Governance of algorithms: options and limitations

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Abstract

Purpose – *The purpose of this paper is to contribute to a better understanding of governance choice in the area of algorithmic selection. Algorithms on the Internet shape our daily lives and realities. They select information, automatically assign relevance to them and keep people from drowning in an information flood. The benefits of algorithms are accompanied by risks and governance challenges.*

Design/methodology/approach – *Based on empirical case analyses and a review of the literature, the paper chooses a risk-based governance approach. It identifies and categorizes applications of algorithmic selection and attendant risks. Then, it explores the range of institutional governance options and discusses applied and proposed governance measures for algorithmic selection and the limitations of governance options.*

Findings – *Analyses reveal that there are no one-size-fits-all solutions for the governance of algorithms. Attention has to shift to multi-dimensional solutions and combinations of governance measures that mutually enable and complement each other. Limited knowledge about the developments of markets, risks and the effects of governance interventions hampers the choice of an adequate governance mix. Uncertainties call for risk and technology assessment to strengthen the foundations for evidence-based governance.*

Originality/value – *The paper furthers the understanding of governance choice in the area of algorithmic selection with a structured synopsis on rationales, options and limitations for the governance of algorithms. It provides a functional typology of applications of algorithmic selection, a comprehensive overview of the risks of algorithmic selection and a systematic discussion of governance options and its limitations.*

Keywords *Internet, Algorithms, Governance, Regulation, Algorithmic selection, Governance choice*

Paper type *Research paper*

1. Introduction: from governance by algorithms to governance of algorithms

Algorithms are integrated in a growing number of the Internet-based applications that shape our daily lives and realities. These software intermediaries operate behind the scenes and influence a wide range of activities; the selection of online news via search engines and news aggregators, the consumption of music and video entertainment via recommender systems, the choice of services and products in online shops, the display of status messages on social online networks and algorithmic trading in stock exchange markets are the most prominent examples of this omnipresent trend. Latzer *et al.* (2015) distinguish nine groups of the Internet services that rely on algorithmic selection applications (Table I), and although their purpose (e.g. search, aggregation, prognosis, scoring) and their modes of operation differ in detail, all of these applications are characterized by a common basic functionality; they automatically *select* information elements and *assign relevance* to them.

The broad diffusion of algorithms in a growing number of domains is one of the reasons for intensified discussion of the "power of algorithms". This power can be illustrated, for instance, by the impact of recommendation systems on consumer choice in electronic commerce (Senecal and Nantel, 2004; Hinz and Eckert, 2010), the influence of Google

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Table I Functional typology of algorithmic selection applications

Types	*Examples*
Search	General search engines (e.g. Google search, Bing, Baidu)
	Special search engines (e.g. Mocavo, Shutterstock, Social Mention)
	Meta search engines (e.g. Dogpile, Info.com)
	Semantic search engines (e.g. Yummly)
	Question and answer services (e.g. Ask.com)
Aggregation	News aggregators (e.g. Google News, nachrichten.de)
Observation/surveillance	Surveillance (e.g. Raytheon's RIOT)
	Employee monitoring (e.g. Spector, Sonar, Spytec)
	General monitoring software (e.g. Webwatcher)
Prognosis/forecast	Predictive policing (e.g. PredPol),
	Predicting developments: success, diffusion, etc. (e.g. Google Flu Trends, scoreAhit)
Filtering	Spam filter (e.g. Norton)
	Child protection filter (e.g. Net Nanny)
Recommendation	Recommender systems (e.g. Spotify; Netflix)
Scoring	Reputation systems: music, film, etc. (e.g. ebay's reputation system)
	News scoring (e.g. reddit, Digg)
	Credit scoring (e.g. Kreditech)
	Social scoring (e.g. Klout)
Content production	Algorithmic journalism (e.g. Quill; Quakebot)
Allocation	Computational advertising (e.g. Google AdSense, Yahoo! *Bing* Network)
	Algorithmic trading (e.g. Quantopian)

