European Commission

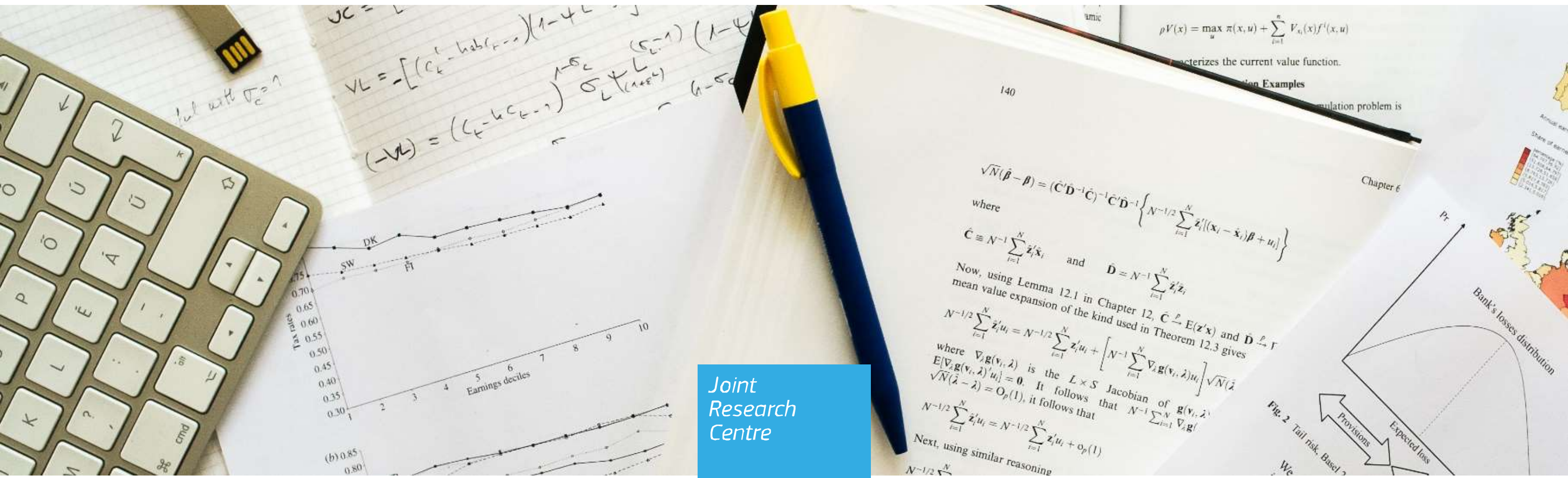
JRC TECHNICAL REPORT

Modelling the diffusion of the deterrent effects of competition policy

Dierx, A., Ilzkovitz, F., Pataracchia, B., Pericoli, F.

2022

JRC Working Papers in Economics and Finance, 2022/16



EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC131332

Ispra: European Commission, 2022

How to cite this report: Dierx, A., Ilzkovitz, F., Pataracchia, B., Pericoli, F., *Modelling the diffusion of the deterrent effects of competition policy*, European Commission, Ispra, 2022, JRC131332.

Executive summary

This paper proposes a novel approach to simulate the deterrent effects associated with a competition authority's merger interventions, cartel prohibitions and other antitrust interventions.

The novelty of the approach adopted is that it models deterrence as a diffusion of information about the competition authority's interventions to market players and that it considers the role of both the competition authority and market players in this process. On the one hand, the mere existence of a competition authority can have deterrent effects on the behaviour of market players. This initial level of deterrence depends on the reputation of the competition authority. In addition, the competition authority sends a signal to market players through its interventions. The strength of this signal depends on the economic importance of the detected infringements of competition rules. On the other hand, market players can contribute to the diffusion of the signal and therefore amplify its deterrent effects. Finally, the deterrent effects of competition policy interventions are assumed to be felt primarily in the markets and sectors directly affected by the interventions of the competition authority. However, this assumption may be relaxed in future work, taking account of the precedent setting nature of the competition policy intervention.

The characteristics of the competition policy regime (for example, the role of leniency regime and fines in cartel deterrence) and the type of intervention (prohibition versus remedied mergers in the deterrence of anticompetitive mergers) can also have an impact on the deterrent effects of competition policy. However, it is fair to say that the literature does not always provide conclusive evidence regarding the impact of factors other than the detection activity and reputation of the competition authority.

This paper presents a novel approach to model the deterrent effects of competition policy interventions, using a database of European Commission's merger decisions, cartel prohibitions and other antitrust interventions over the period 2012-2021. The main advantages of this approach are that the relation between detection and deterrence is based on a robust theoretical framework relying on well-established models used to describe the diffusion of information and that the detection activity of the competition authority is estimated on the basis of real-life data. This framework allows to better integrate the role of both the competition authority and market players in the process of diffusion of information about competition policy interventions and to test the sensitivity of deterrence to the reputation of the competition authority and to the importance of interactions between market players. The mixed-influence model simulations presented above illustrate the importance of these two elements for the deterrent effects of a competition authority's merger, cartel and other antitrust interventions. Reputation and interaction are particularly important for smaller interventions, as measured here by the share of the affected market(s) in the NACE four-digit sector concerned. Moreover, the sensitivity of the deterrent effects to changes in interactions is rather similar to the sensitivity to changes in reputation, with the exception for cartel enforcement, where interactions between market players have a much greater impact. A model simulation of the direct and deterrent effects of competition policy interventions of the European Commission over the period 2012-2021 shows an increase in GDP of 0.6% in the medium term.

Modelling the diffusion of the deterrent effects of competition policy[1]

Adriaan Dierx[2], Fabienne Ilzkovitz[3],
Beatrice Pataracchia[4], Filippo Pericoli[4]

Abstract

Through its competition policy interventions the European Commission not only addresses infringements of EU competition law by the firms directly involved, but it also deters possible future anticompetitive behaviour by these firms and other market players. The present paper represents the diffusion amongst market players of such deterrent effects by a mixed-influence diffusion model, which includes both an external triggering factor and an internal propagation mechanism. Within the present context, interventions by the European Commission serve as the trigger and interactions between market players, in particular via legal counsels and law firms, stimulate the propagation of the interventions' deterrent effects. The parameters of the mixed-influence diffusion model are calibrated using survey-based information on average deterrence multipliers and an assessment of the reputation of the European Commission as an enforcer of EU competition rules. On this basis, estimates of the deterrent effect of each individual intervention by the European Commission can be obtained. A sensitivity analysis shows that small interventions by a competition authority having a good reputation have larger deterrent effects than the same interventions by competition authorities with a worse reputation. However, this difference is less pronounced for interventions affecting large markets. Similarly, an increase in interactions between legal counsels and law firms has important positive effects on deterrence, in particular for smaller interventions. Finally, the sensitivity of the deterrent effects to changes in interactions is rather similar to the sensitivity to changes in reputation, with the exception for cartel enforcement, where the interactions between legal counsels and law firms have a much greater impact.

1. Introduction

This paper proposes a novel approach to simulate the deterrent effects associated with a competition authority's merger interventions, cartel prohibitions and other antitrust interventions. The novelty of the approach adopted is that it models deterrence as a

---

[1] This paper has been written under the sole responsibility of the authors and does not represent the views of the European Commission. The authors would like to thank Marc Ivaldi for his comments and suggestions made at the CRESSE 2022 conference, Gergő Motyovszki and Alexis Stevenson for their review of the paper, and Laura Fracaro for her help in preparing tables and figures.

[2] European Commission, Directorate-General for Competition, Brussels, Belgium.

[3] Université Libre de Bruxelles (ULB), Solvay Brussels School of Economics and Management, Brussels, Belgium.

[4] European Commission, Joint Research Centre (JRC), Ispra, Italy.

diffusion of information about the competition authority's interventions to market players and that it considers the role of both the competition authority and market players in this process. On the one hand, the mere existence of a competition authority can have deterrent effects on the behaviour of market players. This initial level of deterrence depends on the reputation of the competition authority. In addition, the competition authority sends a signal to market players through its interventions. The strength of this signal depends on the economic importance of the detected infringements of competition rules. On the other hand, market players can contribute to the diffusion of the signal and therefore amplify its deterrent effects. Finally, the deterrent effects of competition policy interventions are assumed to be felt primarily in the markets and sectors directly affected by the interventions of the competition authority. However, this assumption may be relaxed in future work, taking account of the precedent setting nature of the competition policy intervention.

The characteristics of the competition policy regime (for example, the role of leniency regime and fines in cartel deterrence) and the type of intervention (prohibition versus remedied mergers in the deterrence of anticompetitive mergers) can also have an impact on the deterrent effects of competition policy. However, it is fair to say that the literature does not always provide conclusive evidence regarding the impact of factors other than the detection activity and reputation of the competition authority. For example, while some authors (Cosnita-Langlais and Sørgard, 2014) consider that a move towards a remedy-based merger control regime would reduce deterrence, others (Clougherty *et al.*, 2016) conclude that Phase I remedies have strong deterrent effects.

This paper is organised as follows. Section 2 defines the concept of deterrence. Section 3 draws lessons from two strands of the literature useful for our analysis, the first on the deterrent effects of competition policy and the second on the models used to describe the diffusion of information. Section 4 sets out the approach used to model the relation between competition policy interventions by the European Commission and their deterrent effects. Section 5 calibrates the values of the model parameters using a database of Commission merger interventions, cartel prohibitions and other antitrust interventions over the period 2012-2021. Section 6 presents the results of the model simulations and conducts a sensitivity analysis. Section 7 concludes by considering various avenues for future research.

2. Definition and types of deterrence

Interventions of competition authorities aim not only at halting the anticompetitive behaviour of market players but also at preventing or reducing in severity future anticompetitive actions, both by the parties directly concerned by these interventions and by other market players. This latter objective is achieved primarily through deterrence.

Interventions can thereby help reduce the number of anticompetitive actions (cartels, other anticompetitive agreements, abuses of dominance or anticompetitive mergers) as well as the harm resulting from such actions**.** They can also affect the characteristics of the undeterred anticompetitive behaviour (for example, the stability and duration of the undeterred cartels, or the character of the notified mergers). The present paper considers the impact of enforcement in the different competition policy domains (including cartel and merger control as well as other antitrust enforcement) on the total value of turnover in the markets being deterred.

A distinction can be made between the deterrent effects exercised on the firms directly affected by a competition policy intervention (to avoid recidivism) and on other firms (third-party deterrence) active in the same or related markets (within-sector deterrence) or even in unrelated markets (see Katsoulacos *et al.*, 2016). Recidivism is primarily an issue for cartel (or other antitrust) enforcement[5] but can also take place in the area of mergers (for example, in the form of repeated 'killer acquisitions').[6] The focus of the present paper is on within-sector deterrence.

According to the literature[7], the deterrent effects of a competition policy regime are influenced by (i) the perceived probability for a company of being caught and convicted, which depends on the current capacity of detection of anticompetitive behaviour by the competition authority; (ii) the expected punishment; and (iii) the reputation of the competition authority, which depends on its past enforcement record and other characteristics of the competition policy regime. This approach can be used to determine the deterrent effects of the different competition policy instruments[8] (including the prohibition of cartels, other anticompetitive agreements and the abuse of market dominance, as well as merger control).

Cartel enforcement has the dual aim of discouraging the formation of cartels and reducing their stability, duration and price overcharges. Cartel deterrence depends on: (i) the perceived likelihood of being detected, influenced by the capacity of the competition authority to detect cases *ex officio* and by the effectiveness of leniency programmes; (ii) the expected punishment depending on the authority's fining rules and the risk of private damages; and (iii) the competition authority's reputation in detecting cartels, sanctioning them with fines and pursuing them in court based on its past cartel decisions and the characteristics of the cartel control system (CMA, 2017). The deterrent effects of other antitrust enforcement actions including the prohibition of anticompetitive agreements and the abuse of dominance can be described along the same lines.

While the basic concept of deterrence remains the same, its definition has to be somewhat adapted to take account of the particular characteristics of merger control (CMA, 2017). In a

---

5 The European Commission explicitly considers the possibility of recidivism in antitrust. In its 2006 Fining guidelines, it defines repeated infringement (or 'recidivism') as the situation 'where an undertaking continues or repeats the same or a similar infringement after the Commission or a national competition authority has made a finding that the undertaking infringed Article [101 or 102 TFEU]'.

6 Cunningham *et al.* (2021) illustrate the prevalence of killer acquisitions in the pharmaceutical industry, where big companies frequently acquire a small potential competitor with the aim of terminating its drug development activities.

