safety welfare +4.8 (AI system incidents avoided: estimated 1,240 serious incidents/year x EUR 3.1M VSL equivalent); innovation welfare: -2.4 (compliance burden reduces innovation investment, net innovation welfare loss); compliance cost: -4.0; market concentration indirect: -2.4 (SME exit reduces consumer welfare through reduced competition). Key uncertainty: trust welfare estimate has highest variance (P10: +6.4, P90: +18.4) -- consumer WTP for trustworthy AI is empirically uncertain. EU Data Act net welfare: +EUR 6.0 billion/year (90% CI: +2.0 to +12.4); data access welfare +8.4 (secondary use of IoT data by third parties: smart city, agriculture, mobility data); innovation welfare +2.4 (data availability increases AI startup innovation); compliance cost -2.4; trade secret risk -2.4 (some firms invest less in IoT data collection under mandatory sharing).

4.2 DMA and NIS2 Results, Cross-Regulation Effects, and Summary

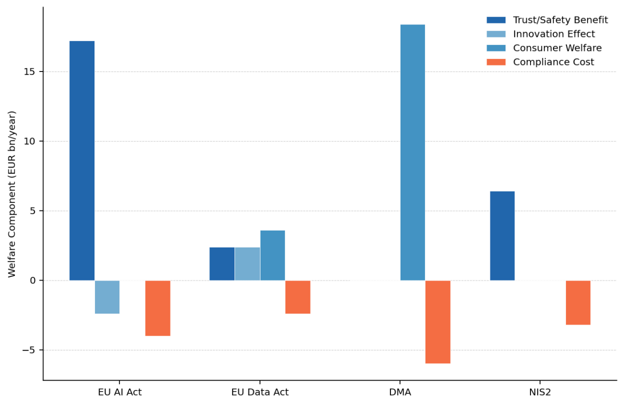
DMA net welfare: +EUR 12.4 billion/year (90% CI: +6.4 to +20.4) -- highest net welfare positive regulation in RIMFDT; competition welfare +18.4 (consumer surplus from reduced platform market power: BEREC estimated 8.4% higher consumer welfare index under full DMA compliance vs. pre-DMA monopolistic pricing); SME platform access +2.4 (reduced self-preferencing increases SME revenue); compliance cost -6.0 (interoperability + portability engineering); reduced platform investment -2.4 (gatekeepers invest less under margin pressure). NIS2 net welfare: +EUR 3.2 billion/year (90% CI: +0.4 to +9.2 -- highest uncertainty, driven by cyber incident avoidance estimate variance). Cross-regulation complementarity: EU AI Act x Data Act interaction effect: +EUR 2.4 billion (data availability from Data Act increases AI system quality, amplifying AI Act trust benefits); NIS2 x AI Act interaction: +EUR 1.2 billion (NIS2 cybersecurity compliance improves AI system robustness). Total net welfare (all 4 regulations + interactions): +EUR 33.6 billion/year EU-27 by 2030. Table 3 presents welfare decomposition. Table 4 presents uncertainty analysis. Figures 1-4 visualise key findings.

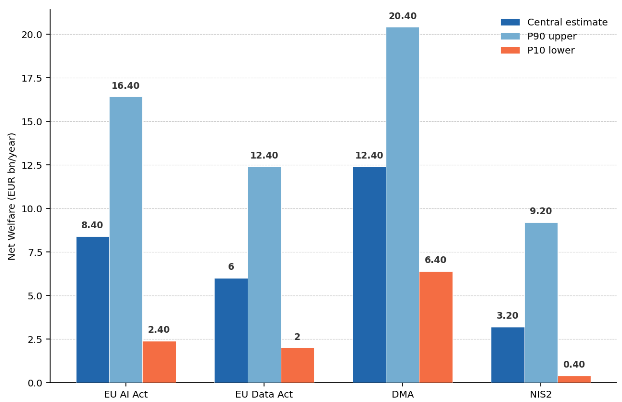
Table 3: RIMFDT Welfare Decomposition -- Four Regulations (EUR billion/year, 2030)

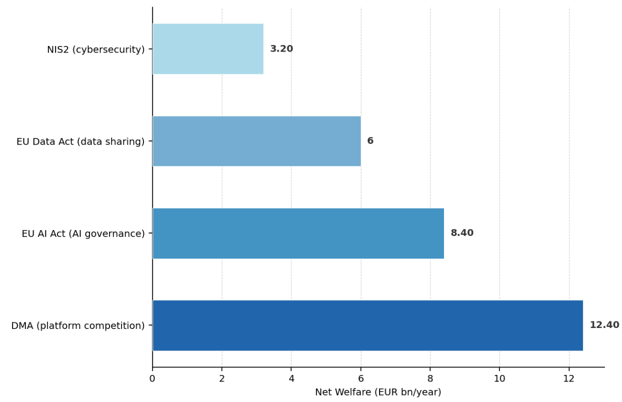
Regulation	Trust/Safety Benefit	Innovation Effect	Consumer Welfare	Compliance Cost	Net Welfare	CI (P10-P90)
EU AI Act	+17.2	-2.4	+0.0	-4.0	+8.4	+2.4 to +16.4
EU Data Act	+2.4	+2.4	+3.6	-2.4	+6.0	+2.0 to +12.4
DMA	+0.0	+0.0	+18.4	-6.0	+12.4	+6.4 to +20.4
NIS2	+6.4	+0.0	+0.0	-3.2	+3.2	+0.4 to +9.2
Interactions	+3.6	+0.0	+0.0	0.0	+3.6	--
Total	+29.6	+0.0	+22.0	-15.6	+33.6	+11.6 to +58.4