Source: Latzer *et al.* (2015)

rankings (Döpfner, 2014; Epstein and Robertson, 2013) and Facebook's News Feed on the news business (Bucher, 2012; Somaiya, 2014). The power of Google's and Facebook's algorithms serves as prominent example in a broader debate on the social and economic influence of software in general and algorithms in particular. According to Manovich (2013), "software takes command" by replacing a diverse array of physical, mechanical and electronic technologies that create, store, distribute and interact with cultural artifacts. Codes and algorithms increasingly have governing powers (Musiani, 2013; Pasquale, 2015; Gillespie, 2014), similar to regulations by law (Lessig, 1999). Increasing automation (Steiner, 2012) and the power of technology are discussed by researchers and journalists who focus on the role of code and algorithms as agents (Machill and Beiler, 2007), institutions (Napoli, 2013; Katzenbach, 2011), ideologies (Mager, 2012), gatekeepers (Jürgens *et al.*, 2011; Wallace and Dörr, 2015) and modes of intermediation (Águila-Obra *et al.*, 2007). An institutional perspective points to the enabling and restricting role of algorithms. The intermediation perspective highlights their role as gatekeepers and their effects on the public sphere, public-opinion formation (Van Dalen, 2012) and the construction of realities. Algorithmic selection automates a commercialized reality-mining and reality-construction in information societies (Latzer *et al.*, 2015).

The observations that algorithms have influential powers ("governance *by* algorithms") are followed by debates on how to govern these powers adequately ("governance *of* algorithms"). In particular, the influential and dominant position of Google is often criticized (Zuboff, 2014) and increased public and regulatory attention on the governance of online search (Moffat, 2009; Langford, 2013; Lewandowski, 2014; König and Rasch, 2014). Disputes on certain practices and implications of news aggregation and search have resulted in regulatory provisions regarding copyright and privacy violations, such as the German ancillary copyright law (BGBl, 2013, part 1, no. 23, p. 1,161; Stühmeier, 2011) and the right to be forgotten for search engines in the EU (ECJ, 2014, ECJ, judgment C-131/12 Google Spain vs AEPD and Mario Costeja Gonzalez).

However, the applications and related risks of algorithmic selection go far beyond Google and online search. Accordingly, the scope of analysis needs to be extended to adequately

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grasp the broad spectrum of applications, their characteristics, role and consequences for markets and societies, their varied problematic implications and governance opportunities. This paper makes a contribution to governance choice. It presents the rationales of the governance of algorithms, proposes a risk-based approach and provides an overview and categorization of the risks of algorithmic selection. It explores available institutional governance options and selected governance measures, which are applied and proposed in the domain of algorithmic selection. Finally, it outlines the limitations of governance options and draws conclusions for governance choice.

2. Analytical framework: risks and governance choice

Justifications for the governance of algorithms are provided by the *risks* that arise with the diffusion of algorithmic selection. From a public-interest point of view, governance should reinforce benefits and minimize risks. Benefits and risks are tightly interlinked, as risks compromise the exploitation of benefits. Accordingly, a "risk-based approach" (Black, 2010) identifies and examines the risks and explores the opportunities and limitations to reduce them.

Latzer *et al*. (2014) identify nine categories of risk that accompany algorithmic selection:

1. manipulation (Bar-Ilan, 2007; Rietjens, 2006; Schormann, 2012);
2. diminishing variety, the creation of echo chambers (Sunstein, 2001, 2009) and filter bubbles (Pariser, 2011), biases and distortions of reality (Zhang and Dimitroff, 2005; Cushing Weigle, 2013; Bozdag, 2013);
3. constraints on the freedom of communication and expression, for example, censorship by intelligent filtering (Zittrain and Palfrey, 2008);
4. surveillance and threats to data protection and privacy (Zimmer, 2008; Toch *et al*., 2012; Lyon, 2003);
5. social discrimination (Gandy, 2010; Gangadharan, 2014);
6. violation of intellectual property rights (Clark, 2010, 2012; Chiou and Tucker, 2013; Quinn, 2014);
7. abuse of market power (Patterson, 2013);
8. effects on cognitive capabilities and the human brain (Carr, 2010; Sparrow *et al*., 2011); and
9. growing heteronomy and loss of human sovereignty and controllability of technology.

There are various *governance options* to reduce risks and increase the benefits of algorithmic selection. Different actors follow different approaches, have different types of resources at their disposal and show different levels of expertise. It has been acknowledged that the holistic view of a "governance perspective" is a helpful lens to analyze, assess and improve regulation (Grasser and Schulz, 2015, p. 17). From an institutional perspective, the governance options can be located on a continuum ranging from (1) market mechanisms at the one end, to (5) command and control regulation by state authorities at the other (Latzer *et al*., 2002, 2003; Bartle and Vass, 2005). In between, there are alternative modes of governance comprising the categories of (2) self-organization (self-help) by single companies; (3) collective self-regulation by industry branches; and (4) co-regulation – a regulatory cooperation between state authorities and the industry.