7 See for example, Block et al. (1981), Bryant and Eckard (1981), Werden et al. (2011).

8 For example, Buccirossi *et al.* (2014) use this approach to develop composite indicators measuring the deterrence properties of competition policy regimes in thirteen OECD countries.

system of merger control characterised by merger notifications that are compulsory (such as that of the European Union), undeterred mergers need to be notified if the size of the merger exceeds certain thresholds and mergers can be remedied or prohibited following notification. Within this system, the main concern of the competition authority is not to detect mergers but rather to identify and eliminate their anticompetitive effects. Therefore, the deterrent effects of merger control can be defined as the extent to which companies decide to abandon or modify their merger plans in order to lessen the competitive concerns of the competition authority. These effects depend on: (i) the capacity of the competition authority to detect the anticompetitive nature of the notified mergers in order to avoid unduly clearing these mergers; (ii) on the expected 'punishment'[9], which takes the form of the costs imposed on the merging parties if their merger is subjected to an in-depth review by a competition authority, with a risk of being prohibited (these costs include the administrative costs if the merger is delayed and the costs associated with the remedies imposed by the competition authority to address its concerns); and (iii) on the reputation of the competition authority based on its past merger decisions and the characteristics of the merger control system.

3. Literature review

3.1 Measuring the deterrent effects of competition policy[10]

Measuring deterrence is inherently difficult, as it requires information on the changes in future behaviour of market players because of competition authorities' actions. However, these changes cannot be observed and necessitates making inference about anticompetitive behaviour that does not take place. The literature on the deterrent effects of competition policy (see for example, Ormosi (2014) for the deterrent effects of cartel control and Baarsma et al. (2012) for merger control) suggests that these effects are of crucial importance for the effectiveness and the legitimacy of competition policy enforcement and that they are larger than the observed effects of competition policy interventions on the markets directly affected. Overall, there is a broad literature on cartel deterrence, an emerging literature on merger deterrence and very little evidence on the deterrent effects of interventions tackling other anticompetitive agreements and the abuse of dominance. The reasons are the relatively low volume of infringement decisions in antitrust and the high heterogeneity of theories of harm that characterise such interventions, making them more difficult to study. This section aims at drawing the main lessons from this literature for the modelling of the deterrent effects of competition policy.

---

9 Strictly speaking, merger control does not rely on a system of punishment to dissuade anticompetitive mergers.

10 This section is mainly based on two recent surveys of the literature on the deterrent effects of competition policy (see CMA (2017) and Dierx et al. (2020)).

3.1.1 A positive relation between detection and deterrence

The literature on the deterrent effects of law enforcement suggests that there is a positive relation between the enforcement activity of public authorities and its deterrent effects (Becker (1968), Anker *et al.* (2021)). Within the specific context of competition law enforcement, the positive link between effective enforcement and deterrence has also been recognised, *inter alia* by Block *et al.* (1981), Bryant and Eckard (1991), Combe *et al.* (2008), and Werden *et al.* (2011).

Most papers on cartel deterrence indicate that the existence of cartel control and more effective cartel enforcement lead to fewer cartels, with those being formed being less stable, shorter lived and less able to raise prices (see for example, CMA (2017), Davies *et al.* (2018) and Katsoulacos *et al.* (2017)). As mentioned in Section 2, the key elements determining the effectiveness of a cartel control policy are the probability of being detected (depending, for example, on leniency policies or "whistle-blower" tools), and the reputation of the competition authority in light of its track record of cartel investigations and punishment.

Similarly, the literature on the deterrent effects of merger control finds that having an effective merger control regime able to detect, remedy or prohibit anticompetitive mergers leads to a reduction in the notification of these anticompetitive mergers, implying a greater level of deterrence. Surveys (see Subsection 3.1.4 for more details) find significant deterrent effects of merger interventions and there is some evidence showing that challenging more mergers contributes to greater deterrence. However, there is no consensus on the type of decisions (imposition of merger remedies or merger prohibitions) having the strongest deterrent effects. On the one hand, increasing the acceptability of remedies might encourage firms to propose anticompetitive mergers secure in the knowledge that they can use remedies as a fall-back position (Cosnita-Langlais and Sorgard, 2014). On the other hand, the costs of these remedies may discourage the notification of anticompetitive mergers (Clougherty *et al.*, 2016).

This leads us to conclude that the detection of anticompetitive behaviour is an important factor influencing the deterrent effects of competition policy enforcement. Successful detection of cartels, other anticompetitive agreements and abuses of dominance should discourage anticompetitive behaviour in the future. Similarly, an increased capacity of competition authorities to recognise the anticompetitive nature of notified mergers should dissuade companies from notifying such mergers to them. On that basis, the model used in this paper posits a positive relation between the economic importance of the cases detected by the competition authority and the scale of the deterrent effects. The question however remains what is the shape of the relation between detection and deterrence.

3.1.2 The relation between detection and deterrence is non-linear

As described by Armoogum *et al.* (2017), a competition authority may have a very low caseload either because it is ineffective in detecting anticompetitive behaviour or because it is so effective in deterring such behaviour that few cases remain to be detected. Likewise, a more effective enforcement and the resulting increase in deterrence leaves fewer cases still to be detected and then deterred. In the extreme, a competition policy regime that can be counted on to pursue all antitrust infringements and block all anticompetitive mergers will be fully deterrent, leaving to no more cases to be investigated (Buccirossi *et al.*, 2014).

All this means that the marginal effect of an increase in detection activity on deterrence is not constant and that there is a non-linear relationship between detection and deterrence. If detection activity is low, the marginal effect of an increase in detection is increasing, which implies that the relationship between detection and deterrence is convex. For higher detection rates, the marginal effect of an increase in detection activity is decreasing, which corresponds to a concave relationship between detection and deterrence. These observations have fed into the S-shaped relationship between detection and deterrence proposed in Section 4 to model the deterrent effects of competition policy interventions as a process of diffusion of information to market players about such interventions.

3.1.3 Within-sector diffusion of the signal sent by competition authorities' interventions

Some business surveys show that anticompetitive behaviour is more likely to be halted in sectors where the authorities have conducted cartel or other antitrust investigations, where they have recently prohibited or imposed severe remedies on a merger, or where they have conducted a sector inquiry or market study (CMA, 2017). A survey by Deloitte (2007) suggests that mergers in the UK are more likely to be abandoned or modified to limit their anticompetitive effects if there has been a recent inquiry by the UK competition authority in the sector. Similarly, London Economics (2011) reports that companies in sectors with merger investigations are more knowledgeable about the responsibilities of the competition authority, the implication being that they will be more easily deterred. There is also some evidence that cartel detection in a market negatively affects the rate of cartel formation in related markets (Harrington, 2008).

On that basis, one can expect that the deterrent effects of competition policy interventions in a given sector are more likely to be diffused to other companies belonging to that same sector. For example, an important cartel decision involving truck producers will likely discourage the formation of cartels in the truck manufacturing industry. We therefore consider that the deterrent effects of competition authorities' interventions are felt primarily in the directly affected sectors, reflecting the diffusion of the information about such interventions between companies with activities in that same sector. However, it might happen that a competition policy intervention is so important that there is a diffusion of its effects to neighbouring sectors or even to a large part of industry or services. Similarly, small decisions can serve as a precedent indicating that the competition authority intends to pursue similar cases in the future. Therefore, one should consider relaxing this assumption in further work.

3.1.4 Survey evidence on the size of the deterrent effects of competition policy

The most commonly used approach to estimate the deterrent effects of cartel, antitrust and merger control policies relies on surveys amongst companies and legal advisors. More recently, statistical methods linking the probability of cartel deterrence to the probability of cartel detection (see Davies *et al.*, 2018) and theoretical models describing cartel behaviour in the presence of different characteristics of cartel policy enforcement have been used to assess the deterrent effects of cartel policy (see Katsoulacos *et al.*, 2016 and 2020). Other methods, such as before and after comparison studies, event studies and laboratory experiments, have been more rarely considered.[11]

Table 1: Summary of the results of surveys on deterrent effects

Source	Respondent and Period	Number of Mergers Abandoned or Modified for Every Merger Blocked or Remedied	Number of Cartels Deterred for Every Cartel Detected	Number of anti-competitive Agreements Deterred for Every Anti-Competitive Agreement Detected	Number of Abuse Deterred for every Abuse Detected
Twynstra Gudde (2005)	Competition lawyers and companies (2003)	7.5	-	-	-
Gordon and Squires based on Deloitte (2007)	Competition lawyers (2004-2006)	5.3	5	7	4
	Large firms (2004-2006)	-	16	29	10
London Economics (2011)	Large and small firms (2003-2011)	1.8*	28	40	12
Baarsma et al. (2012)	Companies 2005 to mid-2010	3.1-7.3	5	-	-

Source: Dierx et al. (2020), which has been completed for anticompetitive agreements other than cartels and abuses.

*While the estimates by London Economics of cartel, other anticompetitive agreements and abuses are based on a large sample of 800 businesses surveyed, the estimates of merger deterrence (1.8 merger abandoned or modified for every merger blocked or remedied) are based on a sample of 33 mergers and are therefore not reliable.

The surveys measure deterrence by asking companies and their legal advisors how many anticompetitive mergers or agreements were abandoned or modified because of

[11] See Dierx et al. (2020) for a more detailed presentation of these other methods.

competition law. These surveys need to be carefully designed and should rely on a sufficiently large sample size to provide unbiased results, which has not always been the case. Moreover, as shown in Table 1, the existing surveys are not very recent, the last ones dating from 2010-2011, and they cover only a limited number of European countries (the Netherlands, the United Kingdom and to a limited extent, Brussels based law firms).

Nevertheless, the results of surveys can be useful to get a first idea of the order of magnitude of the deterrent effects of competition policy interventions (see Table 1). Based on the survey coverage and the number of respondents, the Twynstra Gudde survey and the survey of London Economics for mergers do not seem very reliable (see Annex 1 for detailed information about these surveys). Table 1 shows that between 3 and 8 mergers are deterred for every merger blocked or remedied, between 5 and 28 cartels are deterred per cartel detected[12], between 7 and 40 other anticompetitive agreements are deterred for each anticompetitive agreement detected and between 4 and 12 abuses are deterred per abuse detected. This information will be used to calibrate the parameters of the model considered in this paper to describe the diffusion of the information on the competition authority's intervention.

3.2 Models used to describe the diffusion of information

This section presents models explaining the diffusion of information over time in a population. These models will be used to describe how the signal sent by the competition authority through its intervention is diffused within the sector where the intervention occurs. These models rely on the mathematical theory of epidemiology, generally employed for example to describe the spread of the infection during an epidemic, as the diffusion of information can be equated to the diffusion of a virus during a pandemic episode. Three main models can be distinguished. The first one, the exponential model, belongs to the class of external-influence diffusion models, as it describes a situation where the probability for a disease of reaching a target population depends on an external triggering factor. The second is the logistic model, which belongs to the class of internal-influence diffusion models, as it describes the diffusion of the disease as depending on the endogenous interactions in the affected population. The third model by Bass (1968) is a mixed-influence diffusion model, which includes both an external triggering factor activating the process as in the exponential case, as well as an endogenous propagation mechanism as in the logistic model. Hall (2004) considers the Bass model as the leading model to describe diffusion processes in marketing and sociology, which has also been widely used in economics. In this section, we introduce these three fundamental models of diffusion, while we illustrate their use in the context of competition policies in Section 4.2.

[12] As reported in Dierx et al. (2020), these numbers overlap with the ranges for the ratio of deterred harm over detected harm derived from more sophisticated statistical and theoretical models.

Let denote by ω the share of the population informed about a phenomena, which measures the diffusion of information about this phenomena, and by t time. According to the standard theory of diffusion, the growth over time in diffusion is proportional to a generic function $g(t)$ describing the fundamental characteristic of the diffusion process. Moreover, the growth in diffusion is proportional to the distance of the current level of diffusion $\omega(t)$ to a ceiling given by the maximum theoretical possible level of ω. We assume that information can reach potentially all the population, and therefore the maximum theoretical value of diffusion in our case is equal to one. In formulas, we have (see among others Geroski (2000) and Kijek and Kijek (2010)):

$$\frac{d\omega}{dt} = g(t) * \{1 - \omega(t)\} \quad (1)$$

According to Equation (1), when diffusion spreads to the whole population ($\omega(t) = 1$), the second term on the right hand side approaches zero, and no further increase in diffusion can be registered.
For different specific choices of the function $g(t)$, it is possible to derive different models of diffusion.