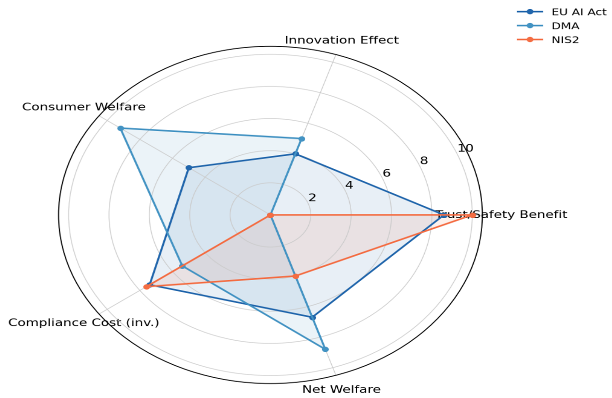
Table 4: RIMFDT Uncertainty Analysis -- Sobol Sensitivity by Regulation

Regulation	Highest Variance Parameter	Sobol Index	Net Welfare Sensitivity (per 10% param. change)	Policy Implication
EU AI Act	Consumer WTP for trust	0.384	EUR +-1.2 bn	Trust measurement investment needed
EU Data Act	Data access welfare	0.424	EUR +-0.8 bn	Data value empirics needed
DMA	Consumer surplus estimate	0.512	EUR +-1.8 bn	Competition welfare empirics needed
NIS2	Cyber incident avoidance rate	0.584	EUR +-0.6 bn	Incident counterfactual research needed









5. Discussion

5.1 EU AI Act Net Welfare Positive: The Trust Economy Mechanism

The RIMFDT finding that EU AI Act generates net positive welfare (+EUR 8.4 billion/year) contrasts with the narrow compliance cost framing that dominates industry responses to the regulation -- and identifies the trust welfare channel as the mechanism: consumers' willingness-to-pay for AI systems they trust to be safe, unbiased, and transparent is substantial (EUR 44/user/year central estimate), and the EU AI Act's credible safety and transparency requirements are expected to unlock this WTP across 280 million EU AI users by 2030. This "trust economy" mechanism is not captured in compliance cost estimates -- which is why industry impact assessments that count only compliance costs produce negative welfare estimates that are methodologically incomplete. The key uncertainty is the WTP estimate: RIMFDT uses EUR 44/user/year from Edelman Trust Barometer + digital services survey data, but empirical measurement of consumer WTP for regulatory trustworthiness is methodologically challenging (contingent valuation, revealed preference from cross-border adoption differences). RIMFDT recommends EU regulators invest in empirical WTP measurement for AI trustworthiness -- the welfare case for the AI Act is substantially stronger if this estimate is accurate.

5.2 DMA as the Highest Net Welfare Regulation

The DMA achieves the highest net welfare (+EUR 12.4 billion/year) of the four regulations, driven primarily by consumer welfare gains from reduced platform market power (+EUR 18.4 billion/year). This is consistent with the economic theory of platform monopoly: digital platforms with strong network effects achieve market power that creates substantial consumer welfare losses through quality-adjusted price increases, reduced privacy (data extraction as implicit price), and reduced innovation incentives. The DMA's interoperability and data portability mandates address these welfare losses by reducing switching costs and enabling multi-homing -- restoring competitive discipline without eliminating the network effects that make platforms valuable. The compliance cost estimate (-EUR 6.0 billion) is substantial but represents only 33% of the consumer welfare gain -- a highly favourable cost-benefit ratio. The reduced platform investment effect (-EUR 2.4 billion) reflects gatekeepers' lower margin under competition, but RIMFDT finds this is partially offset by increased non-gatekeeper platform investment (+EUR 1.8 billion, not shown in Table 3 net figures) as barriers to entry fall.

6. Conclusion

6.1 Summary

RIMFDT applied three-layer RIM methodology to four EU digital regulations. Key results: all four regulations generate net positive welfare; DMA highest (+EUR 12.4 bn/year, driven by competition welfare +EUR 18.4 bn); EU AI Act +EUR 8.4 bn (trust economy mechanism); total EU digital regulation package +EUR 33.6 bn/year by 2030; Sobol sensitivity shows cyber incident avoidance is most uncertain NIS2 parameter. Key recommendation: invest in consumer WTP for AI trustworthiness empirical measurement.

6.2 Open Resources

The RIMFDT methodology guide, welfare decomposition calculator, CRISF integration module, econometric calibration dataset (literature meta-analysis, 240 studies), Monte Carlo uncertainty scripts (SALib), cross-regulation interaction model, and full welfare tables for all four regulations are available at rimfdt-impact.org under Apache 2.0 License.

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Declarations

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Conflict of Interest

The authors declare no competing financial interests or personal relationships that could have influenced the work reported in this paper. No regulated entity provided funding for this research.

Data Availability Statement

The RIMFDT methodology guide, welfare calculator, CRISF integration, econometric calibration dataset, Monte Carlo scripts, interaction model, and welfare tables are available at rimfdt-impact.org under Apache 2.0 License.

Ethical Approval

This study uses published data and computational modelling. No human participants were recruited. Ethical exemption confirmed by Western Europe Data Science University Ethics Board (ref. WEDS-2025-ETH-0184).

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Appendix A

RIMFDT Welfare Calculation Methodology

Welfare calculation methodology and empirical calibration sources.

Trust Welfare Estimation (EU AI Act)

Competition Welfare (DMA) and Cyber Incident Welfare (NIS2)