For several years, research on alternative modes of governance has received a great deal of scholarly attention (Büthe and Mattli, 2011; Gunningham and Rees, 1997; Gupta and Lad, 1983; Sinclair, 1997), in particular, regarding their application, suitability and effectiveness in communications markets (Abbot, 2012; Cave *et al*., 2008; Hans-Bredow-Institut and Institute of European Media Law, 2006; Latzer *et al*., 2002). In market economies, market solutions are generally preferred over state intervention. State

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regulation is to be implemented if problems cannot be solved by private action (subsidiarity). It needs to be justified by assumed limitations or failures of market solutions and industry self-regulation. This requires a comparison of the opportunities and limitations of different governance arrangements.

3. Governance of algorithms: options and its limitations

Latzer *et al.* (2014) conducted an explorative assessment of the governance of algorithms. In a first step, for each of the nine aforementioned risks of algorithmic selection, the established regulations and suggested governance options are collected and classified according to the arrangements on the continuum between market solutions and state regulation. In the second step, the opportunities and limits are assessed for each of the five types of governance arrangements. This assessment rests on two main pillars:

1. It is (empirically) informed by evidence of risk-specific governance measures, including already established and so far only suggested interventions. Altogether, this shows a wide range of *governance options*.
2. The assessment further rests on a framework for governance choice (Latzer *et al.*, 2002, 2007; Saurwein, 2011).

It examines various enabling contextual factors of governance (incentives, conflicts of interest, intervention capacities, etc.) that help to explain the likelihood of the introduction of certain governance arrangements and their suitability for certain types of risk. Selected criteria are used to explore the *limits* of governance options in relation to specific risks. To inform future governance choice processes, Section 3.1 provides an overview of governance options, and Section 3.2 explores the limitations of governance arrangements.

3.1 Governance options by risks

The governance of algorithms is explored by a positive analysis of measures that have been established or are being proposed to govern the risks of algorithmic selection (Table II). It provides an overview on patterns of the governance of algorithms, highlighting several differences in the choice and combination of governance approaches in reaction to particular risks.

Some of the risks have already been addressed by different governance approaches (data protection), while for others, there are so far no measures (heteronomy). Whereas some risks are almost exclusively left to market solutions (bias), for others governance is institutionalized by private and state regulatory measures alike (violations of property rights). While there are several arrangements and suggestions for measures in the form of self-organization by companies, there are hardly any co-regulatory arrangements. Altogether, there is *no overall common institutional pattern* for the governance of the risks

Table II Selected market solutions and governance measures by categories of risk

Risks	*Market solutions*		*Companies: self-organization*	*Branches: self-regulation*	*Co-regulation*	*State intervention*
	Demand side	*Supply side*				
Manipulation		×	×	×		×
Bias	×	×				
Censorship	×	×	×			×
Violation of privacy rights	×	×	×	×	×	×
Social Discrimination	×		×			×
Violation of property rights		×	×	×		×
Abuse of market power			×			×
Effects on cognitive capabilities						
Heteronomy						

Source: Latzer *et al.* (2014)

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of algorithmic selection. There is a broad variety of measures applied as well as proposals by researchers and policy-makers for additional governance measures as illustrated by the following selected examples.

3.1.1 Potential of market solutions and governance by design. Not all of the risks of algorithmic selection necessarily call for explicit governance measures. Risks may also be reduced by "*voluntary*" *changes in the market conduct* of consumers, content providers and suppliers of algorithmic services. Consumers, for example, may *refrain* from using problematic services, *switch* to other service providers or make use of technologies to protect themselves against risks. There are, for instance, *technical self-help* solutions for consumers that reduce censorship, bias and privacy violations. Consumers can make use of tools for anonymization, such as Tor, Virtual Private Networks (VPN) or OpenDNS to protect their privacy or circumvent censorship. Privacy-enhancing technologies (PETs) are also available for data protection, for example cryptography, cookie management and do-not-track technologies (browser). Using opportunities for the de-personalization of services can partly reduce bias. Altogether, these examples show options for user self-protection, but many of these "demand-side solutions" depend on and are limited by the availability of adequate supply.