Here, we focus on three fundamental models, which correspond to different specifications of the function $g(t)$. The three models are respectively: the exponential model (also known as the external-influence model), the logistic model (also known as the internal-influence model), and the Bass model (also known as the mixed-influence model).

The first of the three models analysed in the following corresponds to $g(t) = \alpha$. In this case, equation (1) becomes:

$$\frac{d\omega}{dt} = \alpha * \{1 - \omega(t)\} \quad (2)$$

Equation (2) states that growth over time in diffusion of information in the population is constant and reaches $\alpha\%$ of the population each period. By solving differential equation (2), one arrives at the exponential diffusion model describing the evolution over time of diffusion in the population:

$$\omega(t) = \{1 - (1 - \omega_0)\, exp(-\alpha t)\} \quad (3)$$

This model is known in the literature as the external-influence model, as the level of diffusion depends on an external source and not on the state of diffusion reached in the population. This model is thus appropriate to model diffusion in a framework where the source of information comes from outside the population. This model describes the diffusion of information over time as a monotonically increasing and concave function.

The second model corresponds to a diffusion function equal to $g(t) = \beta * \omega(t)$. In this case, equation (1) becomes:

$$\frac{d\omega}{dt} = \beta * \omega(t) * \{1 - \omega(t)\} \quad (4)$$

Equation (4) states that the increase in diffusion depends on the interactions within the population, which is proportional to the level of diffusion already achieved in the population and the probability that contact will take place within the population, $\beta * \omega(t)$. Solving equation (4), one gets the logistic or internal diffusion model:

$$\omega(t) = \frac{1}{1+\left(\frac{1-\omega_0}{\omega_0}\right)*exp(-\beta*t)} \quad (5)$$

In equation (5), diffusion depends not only on the parameter β but also on the starting point of diffusion itself, which has to be strictly positive ($\omega_0 > 0$). This condition is necessary to start the endogenous 'internal' propagation of the external starting point, which remains to be explained. This model describes the diffusion of information as a convex function up to an inflection point and becomes concave afterwards.

The third model is based on the diffusion function $g(t) = \alpha + \beta * \omega(t)$. In this case, equation (1) becomes:

$$\frac{d\omega}{dt} = \{\alpha + \beta * \omega(t)\} * \{1 - \omega(t)\} \quad (6)$$

Equation (6) states that the increase of diffusion depends on:

- An external signal, which reaches α% of the population each period of time, as in the exponential model (external influence) ;
- The endogenous interactions between the population (internal influence), which depend on the level of information already present in the population and the probability that contact will take place within the population ($\beta * \omega(t)$) ;
- $\{1 - \omega(t)\}$: the distance of the current level of information present in the population from a ceiling, which is equal to 1 as we assume that information can reach potentially all the population.

This model is known in the literature as the Bass diffusion model, or the mixed-influence diffusion model as it contains both characteristics of the external-influence model and of the internal-influence model. In this model, a population is subject to two sources of information: the common external source of information that reaches the population at a constant rate α over time and the transmission of information resulting from the interactions between the members of the population. This linear formulation of the diffusion model remains very general and flexible. For different configurations of parameters, the pattern of diffusion over time can assume very different shapes. Moreover, this linearity facilitates the derivation of the solution to differential equation (6):

$$\omega(t) = \frac{1 - \frac{\alpha(1-\omega_0)}{\alpha+\beta\omega_0} \exp(-(\alpha+\beta) * t)}{1 + \frac{\beta(1-\omega_0)}{\alpha+\beta\omega_0} \exp(-(\alpha+\beta) * t)} \quad (7)$$

For $(\alpha \neq 0, \beta = 0)$ one gets the exponential model, while for $(\alpha = 0, \beta \neq 0)$, one gets the logistic model. Thus, the Bass or mixed-influence diffusion model nests both the exponential and the logistic one as particular cases. This mixed-influence model will be used in the rest of this paper.

4. The proposed approach

The approach followed in this paper aims at quantifying the deterrent effects of merger interventions, cartel prohibitions and other antitrust interventions by the European Commission over the period 2012-2021. It assumes that deterrence is positively associated with detection: the higher the detection of infringements of competition rules, the stronger are the deterrent effects of competition policy interventions tackling such infringements. The relation between detection and deterrence is modelled as a diffusion of information about the competition policy interventions to and between market players. The model used to describe this relation is the Bass or mixed-influence diffusion model whose parameter values are set to ensure consistency with the results of surveys aimed at measuring the deterrent effects of competition policy and presented in Table 1 above.

The next sections will present the main principles and advantages of the novel approach proposed, the interpretation and assumptions considered in the Bass or mixed-influence diffusion model and the information used to estimate the detection activity of the competition authority.

4.1 Main principles underlying the modelling of the deterrent effects

Before presenting the interpretation of the Bass or mixed-influence diffusion model used to estimate the deterrent effects of competition policy interventions, the basic principles underlying this modelling exercise should be set out. These principles are based on the lessons of the literature described in Section 3.1.

In the literature, two key determinants of deterrence are the perceived probability for a company of being caught and convicted, which depends on the current capacity of detection of anti-competitive behaviour by the competition authority, and the reputation of the competition authority which is influenced by its past enforcement record. In this paper, these two main determinants are integrated into a model.

According to this model, we assume that, by detecting and stopping anticompetitive behaviour, the competition authority sends a signal, which is diffused amongst market players and amplified by interactions between market players. The strength of this signal is captured by the size of the market directly affected by the competition policy intervention relative to the size of the sector to which this market belongs. This implies that the deterrent effects are only significant within the sector (defined at the NACE four-digit level) to which the market directly affected by the competition policy intervention belongs, which is also in line with the literature reviewed in Subsection 3.1.2.

The diffusion of this signal to market players within the sector is modeled by the Bass or mixed-influence diffusion model described in Section 3.2. The advantage of this approach is that the relation between detection and deterrence is not described as a generic correlation (as in Davies *et al.*, 2018) but based on a more robust theoretical framework relying on a well-established model formalising the diffusion of information. The Bass or mixed-influence diffusion model used here also captures the non-linear relationship between detection and deterrence identified in the literature. In this model, the marginal effect of an increase in detection activity is not constant: for small cases, the marginal effect is increasing, which implies a convex relation between case detection and deterrence, while for large cases, the marginal effect is decreasing, implying a concave relation. Asymptotically, when the detection activity increases to its maximum value of 1, the deterrent effect reaches a value of 1 as well. This is an indication that in the extreme, all anticompetitive behaviour within the four-digit sector concerned is deterred.

Finally, this framework allows integrating the role of both the competition authority and market players in the process of diffusion of information about competition policy interventions. On the one hand, the competition authority is the signalling authority external to the markets affected whose reputation and activities have deterrent effects. The mere existence of a competition authority can have deterrent effects depending on its reputation. On the other hand, the market players can contribute to the diffusion of the signal and therefore amplify its deterrent effects. Van Waarden and Drahos (2002) identify an expert community, including specialised lawyers and business consultants, as the most important channel for diffusion of the influence of EU competition law. This expert community functions, in particular, as a channel of information exchange, learning and imitation. This observation is consistent with the results of the SEO survey for the Dutch competition authority, which reports that 85% of companies consult external advisors (mainly lawyers, accountants and consultants) on matters related to compliance with the Dutch competition law.[13] This reinforces the argument that the interaction between market players via their legal counsels and law firms positively affect the deterrent effects of competition policy interventions.

4.2 Interpretation and assumptions considered in the Bass model

One main contribution of this paper consists in eliciting a functional link between the detection and deterrence of competition law infringements. As explained in Section 3.1, several authors have identified the positive link between detection and deterrence.

---

13 See SEO (2011), table 4.1.

In the following, we use the Bass or mixed-influence diffusion model defined in Section 3.2 to describe the diffusion of the information related to competition policy interventions in a given sector (as opposed to time t used in the standard modelling approach). In the epidemiological domain for example, the factor driving the diffusion of a virus is time, as the development of biological processes behind infection requires time. Differently, in our framework, the driving factor of the diffusion process is not time, but the strength of competition enforcement within a sector. Therefore, the independent variable σ is the signal sent by the competition authority to market players in the sector directly affected by the competition policy interventions. The strength of this signal depends on the importance of the detection activity by the competition authority in this sector. The dependent variable ω represents the deterrent effects of such detection activity.

In analogy with equation (6), the information diffusion process can be described by the following differential equation:

$$\frac{d\omega}{d\sigma} = (\alpha + \beta * \omega(\sigma)) * \{1 - \omega(\sigma)\} \qquad (8)$$

In equation (8), the marginal impact of detection on deterrence $\frac{d\omega}{d\sigma}$ depends on an external influence (i.e. the sensitivity α of the market players to the signals sent by the competition authority) and an internal influence (i.e. the interactions between market players, which depend on the propensity β of market players to interact and on the level of deterrence $\omega(\sigma)$ already achieved in the market). The values of α and β are no longer constrained between 0 and 1, because we move from the diffusion of information over time to the diffusion of deterrent effects within a given four-digit sector. While in the standard modelling approach, time t is a discrete variable with a range of (0; ∞), the strength σ of the signal sent by the competition authority has a more limited range of (0; 1]. Deterrence $\omega(\sigma)$ has an upper bound of 1 as well, reflecting our assumption that the deterrent effects do not go beyond the four-digit sector affected by the external signal. This necessarily implies that the marginal effect of detection on deterrence $\frac{d\omega}{d\sigma}$ starts by rising until the share of already deterred market players reaches a certain level and then it declines.

The solution of the differential equation is:

$$\omega(\sigma) = \frac{1 - \frac{\alpha(1-\omega_0)}{\alpha+\beta\omega_0} * exp(-(\alpha+\beta)*\sigma)}{1 + \frac{\beta(1-\omega_0)}{\alpha+\beta\omega_0} * exp(-(\alpha+\beta)*\sigma)} \qquad (9)$$

Equation (9) shows that the deterrent effects of a given intervention depend on the following parameter values:

- the initial level of deterrence in the market (ω_0);
- the sensitivity of market players to the external signals sent by the competition authority (α);
- and the internal interactions between market players ($\beta * \omega(\sigma)$).

5. Definition of model variables and calibration of parameter values

5.1 Measures of detection (σ) and deterrence $\omega(\sigma)$

The importance of the detection activity of a competition authority is often measured by its case detection rate. In cartel enforcement, the detection rate can be defined as the number of the detected cartels over the population of non-deterred cartels (see Combe *et al.* (2008), Connor and Lande (2012), Davies *et al.* (2018), and Katsoulacos *et al.* (2017)). In merger control, it may be defined as the number of detected anticompetitive mergers over the population of notified mergers (see Dierx *et al.*, 2020). The measurement of the detection rate requires making assumptions about the size of the population of non-deterred cartels and the frequency of type-II errors in merger control (i.e. the number of anticompetitive mergers that are unduly cleared), which is inherently difficult. Davies *et al.* (2018), for example, base their cartel work on measures of aggregate detection found in the literature.

In this paper, instead of making assumptions on the detection rate, we use actual market interventions by the European Commission (see Section 5.2) as an indicator of the competition authority's detection activity. Detection (σ) is measured by the size of the markets directly affected by the Commission's competition policy intervention (mkt) over gross output in the corresponding NACE four-digit sector (GO4), i.e. σ = mkt / GO4. The deterrent effects ω of a given intervention σ are defined as the share of deterred markets in the four-digit sector, not taking into account the markets directly affected by the intervention, i.e. $\omega(\sigma)$ = mkt^D / (GO4 – mkt). On this basis, a deterrence multiplier associated with a specific competition policy intervention can be calculated as: mkt^D / mkt = ω (1-σ)/σ[14].

5.2 Competition policy interventions by the European Commission over the period 2012-2021

This section describes the sample (see Annex 2 for detailed tables) of European Commission merger interventions, cartel prohibitions and other antitrust interventions under Articles 101 and 102 TFEU, which is used to measure the Commission's detection activity in the three policy domains over the period 2012-2021. The total sample includes 197 merger cases, 49 cartel prohibitions and 59 other antitrust interventions under Articles 101 and 102 TFEU. Merger cases are also predominant in terms of the size of the markets directly affected by the European Commission's competition interventions (see Figure 1). Affected market size varies significantly from one year to another. In 2016, 2018 and 2020, for instance, the total affected market size is more that 50% above the annual average of 82 billion over the period 2012-2021. By contrast, in 2015 the size of the markets affected by competition policy interventions is around one third of the annual average.