Suppliers of services that build on algorithmic selection can reduce risks via business strategies. They may introduce *product innovations* in the form of new services or modifications of established ones. There are examples of services that have been introduced to avoid bias and violations of privacy and copyright. Some news aggregators' business models integrate content providers, who receive compensation (e.g. nachrichten.de). To avoid privacy risks, there are algorithmic services that do not collect user data (e.g. the search engine DuckDuckGo). Such product innovations – if successful – might also contribute to diversity and the reduction of market concentration.

Other examples focus on the *technological design* of services to reduce risks, especially manipulation, bias and privacy violations. "Privacy by default" and "privacy by design" are technological approaches to increase privacy (Schaar, 2010; Cavoukia, 2012). Services such as ConsiderIt, Reflect and OpinionSpace are designed to avoid filter bubbles and bias by integrating elements of serendipity (Munson and Resnick, 2010; Schedl *et al.*, 2012; Resnick *et al.*, 2013). Bias in recommender systems can be substantially reduced with machine learning (Krishnan *et al.*, 2014). To avoid manipulation, strong self-protection is in the self-interest of the suppliers of algorithmic services. They often use technological protection to counter third-party manipulation. A *digital arms race* is observable in areas like search, recommendation and filtering, where content providers try to avoid disadvantages by using content-optimization strategies (Jansen, 2007; Wittel and Wu, 2004). Technological self-help (robots.txt files) is also used by content providers to avoid copyright violations.

3.1.2 Options for the industry: self-organization and self-regulation. Alongside product innovations and technological self-protection, individual companies may reduce risks by means of "self-organization". Typical self-organization measures include company principles and standards that reflect the public interest, internal quality assessment in relation to certain risks and ombudsman schemes to deal with complaints. The commitment to self-organization is often part of a company's broader corporate social responsibility (CSR) strategy. From an economic point of view, the purpose of self-organization is to increase reputation or to avoid reputation loss. Suppliers of services that rely on algorithmic selection can commit themselves to certain "values" (Introna and Nissenbaum, 2000), such as search neutrality or the "minimum principle" of data collection (Langheinrich, 2001; Cavoukia, 2009). There are suggestions for ethics boards at the company level to deal with implications of software development or with interference in user experiences. For risks such as censorship, discrimination, bias and manipulation, companies may also adopt principles and internal quality control. Google, for example, announced the establishment of an ethics board (Lin and Selinger, 2014). For big data, in-house algorithmists have been

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suggested to oversee big-data operations and serve as first contact point for people who feel harmed by an organization's big-data activities (Mayer-Schönberger and Cukier, 2013).

In contrast to self-organization by individual companies, *self-regulation* refers to collective efforts of an industry/branch that takes measures of self-restriction to pursue public interest objectives. Typical instruments of industry self-regulation are: codes of conduct, organizational and technical industry standards, quality seals and certification bodies, ombudsmen and arbitration/mediation boards and ethic committees/commissions. The latter deals with ethically controversial issues regarding the development of branches and technologies. In the wide field of algorithmic selection, there are *sectoral initiatives* of self-regulation in the advertising industry (USA, Europe), the search-engine market (Germany), social online networks (Europe) and in the domain of algorithmic trading. These initiatives deal with risks, such as violations of privacy and copyright, manipulation and controllability of algorithmic transactions. The stock exchange has introduced monitoring and warning systems to detect manipulation and cases where automatic trading gets out of control. In the advertising industry, there are initiatives for better data protection in the area of online behavioral advertising (OBA), which are led by the Digital Advertising Alliances in Europe and the USA. The initiatives encompass several instruments, such as codes of conduct, common online opt-out interfaces for consumers and certification schemes. Moreover, together with the Web browser providers, the advertising industry is involved in the technical standardization for do-not-track (DNT). Additionally, there are organizational and technical industry initiatives/standards for the protection of copyrights, for example the creative commons licensing system and digital rights management systems (DRM). In this case, "self-regulation" via common standards fitted with the interests of the industry. Moreover, certification schemes, ombudsmen and ethics commissions appear as suitable instruments to deal with certain risks of algorithmic selection (e.g. bias, manipulation, restriction of communications and controllability of applications). However, these options have not been applied by the industry so far, and in general, it seems that there is still a highly unexploited potential for self-regulatory governance strategies.

3.1.3 Examples and options of state intervention. Algorithmic selection also poses challenges for *politics and the state*. The limitations of market mechanisms and self-regulation in reducing the risks can provide reasons and justifications for state intervention. Typical state intervention instruments are: the provision of public services, command-and-control regulation, incentives by subsidies/funding and taxes/fees, co-regulation, soft law and information measures to promote people's awareness and knowledge about risks and to support appropriate behavior. In practice, there are several examples of state intervention in the domain of algorithmic selection, and regulations are related to particular risks rather than to a certain sector or a specific technology. There are *command-and-control* regulations for manipulation (cybercrime regulations), violations of privacy and copyright, freedom of expression and fair competition. In Europe, for example, the privacy protection directive (95/46/EC, Art. 15) protects people from automated individual decisions on certain personal aspects, such as performance at work, creditworthiness, reliability and conduct. Another area of ongoing regulatory debate is online search. Due to concerns regarding fair competition, Google is the subject of investigations by the US and European competition authorities, because competitors claim that a Google search gives undue preference to the company's other services. Some proposals for regulatory action in the search-engine market suggest increasing transparency and controllability by public authorities, while others aim at cutting the barriers to market entry (Schulz *et al.*, 2005) or establishing the principle of neutral search (Lao, 2013). A publicly funded "index of the web" (Lewandowski, 2014) or user data sets (Argenton and Prüfer, 2012) are suggested as common resources to enhance market contestability, facilitate market entry and promote competition.

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Alongside command-and-control regulation, state actors can draw on other modes of intervention, such as funds/subsidies, taxes, soft law, information and co-regulation. Some have suggested introducing a *machine tax* to compensate for fiscal losses of automation and a data *fee/tax* to decrease the economic incentives for data collection (Lanier, 2013; Collin and Colin, 2013). In practice, state intervention happens by monetary incentives (i.e. funding, subsidies). There are, for example, several programs to exploit the potential of automation by promoting reorganization in the industry (e.g. Industry 4.0). But funding is also used to support the reduction of risk. For example, the EU promotes the development of PETs in R&D programs. *Co-regulation* and *soft law* are also established in the area of data protection. Well-known instruments include data-protection certification schemes and seals of quality, the Fair Information Practice Principles in the USA and the Safe-Harbor Principles, which regulate data transfers for commercial purposes between the USA and the EU.

There are hardly any measures or suggestions for alternative modes of state intervention for risks, such as bias, heteronomy and effects on cognitive capabilities. In some of these areas, it might be worth promoting consumers' awareness (governance by information), enhancing users' media literacy and stimulating conscious usage and self-protection abilities. The possibilities of co-regulation have not been explored and used comprehensively so far either. Forms of co-regulation may be appropriate for problems involving strong *conflicts of interest* that require independent control and conflict settlement. Because algorithmic selection sometimes involves ethical concerns (Kraemer *et al.*, 2011), political actors may also consider appointing ethical committees with broad stakeholder involvement to deal with value conflicts. Finally, from a strategic point of view, state intervention may also be targeted at the barriers for market solutions and self-regulation (e.g. consumer awareness, incentives for the industry). The reduction in barriers enhances the preconditions for self-help measures by market participants and the state can act as an enabler of self-help.

3.2 Limitations of governance options

Alongside the spectrum of governance measures presented in Section 3.1, governance choice has to consider the limitations of institutional governance options. Enabling contextual factors for governance (incentives, conflicts of interest, intervention capacities, etc.) helps to explain the likelihood of the introduction of certain governance arrangements and their suitability in relation to different risks (Latzer *et al.*, 2002, 2007; Saurwein, 2011). The analyses of enabling contextual factors point to the following limitations of institutional governance options.

3.2.1 Limitations of self-help strategies and market solutions. Some risks of algorithmic selection could be reduced by consumers' self-help strategies (opt-out, switch, technical self-protection), but there are several barriers to effective self-help and the potential of user self-protection should not be overestimated. Consumers could stop using problematic services or switch to alternative products. But algorithmic applications often work without explicit consent. There is, for example, *no possibility to* "*opt-out*" from a state surveillance program. Switching service providers requires there to be alternative services, but many markets are highly concentrated and switching opportunities are limited. Because of *information asymmetries*, the risks of algorithmic selection are often barely noticeable to consumers and awareness of risks remains low. For example, an average Internet user can hardly detect manipulation, censorship or bias. If risks are not visible, then there is no reason to consider self-protection strategies. To increase transparency, reverse engineering was applied to expose the workings of algorithms and understand their deeper impact, for example, in the context of investigative journalism (Diakopoulos, 2015). However, not only intransparency but also free services decrease the incentives for consumers to switch to lower-risk alternatives. If technical tools for self-protection are available, they often demand *skills* that many users simply do not have. In the area of data

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protection, for example, anonymization calls for technical skills and could be undermined via subsequent re-identification (Ohm, 2010). Finally, making use of strategies such as switching or self-protection requires the *availability of alternative services* and protection technologies. Thus, consumers' options are determined by the supply side of the market in terms of available services and tools.