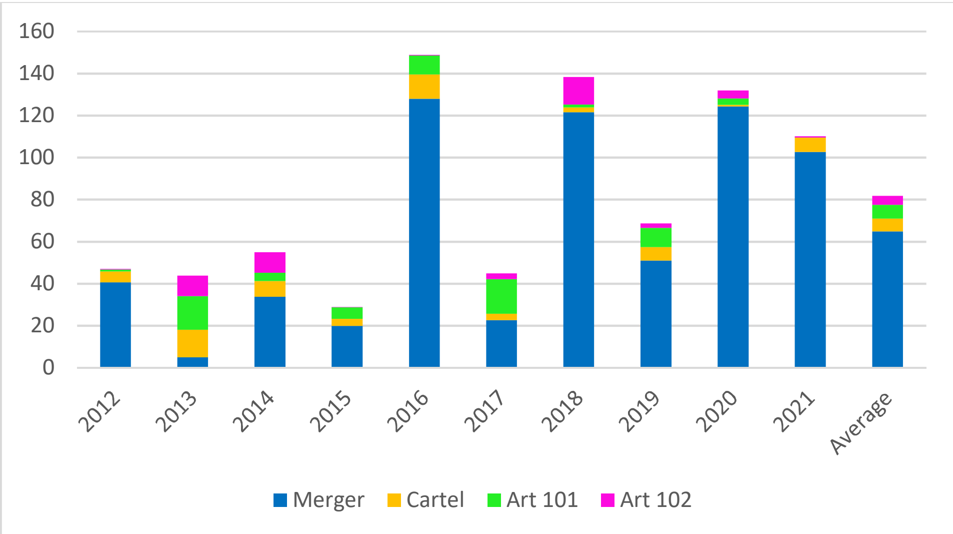
---

[14] This can be derived from the definitions of ω and σ:
ω = mkt^D / (GO4 - mkt) and σ = mkt/GO4,
with mkt^D = deterred market, mkt = market directly affected by the competition policy intervention, and GO4 = gross output in the corresponding NACE four-digit sector.

With the information contained in the sample of competition enforcement actions by the European Commission, it is possible to construct an indicator of the strength of the Commission's detection activity in the different NACE four-digit sectors. This indicator can then be used as a determinant of the deterrent effects of competition policy within that same four-digit sector. In fact, as explained in Section 5.1, the indicator of detection activity used in the present paper is the ratio of the size of the markets directly affected by the Commission's competition policy interventions over the size of the sector (defined at the NACE four-digit level) to which these markets belong.

The indicator of detection activity considered here is similar to the so-called "commerce quotient" used by the US Department of Justice around 1970-1980 to analyse merger complaints and cartel indictments. According to Werden and Froeb (2018) and Werden (2022), the commerce quotient can be defined as the ratio between the annual volumes of commerce of the alleged relevant market divided by the value of industry in the corresponding SIC four-digit industry. As these authors explain, the commerce quotient made it possible to quantify the importance of the alleged relevant market with respect to the corresponding industry. They go on to show that commerce quotients tend to be extremely small and use this finding to explain why observing an increase in concentration at the industry level does not necessarily imply an increase in concentration at a more disaggregated level.

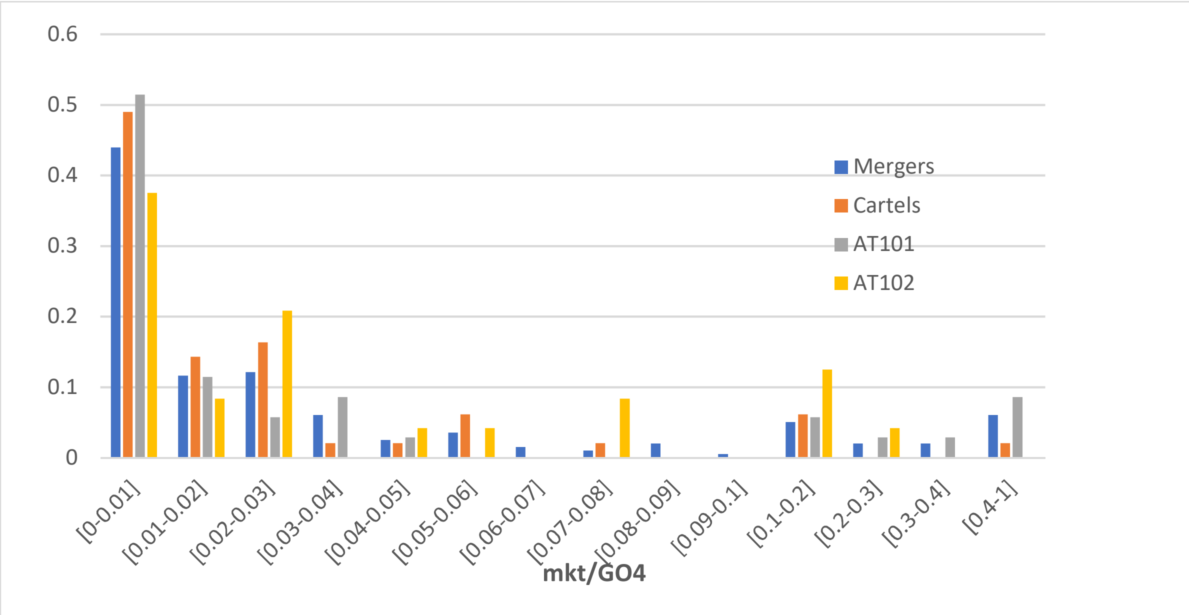
Figure 1: Size of markets affected by Commission interventions in billions of euro (2012-2021)



Interestingly, the distribution of commerce quotients for the merger complaints filed by the US Department of Justice during the fiscal years 2013-2015 (see Figure 1 in Werden and Froeb), is very much comparable to the one obtained for the merger cases investigated by the European Commission during the years 2012-2021 (see Figure 2 below). Both in the EU and in the US, the frequency distribution is strongly skewed to the right, reflecting the fact that most cases have small or even very small commerce quotients. This implies that most of the merger interventions made by the European Commission and the US Department of Justice concern cases where the size of the affected market accounts for 4% or less of the corresponding four-digit sector. A quick look at Figure 2 shows that the same holds true for cartel and other antitrust cases pursued by the Commission.

Focusing once more on the competition policy interventions by the European Commission, Figure 2 shows frequency distributions with a long right tail: for most of the interventions, the size of the markets affected by the intervention is relatively small with respect to the corresponding four-digit sector. Around 50% of the sample of interventions has a market size representing no more than 1% of the corresponding sector and most interventions are small cases having a market size representing less than 4% of the corresponding sector. Nevertheless, there are a small number of cases for which the commerce quotients on exceeds 40% (see final set of columns in the bar chart). These very big cases include for example the 2012 merger between Glencore and Xstrata in the lead, zinc and tin production sector, and the 2016 merger between AB Inbev and Sabmiller in the beer-manufacturing sector.

Figure 2: Frequency distribution of detection activity by policy instrument (in percentage of total, 2012-2021)



5.3 Calibration of model parameter values under the baseline scenario

To define a baseline scenario, we have to calibrate the three parameters of the Bass or mixed-influence diffusion model (see equation (9) above): ω_0, which represents the initial level of deterrence in the market, interpreted as the deterrence associated with the reputation of the competition authority; α, which represents the sensitivity of deterrence to the external signal sent by the competition authority to the market players; and β, which describes the strength of the internal interactions between market players. The higher the ratio (β/α), the higher is the internal influence of interactions between market players relative to the external signal of the authority's intervention.

As the reputation of a competition authority depends on its past enforcement record, the parameter ω_0 is approximated by the average annual intervention rate of the European Commission over the period 2012-2021. More precisely, ω_0 corresponds to the average commerce quotient, which is calculated as the case average of the affected market value over gross output at the four-digit sector level over the period 2012-2021[15]. The value of ω_0 varies between the different competition policy instruments, ranging between 3-4% of sector gross output (for antitrust enforcement under Article 101 and cartel enforcement) and 6-7% (for antitrust enforcement under Article 102 and merger control).

The ratio of β/α is set at five as this yields an S-shaped relationship between detection and deterrence, which fits with the non-linear relation described in the literature (see Subsection 3.1.2). This choice is also motivated by an analysis of the iso-multiplier curves that can be derived for each competition policy instrument: iso-multiplier curves represents combinations of α and β values corresponding to the same level of weighted average deterrence multiplier, all other parameters being equal. The weighted average deterrence multiplier can be defined as the weighted average of the case-specific ratios of deterred markets (mkt^D) over detected markets (mkt)[16]. Figure 3 illustrates the iso-multiplier curve for mergers with ω_0 set at 7%.

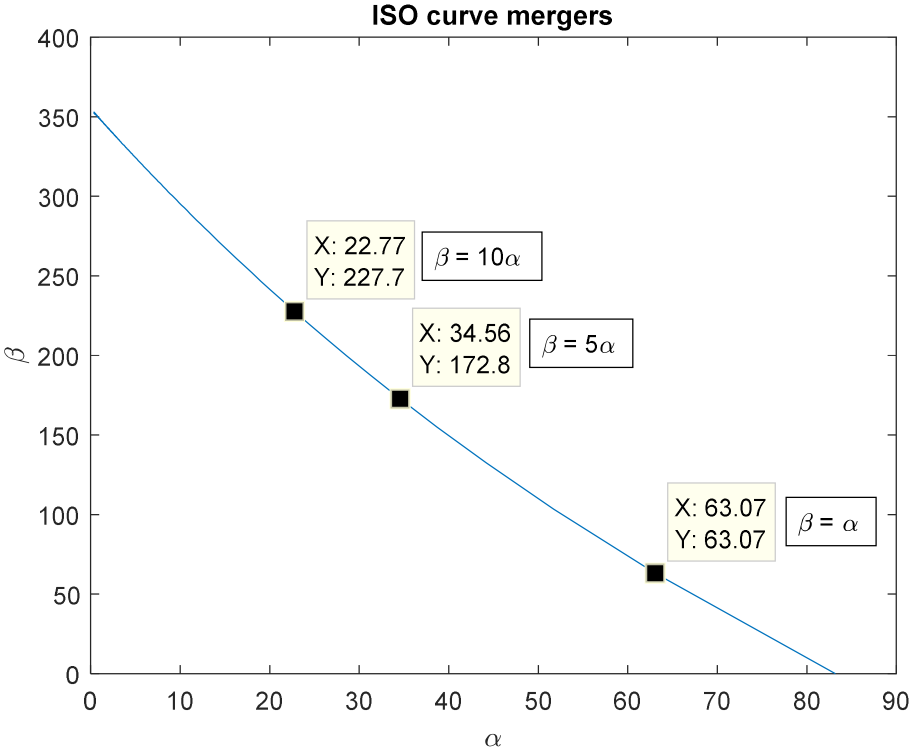
Each point on the line corresponds to a calibration of the Bass function delivering the same deterrence multiplier. The values of α are represented on the x-axis and values of β on the y-axis. The shape of the curve defines a substitutability behaviour between the two parameters: it can inform us on how much external diffusion effect (α) should increase to compensate for a decrease in the endogenous propagation (β) while keeping deterrence constant. Which would be then a good candidate value for β/α to select if we were to think about a baseline scenario? It would seem reasonable to focus on a *median* region of the curve (in order to be distant from extreme cases where β or α is zero). Figure 3 demonstrates that the baseline value of five chosen for β/α is a reasonable median parametrisation as it roughly corresponds to the middle point on the iso-multiplier curve drawn in the Cartesian plane. Annex 3 presents a more detailed explanation of the baseline value chosen for β/α. It shows that a baseline value of five is located in the median region of the iso-multiplier curves for all competition policy instruments.

---

15 An analysis of the evolution of the commerce quotient over the period 2012-2016 versus the period 2017-2021 shows that this coefficient has increased over time (except for cartels for which it is stable).

16 The weighted average of the deterrence multiplier is defined as $\sum_i mkt_i \frac{mkt_i^D}{mkt_i} / \sum_i mkt_i$, where the size of the markets directly affected by competition policy interventions mkt_i are used as weights. This weighted average corresponds to the total value of deterred markets over the total value of markets directly affected by the European Commission's competition policy interventions, i.e., $\sum_i mkt_i \frac{mkt_i^D}{mkt_i} / \sum_i mkt_i = \sum_i mkt_i^D / \sum_i mkt_i$.