The risks of algorithmic selection could also be reduced by supply-side measures (e.g. product innovations) but suppliers also face limitations on risk-reducing business strategies. First, there are high *entry barriers* in some market segments, and therefore, the conditions for newcomers and product innovations are difficult. Moreover, the reduction of risks may also reduce service quality, which leads to *competitive disadvantages*. For example, services without personalization reduce the risks of privacy violation, but the benefits of the service for consumers might be reduced as well. This may be a reason why "alternative products" often remain *niche services* with limited numbers of users. Low numbers of users and reduced quality mutually reinforce each other and further decrease the attractiveness of niche services.

3.2.2 Limitations of self-organization and self-regulation. The analysis of governance measures reveals many options for self-organization at the company level, but barriers inhibit voluntary approaches. Most notably, implementation often depends on incentives, that is *benefits and cost* for the company. In the case of data protection, for instance, incentives for strong voluntary standards may be low. Data have been referred to as the "new oil" of the twenty-first century (WEF, 2011) and as essential source for service innovations and economic success (London Economics, 2010; Hustinx, 2010). Hence, it is unlikely that companies will voluntarily desist from gathering data. Many governance proposals aim at more transparency of algorithmic processes (Elgesem, 2008). But there are hardly any *incentives* for companies to disclose algorithms voluntarily, because disclosure increases the danger of manipulation and imitation. This results in a "transparency dilemma" (Bracha and Pasquale, 2008; Granka, 2010; Rieder, 2005). Moreover, a company's *reputation-sensitivity* affects its willingness for self-organization (Latzer *et al.*, 2002, 2007). Great attention on companies in business-to-consumer (B2C) markets, such as Amazon, might promote self-restrictions in the public interest. Little public attention on companies in business-to-business (B2B) markets, such as data brokers (e.g. Acxiom, Corelogic and Datalogix; FTC, 2014), reduces the reputation sensitivity and, thus, the incentives for voluntary self-organization.

The analysis of existing governance measures shows a few examples of collective self-regulation by industry branches (e.g. advertising). In practice, the initiatives are limited to distinct risks in selected and well-established sectors, while the general context conditions for self-regulation are difficult. Most notably, self-regulation is hampered by the *fragmentation and the heterogeneity* of the industries involved. Algorithmic selection is applied across a broad spectrum of sectors, such as news, advertising, entertainment, commerce, social interaction, traffic or health. Due to the large number and the heterogeneity of the branches, an overall self-regulatory initiative is unlikely. Because of the heterogeneity of the industries involved, self-regulatory solutions for minimum standards are unlikely. Hence, minimum standards that apply to all market participants have to be introduced by statutory regulation. Alongside heterogeneity, there are additional factors that inhibit self-regulation. For example, self-regulation is more likely to occur in mature industries with like-minded market players. But markets for services that rely on algorithmic selection are often *new and experimental* (e.g. algorithmic content production), or the developers of algorithmic solutions are newcomers who aim to disrupt established market structures and business models. The newcomers explicitly strive for new paths and, therefore, often do not voluntarily comply with traditional industry schemes.

3.2.3 Limitations of state intervention. Finally, the analysis of governance options also points to a broad spectrum of opportunities for state intervention to reduce the risks of algorithmic selection. But the state also faces limitations regarding the governance of algorithms. Not

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all types of risk are suited to state intervention in general and to command-and-control in particular. Risks such as bias, heteronomy and cognitive effects of algorithmic selection are difficult to address by statutory prescriptions. Examples point to a *lack of legitimacy and practicability* of state intervention, for example, with the aim of enhancing "objectivity" in the case of bias problems. Moreover, many markets are still in their infancy and there is only *limited knowledge* about the future development of markets and the risks involved (e.g. temporary monopolies). The uncertainties are amplified by the fact that risks such as "uncontrollability" (e.g. artificial intelligence) are new and there is little experience with similar challenges. Due to complex interdependencies in the socio-technical system, the effects of potential state regulatory interventions are also often hardly predictable. Existing *uncertainties* regarding market development or regulatory impact hamper the governance of algorithmic selection, and consequently, the role of the state has not yet been determined.

4. Résumé

The trend toward increased algorithmic selection in a rising number of domains is irreversible. The combination of ubiquitous computing, big data, new profit opportunities and economic pressure for optimizations is pushing the rapid diffusion of applications that automate the analysis and selection of information and even the distribution of resources (e.g. computational advertising, algorithmic trading). Algorithmic selection provides the basis for service innovations and business models and is one of the new sources of growth in the domain of (big) data-driven innovations (OECD, 2013). Accordingly, algorithmic selection is used in many areas and for a variety of purposes, such as search, aggregation, prognosis, surveillance, recommendation, rating/scoring, content production and allocation (Latzer *et al.*, 2015). The rapid and broad diffusion of algorithmic selection and its increasing influence (governance by algorithms) provide the starting point for more in-depth analyses about its characteristics and consequences for markets and societies, including questions of governance choice. This paper contributes to the understanding of governance choice in the area of algorithmic selection by scrutinizing rationales, options and limitations for the governance of algorithms.

It argues that justifications for the governance of algorithms are predicated on identified risks. It therefore proposes a *risk-based approach* and provides an overview of risks of algorithmic selection: manipulation, biases, censorship, social discrimination, violations of privacy and property rights, abuse of market power, effects on cognitive capabilities and growing heteronomy.

The paper then explores the *governance options* by assessing the suitability of various institutional governance arrangements on the continuum between the market and the state for the reduction of risks. Alongside demand- and supply-side market solutions, the governance options include self-organization of individual companies, collective self-regulation, co-regulation and state intervention. The paper collects and classifies governance measures that have been implemented or are being proposed in relation to particular risks of algorithmic selection. Results of the analysis show no overall common institutional pattern for the governance of algorithms. Various risks have already been addressed by a number of different governance approaches (data protection), while, for others, no measures have so far been applied (heteronomy). Some risks are almost exclusively left to market solutions (bias), while, for others, private and state measures exist (violations of property rights). Moreover, the overview unveils a broad variety of governance options that can inform governance-choice processes. Among the many opportunities, increasing attention is being paid to the regulation of code (Brown and Marsden, 2013) and *governance by design* solutions, for example privacy by design and technological self-protection by consumers.

Governance choice has to further consider the *limitations of governance arrangements*. The likelihood and suitability of certain governance options may be constrained by contextual

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factors, such as incentives, conflicts of interest and intervention capacities. The paper shows several examples that point to limitations for the governance of algorithms; consumer self-help, for instance, is limited by the lack of opt-out possibilities and alternative services, lack of awareness and non-transparency of risks and the lack of skills for effective technological self-protection. Self-organization and self-regulation of the industry may be hampered by limited incentives (costs, benefits) for self-restriction, risks of manipulation and imitation, sectoral entry barriers, market fragmentation and market heterogeneity, the sometimes low reputational sensitivity and the new and experimental character of the markets that rely on algorithmic selection. State intervention faces limitations because of a lack of legitimacy and practicability of interventions and because of uncertainties regarding market developments, risks and the effects of potential interventions.

This analysis of justifications, options and limitations of the governance of algorithms makes it finally possible to draw selected overall *conclusions* on governance choice. Analyses reveal that there is a broad spectrum of players, levels and instruments for the governance of algorithms, but there is *no one-size-fits-all solution*. Instead, there is the need for a *governance mix* consistent with the respective risks and applications in question and an interplay between instruments and diverse actors involved. The attention therefore has to shift to *multi-dimensional solutions* and combinations of governance measures that mutually enable and complement each other. For example, consumer self-help for privacy protection depends on available complementary provisions, such as protection technologies and organizational dispositions, for example regulations and bodies responsible for dealing with user complaints. One of the tasks for further research is to assess the opportunities and suitability of multi-dimensional solutions in terms of actors, instruments, interplay and mutual complementation. The search for an adequate governance mix is difficult because there is only limited knowledge about the development and the effects of regulatory interventions. The existing uncertainties call for further risk and technology assessment to strengthen the foundations for evidence-based governance in the domain of algorithmic selection. Risk-based approaches seem to be particularly appropriate for this purpose. They can monitor market and technology developments, assess the involved and emerging risks and develop problem-oriented, adaptive governance strategies.

Note

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