Figure 3: The iso-multiplier curve for merger cases with $\omega_0 = 0.07$



After having set ω_0 and β/α as described above, the parameters α (external influence) and β (internal influence) are calibrated in order to ensure that the weighted average deterrence multiplier for each competition policy instrument is in line with the survey results, which report on the number of deterred cases per detected case (see Table 1):

- 10 for merger interventions;
- 20 for cartel prohibitions;
- 20 for other antitrust interventions under Article 101;
- 10 for antitrust interventions under Article 102[17].

6. Results

This section describes the estimated deterrence effects of a continued enforcement of competition policy at a level that is similar to that of the European Commission during the period 2012-2021. It defines a number of alternative scenarios to the baseline scenario set out in Section 5.3 with the aim of testing the sensitivity of the deterrence multipliers to the parameters of the Bass or mixed-influence diffusion model, which reflect first, the reputation of the competition authority (ω_0) and second, the relative importance of interactions between market players (β/α). The deterrence multipliers reported in this section concern the European Commission's merger interventions, because merger control is

[17] Dierx *et al.* (2017) present sensitivity analyses with respect to the target deterrence multipliers for different competition instruments.

the competition policy instrument for which we have most observations (see Annex 2) and the largest affected market size (see Figure 1 and Annex 2). Corresponding figures illustrating the estimated deterrence effects of the other instruments are presented in Annex 4. Section 6 concludes by describing the GDP impact of all competition policy interventions by the European Commission under the different scenarios.

6.1 Choice of alternative scenarios

In the reputation scenarios, we fix β/α at five while varying the value of ω_0 between zero (poor reputation) and twice its value under the baseline scenario (very good reputation). In the interactions scenario, we fix ω_0 at its value in the baseline scenario while varying β/α between one (little interaction) and ten (much interaction, which corresponds to a doubling of its value under the baseline scenario (see Table 2).

Table 2: Definition of the baseline and alternative scenarios for mergers

Scenario	$\boldsymbol{\omega_0}$ = reputation of the competition authority	β/α = relative importance of interaction between market players
Baseline	0.07	5
Poor reputation	0.00	5
Very good reputation	0.14 (baseline x 2)	5
Little interaction	0.07	1
Much interaction	0.07	10 (baseline x 2)

6.2 Deterrence multipliers under different model calibrations

Figure 4 presents the relation between detection and deterrence under the merger baseline scenario. In this scenario, the reputation of the European Commission as a competition authority is reflected by the positive value of the parameter ω_0 (ω_0=0.07), which is based on the Commission's past enforcement record. Moreover, the ratio of the internal influence of the interaction between market players over the external influence of the Commission's interventions equals five (β/α=5). Figure 4 illustrates that under this static baseline scenario almost all anticompetitive mergers in the sector are deterred from notification following a merger intervention for which the affected market size exceeds 4% of the sector size. As illustrated in Figure 2 above, only around one quarter of merger interventions over the period 2012-2021 fall into this category. Such merger interventions have occurred in services sectors including mobile telecommunications and energy as well as in manufacturing sectors including the steel, metals, cement, paper and pulp, beer and pesticides sectors. Even if we assume that – in a more dynamic scenario (such as the one considered in the QUEST III simulations whose results are presented in Section 6.3[18]) with a time dimension – the

[18] It is worth noting that that there is no time dimension in the Bass, mixed-influence diffusion model used here. However, the durations of the effects of the different competition policy interventions are taken into consideration in the computation of the

deterrent effects of the Commission's interventions die out after several years, the deterrent effects of competition policy are likely to be particularly important in these sectors.

Figure 4: Detection and deterrence under the baseline scenario (ω_0 = 0.07 and β/α = 5)

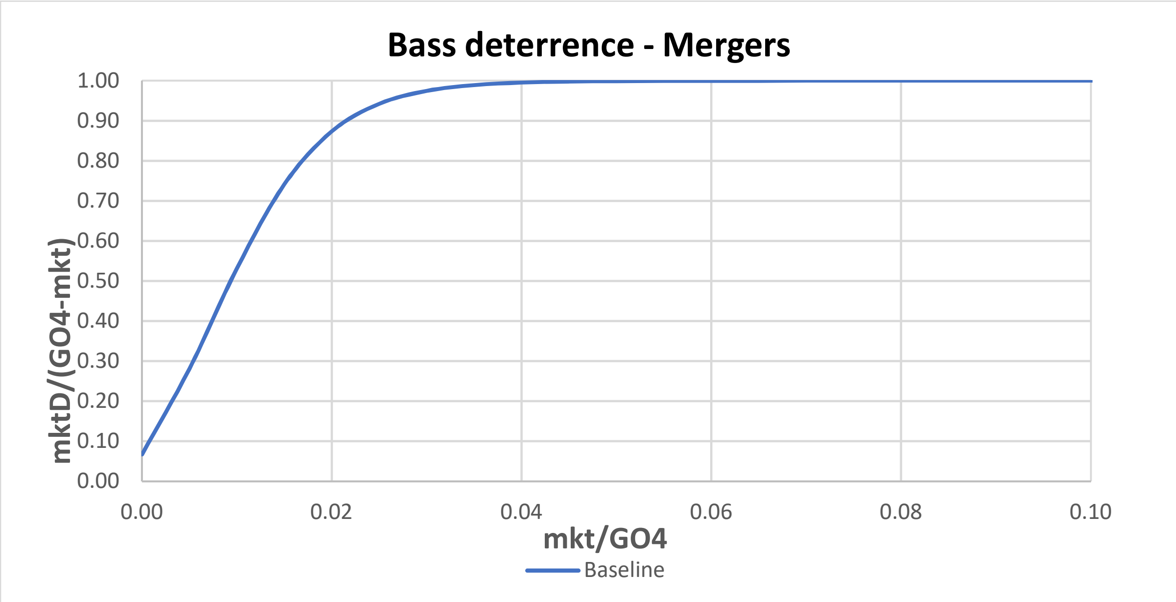
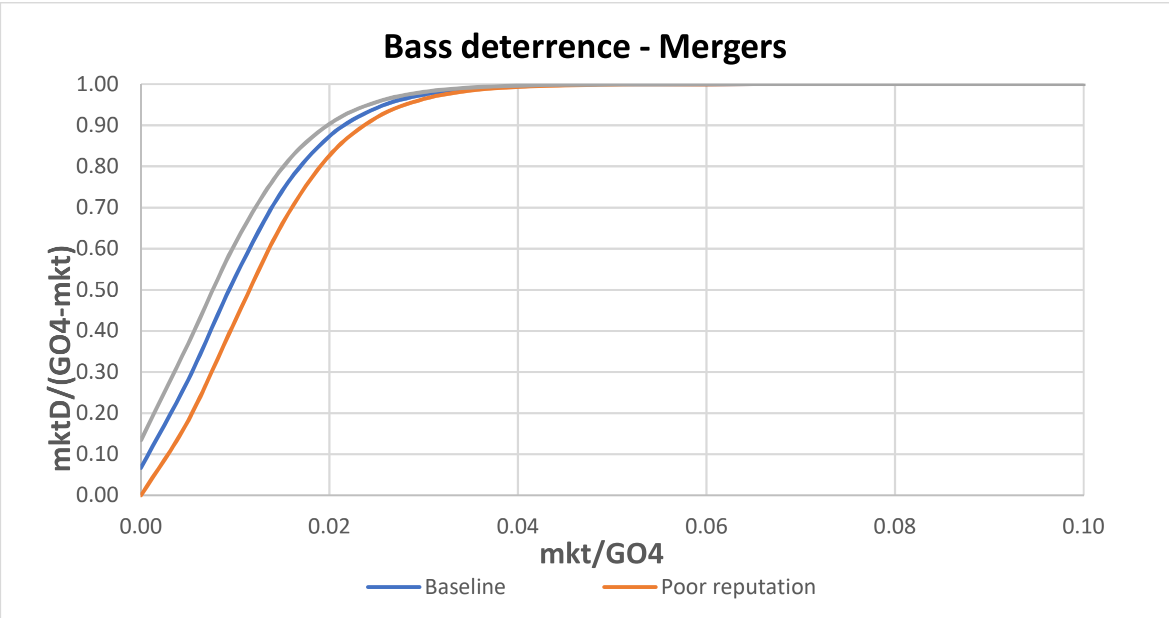


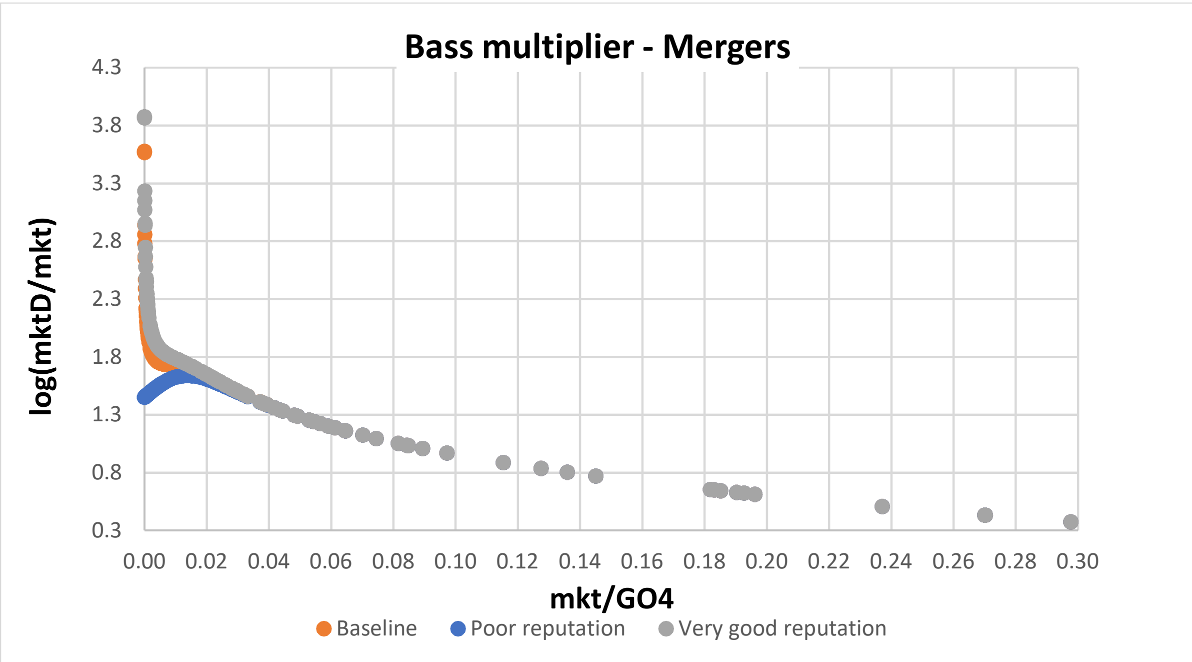
Figure 5: Detection and deterrence under the different reputation scenarios



mark-up shock applied to the QUEST III model. Nevertheless, the mark-up shock itself is a permanent shock reflecting the idea that market players know that the competition authority is there to control anticompetitive behaviour and will continue to be active in the future.

In Figure 5, we modify the baseline scenario by varying the reputation of the competition authority (ω_0) between 0.00 (Poor reputation) to 0.14 (Very good reputation) while keeping the ratio of internal over external influence β/α constant at five. A rise in reputation shifts the deterrence curve upward for all shares of the affected market in the corresponding four-digit sector. The weighted average of the resulting deterrence multipliers increases by 31% when the reputation of the competition authority improves from 'poor' to 'very good'. The effect of a better reputation of the competition authority is more sizeable for interventions affecting markets that are small relative to the four-digit sector concerned. In other words, the small interventions by a competition authority with a very good reputation have stronger deterrent effects than the same interventions by a competition authority with a poor reputation. This difference is less pronounced for interventions affecting larger markets as the marginal effects of an increase in the 'size' of the intervention become less important in particular for competition authorities with a very good reputation. We can therefore conclude that a competition authority's reputation is particularly important for ensuring that 'small' interventions are effective in terms of their deterrent effects.

Figure 6: Deterrence multipliers under the different reputation scenarios



The dots in Figure 6 represent the values of the deterrence multipliers for the individual merger interventions by the Commission over the period 2012-2021 under the three reputation scenarios. The first thing to note is that a great majority of merger cases is small, as measured by the mkt/GO4 ratio (see Figure 2 as well). Nevertheless, small cases account for a large share of the deterrent effects in the baseline scenario: cases with an mkt/GO4 value of 0.04 or less (corresponding to 75% of all cases) account for 70% of the total deterrence because they are so numerous and because they tend to have larger deterrence multipliers. In fact, the y-axis in Figure 6 is put in log-scale as for very small interventions the deterrence ratio can reach very high values.

In line with the survey results, we maintain the assumption that the weighted average of the deterrence multipliers equals 10 in the baseline scenario, which corresponds to 1 on the log-scale. Under all three reputation scenarios, ‘small’ merger interventions (let us say cases with an mkt/GO4 value of 0.04 or less) have deterrence multipliers well above this weighted average of 10. Moreover, for these ‘small’ interventions, reputation has a strong positive effect on deterrence. By contrast, the more limited number of larger interventions (with an mkt/GO4 value of 0.10 or more) have below-average deterrence multipliers. Moreover, the deterrence multipliers of such larger interventions are hardly affected by the reputation of the competition authority. This implies that as the size of the intervention increases, there is a rapid convergence of the deterrence multipliers in the three reputation scenarios.

In the ‘Poor reputation’ scenario that abstracts from reputation effects (ω_0=0), the deterrence multiplier initially increases with size reflecting the idea that for an intervention to become fully effective it needs to affect a minimum share of the sector concerned (in this illustration around 1½%). In the baseline and ‘Very good reputation’ scenarios, on the other hand, the deterrence multiplier is a negative function of the size of the merger intervention, illustrating the fact that the small cases already have important deterrence due to the reputation of the competition authority.

Figure 7: Detection and deterrence under different interaction scenarios

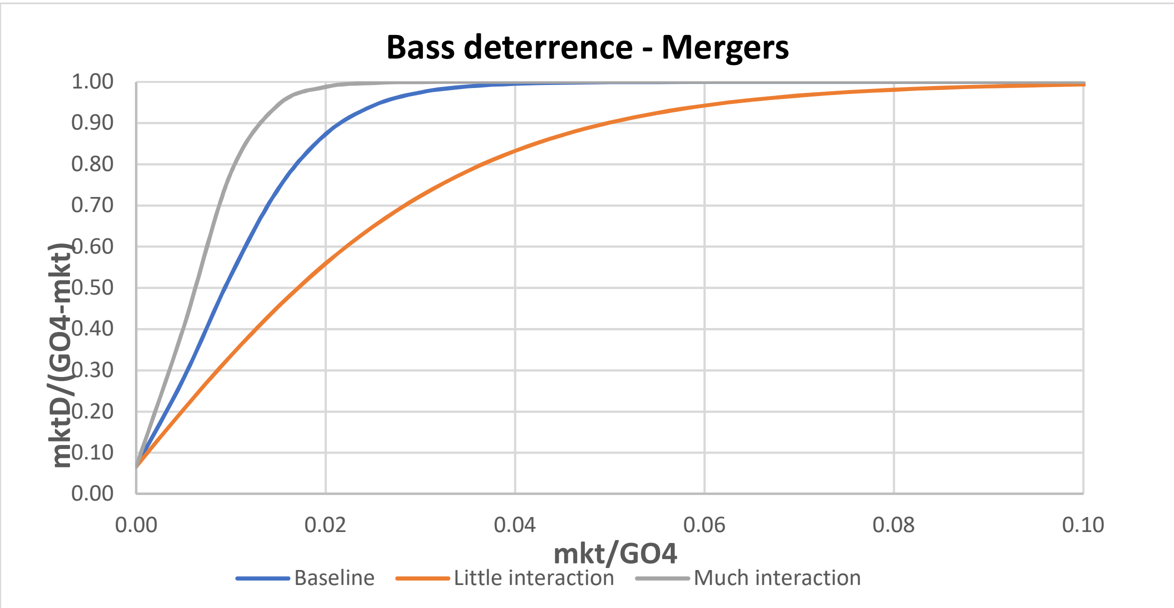


Figure 7 considers the effects of changes in the relative importance of internal versus external influence (β/α) on the diffusion of the deterrent effects. One can observe an increase in the weighted average of the deterrence multipliers by 41% when the interaction between market players increases (from little to much interaction). Under the baseline scenario where β/α has been set at five and the internal influence resulting from interactions between market players (β) is already relatively important, maximum levels of deterrence are reached more rapidly (for cases reaching 4% of the sector), showing the importance for deterrence of such interactions. Under the 'Little Interaction' scenario where internal and external influence are of equal importance (β /α = 1) maximum levels of deterrence are reached only for interventions in which the affected market makes up a much larger share (around 10%) of the four-digit sector concerned. This is a clear illustration of the importance of interactions between legal counsels and law firms for effective enforcement and increased deterrence.

The effects of the interactions between legal counsels and law firms are particularly important for smaller interventions as illustrated in Figure 8. Bass deterrent multipliers under the much interaction scenario are clearly above the multipliers for the two other scenarios, at least for smaller interventions. As the interventions become larger, there is a convergence in deterrent multipliers under the three scenarios.

Figure 8: Deterrence multipliers under the different interaction scenarios

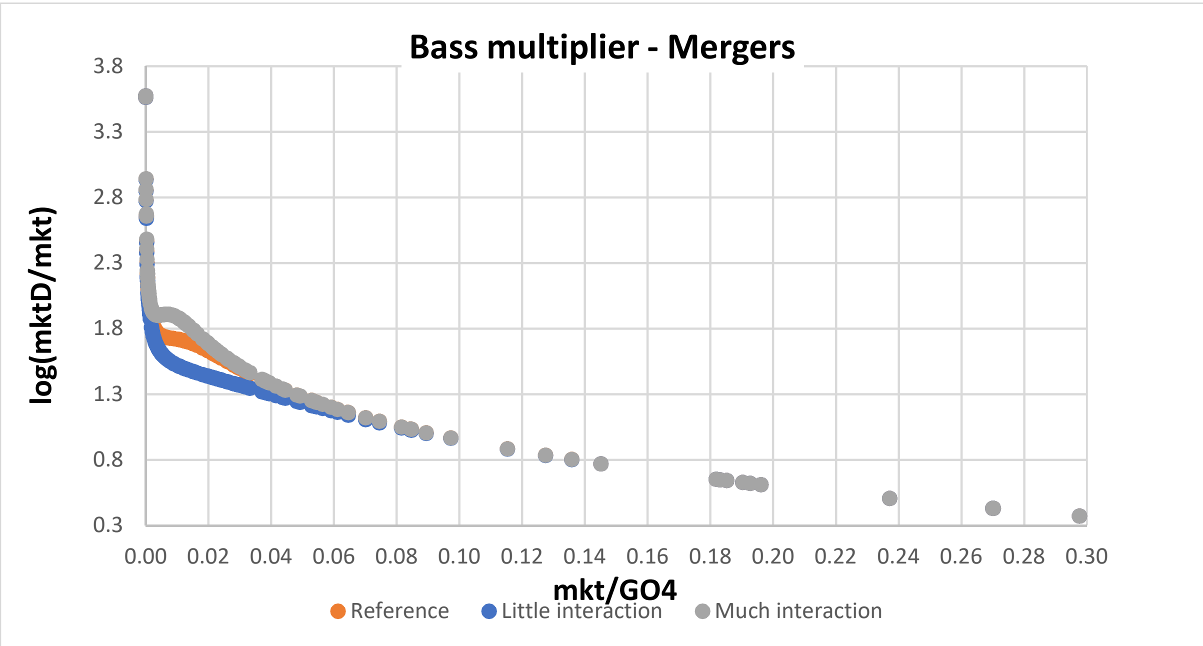


Table 3 shows the computed values for the reputation parameter ω_0 for all cases and presents alternative scenarios of poor reputation and very good reputation (doubling the baseline value).

Table 3: Values of the reputation parameter ω_0 for the different competition policy instruments

	Poor reputation	Baseline reputation	Very good reputation
Merger control	0	0.07	0.14
Cartel enforcement	0	0.03	0.06
Article 101	0	0.08	0.16
Article 102	0	0.04	0.08

Table 4: Sensitivity analysis of the average deterrence multipliers under the different scenarios

Reputation scenarios with $\beta/\alpha = 5$	Poor reputation	Baseline reputation	Very good reputation	Effect of a doubling of the reputation under the baseline
Merger control	8.6	10	11.3	13.0%
Cartel enforcement	17.1	20	22.7	13.5%
Article 101	18.3	20	21.5	7.5%
Article 102	7.3	10	12.6	26.0%

Interaction scenarios with $\boldsymbol{\omega_0}$ = baseline	Little interaction	Baseline	Much interaction	Effect of a doubling of interaction between market players under the baseline
	$\beta/\alpha = 1$	$\beta/\alpha = 5$	$\beta/\alpha = 10$	
Merger control	8.1	10	11.4	14.0%
Cartel enforcement	14.5	20	25.7	28.5%
Article 101	16.9	20	21.4	7.0%
Article 102	7.4	10	12.8	28.0%

Table 4 illustrates the sensitivity of the average deterrence multiplier to changes in the reputation of the European Commission as a competition authority and changes in the degree of interaction between legal counsels and law firms advising market players on competition issues. Two observations stand out. First, the effect on average deterrence of an improvement in the Commission's reputation is rather similar to that of increased interaction between market players. This is true for merger control and antitrust enforcement under Articles 101 and 102 TFEU (see rightmost column of Table 4). A priori, there is no reason why this would be the case. However, the fact that the differential effect of increased interaction is particularly large for cartel enforcement (28.5% as opposed to 13.5%) suggests that interactions between legal counsels and law firms are particularly important in this competition policy domain (e.g. through the implementation of competition compliance programmes). Second, the deterrence effects of improvements in the Commission's reputation and increases in interactions between markets players are notably small for antitrust enforcement under Article 101. One explanation might be that antitrust infringements of Article 101 (excluding cartels) can be very different in nature, implying that the still substantial deterrence effects work through other channels beyond the reputation of the competition authority and company interactions. Another explanation is that a full level of sector deterrence is achieved already for cases with an mkt/GO4 ratio below 1%. This leaves little room to further increase deterrence through a rise of the reputation and interaction parameters.

6.3 Macroeconomic implications

The QUEST III DSGE model[19] is used to simulate the macroeconomic impact of a permanent continuation of competition policy enforcement similar to that of the European Commission over the period 2012-2021. The direct effects resulting from the price reductions in the affected markets due to the Commission interventions and the associated deterrent effects allow calibrating the mark-up shocks to be applied to this model.[20] The deterrent effect of each individual competition policy intervention is derived from the size of the intervention multiplied by the corresponding deterrence multiplier as presented in Section 6.2 and Annex 4. The case-weighted average of the deterrence multipliers varies with the scenario adopted. Moreover, the deterrent effects are limited in duration depending on the characteristics of the markets in which the competition intervention occurs.
The results of the QUEST III model simulations in terms of GDP impact under the different selected scenarios are presented in Table 5.

Table 5: GDP Impact for the different selected scenarios

Percentage change in GDP	1 year	5 years	10 years	50 years
Baseline scenario	**0.33**	**0.56**	**0.75**	**1.08**
Poor reputation	0.29	0.50	0.67	0.95
Very good reputation	0.36	0.62	0.83	1.19
Little interaction	0.26	0.45	0.60	0.86
Much interaction	0.38	0.66	0.88	1.26

*Numbers represent GDP percentage deviation from the equilibrium un-shocked values. Columns report the impact after 1,5,10, and 50 years.

Under the baseline scenario, a continuation of enforcement by the European Commission at the same pace as in 2012-2021 would lead to a reduction in the mark-up level of 1.2 percentage point (from 13.6 percent to 12.4 percent). The magnitude of this mark-up shock appears to be reasonable in comparison with the mark-up shocks reported by studies assessing the impact of a wider set of competition friendly structural reforms. For instance, Varga and in ’t Veld (2014) and in ’t Veld *et al.* (2018) find that structural reforms aimed at narrowing the gap vis-à-vis the three best EU performers correspond to an average mark-up decline in the EU of around 1.5 percentage point. More recently, Ciapanna *et al.* (2020 and

[19] See Ilzkovitz et al. (2020), box 13.1 for a short description of this model. Ratto *et al.* (2009) provide a more comprehensive description of the QUEST model.

[20] Mark-ups have been calibrated at the sector level as proposed by Thum-Thysen and Canton (2015). The economy-wide, negative shock to the mark-up level is calculated as a weighted sum of the price reductions associated with each individual competition policy intervention. See Dierx *et al.* (2017), Chapter 13 in Ilzkovitz and Dierx (2020) and Section 4.2 in European Commission (2022) for more detailed descriptions of the method used to calibrate the mark-up shock.

2022) assume that the reduction in services mark-up due to services liberalisation in Italy over the period 2012-2019 equals 1.1 percentage point. Alternatively, one can assess the negative mark-up shock of 1.2 percentage points against the background of the worldwide increase in mark-ups reported by Díez et al. (2021). While the sector-level mark-up data used in the present model simulations are not comparable to the firm-level data used by Díez et al., a back-of-the-envelope calculation suggests that without interventions by competition authorities the reported 7 percentage point increase in mark-ups would have been larger by one fifth.

The positive supply shock from the increase in competition resulting from competition policy interventions similar to those of the European Commission over the period 2012-2021 leads to a 0.56% rise in real GDP after five years. This positive GDP impact results from the reduction in mark-up and prices due to these interventions, which stimulates consumer demand. In order to satisfy this greater demand, firms invest in production capacity and better technology (leading to higher labour productivity), and hire more workers (see Ilzkovitz *et al.*, 2020).

A doubling of the reputation of the competition authority compared to the baseline scenario increases the deterrent effects of its interventions and therefore their positive impact on GDP after 5 years from 0.56% to 0.62%. Similarly, an increase in deterrence resulting from a doubling of the interaction between market players increases the GDP impact of competition policy interventions after 5 years from 0.56% to 0.66%. According to this model, increasing the interactions between market players has a somewhat larger impact than increasing the reputation of the competition authority on the deterrent effects of competition policy interventions and thus on their positive impact on GDP.

7. Conclusion and avenues for future research

This paper has presented a novel approach to model the deterrent effects of competition policy interventions, using a database of European Commission's merger decisions, cartel prohibitions and other antitrust interventions over the period 2012-2021. The main advantages of this approach are that the relation between detection and deterrence is based on a more robust theoretical framework relying on well-established models used to describe the diffusion of information and that the detection activity of the competition authority is estimated on the basis of real-life data. This framework allows to better integrate the role of both the competition authority and market players in the process of diffusion of information about competition policy interventions and to test the sensitivity of deterrence to the reputation of the competition authority and to the importance of interactions between market players. The mixed-influence model simulations presented above illustrate the importance of these two elements for the deterrent effects of a competition authority's merger, cartel and other antitrust interventions. Reputation and interaction are particularly important for smaller interventions, as measured here by the share of the affected market(s) in the NACE four-digit sector concerned. Moreover, the sensitivity of the deterrent effects to changes in interactions is rather similar to the sensitivity to changes in reputation, with the exception for cartel enforcement, where interactions between market players have a much greater impact. A model simulation of the direct and deterrent effects of competition policy interventions of the European Commission over the period 2012-2021 shows an increase in GDP of 0.6% in the medium term.

Further work could contribute to improving this analytical framework. First, small decisions may act as a precedent indicating that the competition authority intends to pursue similar cases in the future. This is true in particular in the area of antitrust, where the alleged abuse or coordinated action can take different forms, depending on the market and/or sector characteristics. For these cases, the relative impact of interactions between market players might be higher. Second, a competition policy intervention could be so important that there is a diffusion of its effects to neighbouring sectors or even to a large part of industry or services. For these cases, the maximum size of the deterred market could be larger than the NACE four-digit sector in which the direct effect is felt. Third, the choice of the values of the parameters (in particular, regarding the impact of interactions) could be better calibrated based on empirical evidence. Fourth, one could try to better take into account the characteristics of the competition policy regime in this analysis by defining more precisely the different components affecting the reputation of the competition authority (for example, its capacity of investigation and of punishment). One could also try to look at the interactions between different competition policy instruments as, for example, cartel enforcement may affect merger behaviour, the argument being that with the option of collusive profits no longer available, a merger might be a second best alternative. Finally, but more importantly, there is room to improve the survey-based information used to determine the weighted average deterrence multipliers for competition policy interventions. Currently, these estimates are based on dated surveys in a small number of countries. More recent surveys with a broader scope would be most welcome to strengthen the empirical foundation of the work presented here.

References

Anker A.S.T., Doleac J.L. and Landersø R. (2021), "The effects of DNA databases on the deterrence and detection of offenders", American Economic Journal: Applied Economics, vol. 13(4), pp. 194–225.

Armoogum P.K., Davies S. and Mariuzzo F. (2017), "Cartel enforcement and deterrence over the life of a competition authority", Center for Competition Policy Working Paper 17-4, University of East Anglia.

Baarsma B., Kemp R., van der Noll R. and Seldeslachts, J. (2012), "Let's not stick together: Anticipation of cartel and merger control in the Netherlands", De Economist, vol. 160(4), pp. 357-376.

Bass F.M. (1969), "A new product growth model for consumer durables", Management Science, vol. 15(5), pp. 215-227.

Becker G.S. (1968), "Crime and punishment: An economic approach", Journal of Political Economy, vol. 76, pp. 169-217.

Block M.K., Nold F.C. and Sidak J.G. (1981), "The deterrent effect of antitrust enforcement", Journal of Political Economy, vol. 89(3), pp. 429-445.

Bryant P.G. and Eckard E.W. (1991). "The probability of getting caught", The Review of Economics and Statistics, vol. 73(3), pp.531-536.

Buccirossi P., Ciari L., Duso T., Spagnolo G. and Vitale C. (2014), "Deterrence in competition law", in M. Peitz and Y. Spiegel (eds.), The Analysis of Competition Policy and Sectoral Regulation, pp. 423-454.

Ciapanna E., Mocetti S. and Notarpietro A. (2020), "The effects of structural reforms: Evidence from Italy", Banca d'Italia Working Paper 1303, November.

Ciapanna E., Mocetti S. and Notarpietro A. (2022), "The macroeconomic effects of structural reforms: An empirical and model-based approach", VoxEU, CEPR, 1 July.

Clougherty J.A., Duso T., Lee M. and Seldeslachts J. (2016), "Effective European antitrust: Does EC merger policy generate deterrence?", Economic Inquiry, vol. 54(4), pp. 1884-1903.

CMA (2017), "The deterrent effects of competition authorities' work: Literature review", Working Paper, 7 September.

Combe, E., Monnier, C., Legal, R. (2008), "Cartels: The probability of getting caught in the European Union", Bruges European Economic Research papers, n° 12/2008.

Connor J.M. and Lande R.H. (2012), "Cartels as rational business strategy: Crime pays", Cardoso Law Review, vol. 34, pp. 427-489.

Cosnita-Langlais A. and Sørgard L. (2014), "Enforcement vs. deterrence in merger control: Can remedies lead to lower welfare?", Discussion Paper SAM 7 2014, Institutt for Samfunnsøkonomi, Norges Handelshøyskole.

Cunningham C., Ederer F. and Ma S. (2021), "Killer acquisitions", Journal of Political Economy, Vol. 129(3), pp. 649–702.

Davies S.W. and Ormosi P.L. (2012), "A comparative assessment of methodologies used to evaluate competition policy", Journal of Competition Law & Economics, vol. 8(4), pp. 769-803.

Davies S.W. and Ormosi P.L. (2013), "The impact of competition policy: What are the known unknowns?", CCP Working Paper, 13-7.

Davies S.W., Maruzzo F. and Ormosi P.L. (2018), "Quantifying the deterrent effect of anticartel enforcement", Economic Inquiry, vol. 56(4), pp. 1933-1949.

Deloitte (2007), "The deterrent effect of competition enforcement by the OFT", OFT962, Report prepared for the Office of Fair Trading, London.

Dierx A., Ilzkovitz F., Pataracchia B., Ratto M., Thum-Thysen A. and Varga J. (2017), "Does EU competition policy support inclusive growth?", Journal of Competition Law & Economics, vol. 13(2), pp. 225–260 .

Dierx A., Ilzkovitz F., Katsoulacos Y. and Ulph D. (2020), "Deterrent effects of competition policy", in F. Ilzkovitz and A. Dierx (eds.), Ex Post Evaluation of Competition Policy, pp. 423-459, Wolters Kluwer.

Díez F.J., Fan J. and Villegas-Sánchez C. (2021), "Global declining competition?", Journal of International Economics, 132(C).

Duso T. and Neven D.J. (2007), "The political economy of European merger control: Evidence using stock market data", Journal of Law & Economics, vol. 50(3), pp. 455-489.

European Commission (2022), "Modelling the macroeconomic impact of competition policy: 2021 update and further development", report prepared by the Directorate-General for Competition, the Joint Research Centre and the Directorate General for Economic and Financial Affairs, Publications Office of the European Union.

Geroski P.A. (2000), "Models of technology diffusion", Research Policy, vol. 29, pp. 603-625.

Gordon F. and Squires D. (2008). “The deterrent effect of UK competition enforcement”, De Economist, vol. 156(4), pp. 411-432.

Hall. B. (2004), “Innovation and diffusion”, NBER Working Paper, No. 10212, Cambridge.

Harrington J.E. (2008), “Detecting cartels”, in P. Buccirossi (eds.), Handbook of Antitrust Economics, pp. 213-258, MIT Press.

Ilzkovitz F., Cai M., Cardani R., Dierx A. and Pericoli F. (2020), “The Macroeconomic and Sectoral Impact of EU Competition Policy”, in F. Ilzkovitz and A. Dierx (eds.), Ex Post Evaluation of Competition Policy, pp. 461-507, Wolters Kluwer.

Ilzkovitz F. and Dierx A. (2020), “Ex Post Economic Evaluation of Competition Policy: The EU Experience”, Wolters Kluwer.

In ’t Veld J., Varga J. and Roeger W. (2018), “The impact of structural reforms in the EU”, in J. de Haan and J. Parlevliet (eds.) , Structural Reforms: Moving the Economy Forward”, Springer International Publishing.

Katsoulakos Y., Motchenkova E. and Ulph D. (2016), “Measuring the effectiveness of anti-cartel interventions: A conceptual framework”, TILEC Discussion Paper, No. 2016-001.

Katsoulakos Y., Motchenkova E. and Ulph D. (2020), “Combining cartel penalties and private damage actions: The impact on cartel prices”, International Journal of Industrial Organization, Elsevier, vol. 73(C).

Kijek A. and Kijek T. (2010), “Modelling of innovation diffusion”, Operations Research and Decisions, vol. 20(3), pp. 53-68.

Lande R.H. and Connor J.M. (2012), “Cartels as rational business strategy: Crime pays“, Cardozo Law Review, vol. 34(2), pp. 427-490.

London Economics (2011), “The impact of competition interventions on compliance and deterrence”, OFT Report No. 1391, December.

Ormosi P.L. (2014), “A tip of the iceberg? The probability of catching cartels”, Journal of Applied Econometrics, vol. 29(4), pp. 549-566.

Raskolnikov A. (2019), “Deterrence theory: Key findings and challenges”, Cambridge Handbook of Compliance (B. van Rooji, and B. Sokol, eds.), Cambridge University Press.

Ratto M., Roeger W. and in’ t Veld J. (2009), “QUEST III: An estimated DSGE model of the euro area with fiscal and monetary policy”, Economic Modelling, vol. 26(1), pp. 222-233.

SEO (2011), “Anticipating cartel and merger control”, Report prepared for the NMa (Netherlands Competition Authority), January.

Thum-Thysen A. and Canton E. (2015), “Estimation of service sector mark-ups determined by structural reform indicators”, Economic Papers 547, European Economy.

Twynstra Gudde (2005), “Research into the anticipation of merger control”, Report prepared for the NMa (Netherlands Competition Authority), October.

van Waarden F. and Drahos M. (2002), “Courts and (epistemic) communities in the convergence of competition policies”, Journal of European Public Policy, vol. 9(6), pp.913-934.

Varga J. and in ’t Veld J. (2014), “The potential growth impact of structural reforms in the EU. A benchmarking exercise”, Economic Papers 541, European Economy.

Werden G.J. (2022), “Concentration and rising market power: Fears and facts”, in P. Akman, O. Brook and K. Stylianou (eds.), Research Handbook on Abuse of Dominance and Monopolization, forthcoming, Edward Elgar.

Werden G.J. and Froeb L.M. (2018), “Don't panic: A guide to claims of increasing concentration”, Antitrust Magazine, vol. 33(1), 74.

Werden G.J., Hammond S.D. and Barnett B.A. (2011), “Deterrence and detection of cartels: Using all the tools and sanctions, *The Antitrust Bulletin*, vol. 56(2), pp. 207-234.

Annex 1: More detailed information on the various surveys on the deterrent effects

Table A1: Summary of the results of surveys on deterrent effects

Source	Respondent and Period	Number of respondents and type of survey
Twynstra Gudde (2005)	Competition lawyers and companies (2003)	Only for mergers: 16 competition lawyers from 14 law firms cooperated in the research. Interviews of investment bankers and private equity companies: anticipation effect (number not specified).
Gordon and Squires based on Deloitte (2007)	Competition lawyers (2006)	30 interviews with lawyers, economist and companies. Telephone survey of 730 partners and barristers with competition experience based in the UK and Brussels. 234 responses of these senior competition lawyers in the UK and Brussels.
	Large firms (2007)	Telephone survey of 202 UK companies broken down in three categories according to the number of employees (200-499, 500-999 and more than 1000).
London Economics (2011)	Large and small firms (2003-2011)	Business survey of 809 companies (308 responses from small firms and 501 from large companies). Behavioural experiment with 93 business representatives testing drivers of compliance. 27 telephone interviews of competition lawyers. 2 consultations with business stakeholders For mergers, the large companies in the sample only considered 33 mergers over the period 2003-2011.
Baarsma et al. (2012)	Companies 2005 to mid-2010	Online survey sent to 4831 companies: 512 responses of which 342 fully completed. Online survey sent to 343 advisers on competition law: 97 responses of which 40 fully completed.

Annex 2: Sample of competition policy interventions by the European Commission over the period 2012-2021

Table A2: Number of decisions by competition policy instrument (2012-2021)

Year	Mergers	Cartels	Art 101	Art 102	All instruments
	Share in total	Share in total	Share in total	Share in total	Number of decisions
2012	68%	16%	10%	6%	25
2013	58%	17%	17%	8%	24
2013	53%	28%	5%	14%	32
2015	76%	14%	7%	3%	29
2016	75%	14%	7%	4%	36
2017	65%	14%	14%	8%	37
2018	64%	10%	13%	13%	39
2019	59%	13%	19%	9%	32
2020	69%	8%	15%	8%	26
2021	56%	32%	4%	8%	25
Total	**65%**	**16%**	**11%**	**8%**	**305**

Table A3: Size of affected markets by competition policy instrument (2012-2021)

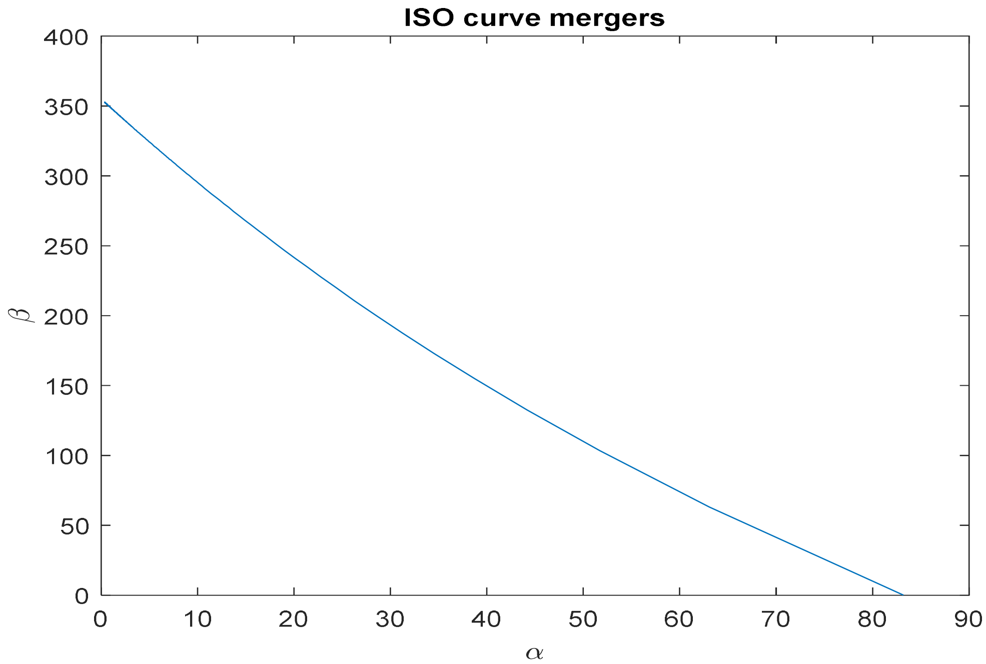
Year	Mergers	Cartels	Art 101	Art 102	All instruments
	Share in total	Share in total	Share in total	Share in total	Affected market size in bn EUR
2012	86%	11%	2%	0%	47
2013	11%	30%	37%	22%	44
2013	61%	14%	7%	18%	55
2015	69%	11%	19%	1%	29
2016	86%	8%	6%	0%	149
2017	50%	7%	37%	6%	45
2018	88%	2%	1%	9%	138
2019	74%	9%	13%	3%	69
2020	94%	1%	2%	3%	132
2021	93%	6%	0%	1%	110
Total	79%	7%	8%	5%	817

Annex 3: Description of the iso-multiplier curves

As made clear in Section 5, the parametrisation of the Bass function is very relevant and care must be placed in the choice of the reputation effect, ω_0 as well in the relative weight of the endogenous propagation over the external triggering factor, β/α. The latter choice is particularly important to discuss, as it may not be immediate to provide a reasonable range on the bases of economic intuition. This Annex explores the topic providing a generalized view of the behaviour of the Bass function when the parameter β/α varies.

Rather than choosing some arbitrary discrete values, we study the properties of the Bass function when the discussed ratio varies from zero to infinite, *ceteris paribus*, that is, keeping fixed all other relevant parameters for the analysis, reputation parameter as well as the target multipliers. This allows us to derive what we name the iso-multiplier curve: a continuum of combinations of β and α which deliver the same level of target multiplier (for each competition instrument) for a given level of reputation. Figure A1 provides an example of the iso-multiplier curve for mergers, where values of α are represented on the x-axis and values of β on the y-axis. Each point in the line corresponds to the same average Bass multiplier. The shape of the curve defines a substitutability behaviour between the two parameters: it can inform us on how much external diffusion effect (α) should increase to compensate for a decrease in the endogenous propagation (β).

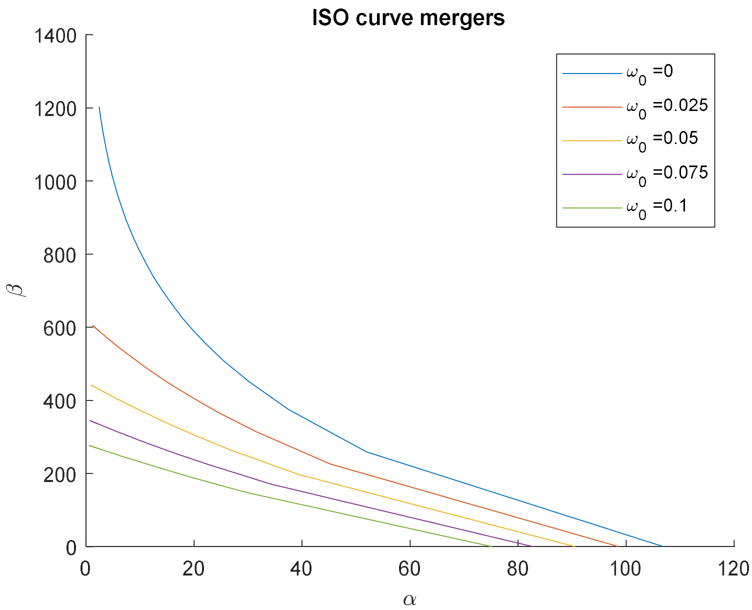
Figure A1: The iso-multiplier curve for merger cases with $\omega_0 = 0.07$



Which would be then a good candidate value for β/α to select if we were to think about a baseline scenario? The iso-multiplier curve can provide useful information on the substitutability between the two parameters and on the sensitivity of the curve to its varying inputs *but it cannot tell us where to place ourselves in the curve*. However, it is reasonable to assume that we would prefer focusing on a *median* region of the curve (in order to be distant from extreme cases where β or α is zero). Figure 3 in Section 5 highlights specific data points along the curve corresponding to the optimised combinations of parameters for a ratio of $\beta/\alpha = 5$ and the alternative values considered in the sensitivity analysis, $\beta/\alpha = 1$ and $\beta/\alpha = 10$. The figure confirms that the baseline value chosen for β/α is a reasonable median parametrisation.

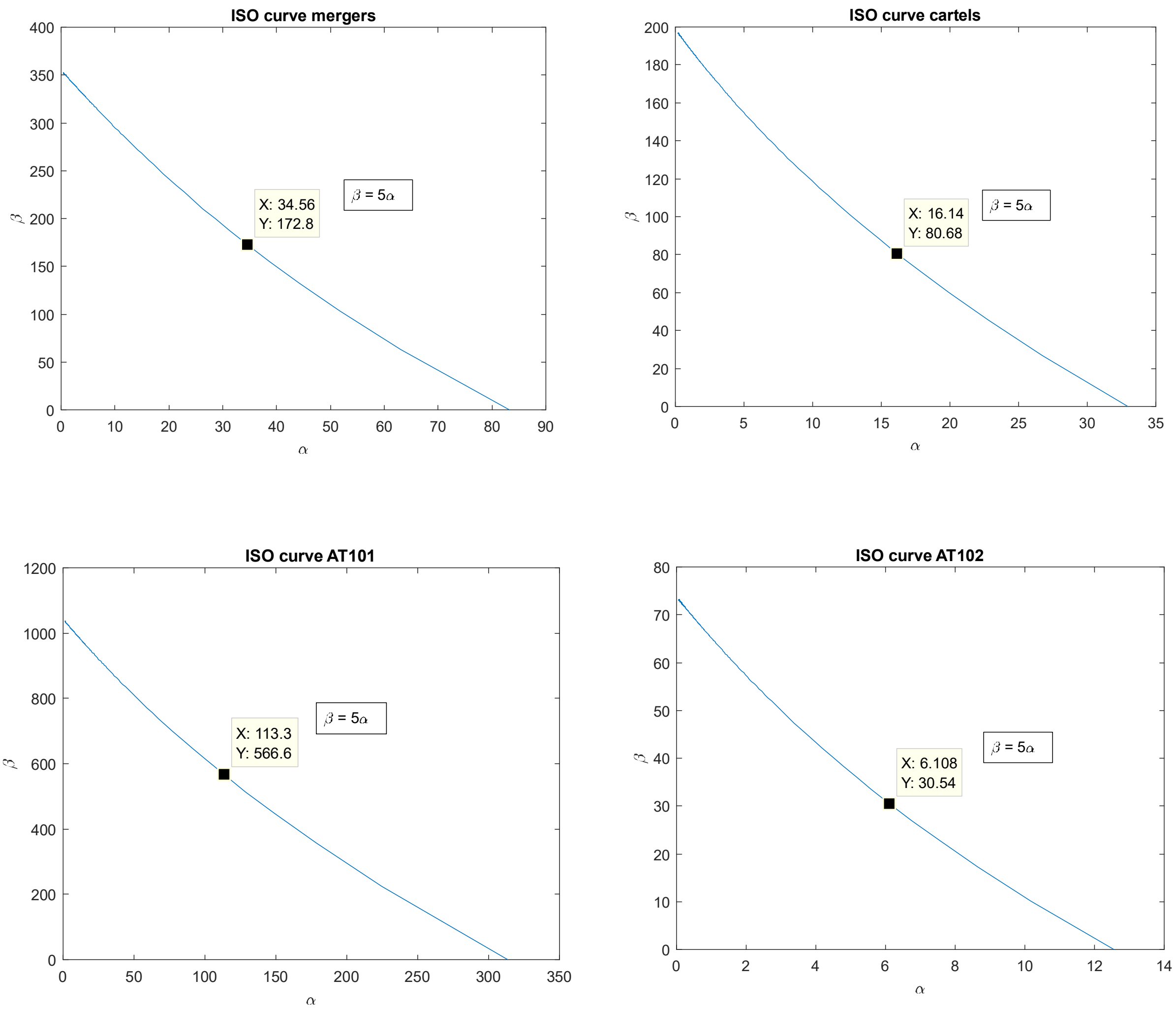
It is worth recalling that the above analysis has assumed a constant reputation effect (i.e. $\omega_0 = 0.07$). It seems interesting then to investigate how the iso-multiplier curves change when varying ω_0 and keeping all else equal. Figure A2 shows – again for our reference instrument of merger control – that the curvature of the curve, in other words, the substitutability between the external influence from competition policy interventions (α) and internal influence from interactions between market players (β), is indeed sensitive to the value of competition authority's reputation. The poorer is the reputation of the competition authority the bigger must be the external or internal influence, all else being equal, to ensure the given level of deterrence. The figure also shows how a loss in reputation would require an increase of the diffusion triggering factors (either external or internal) in order to preserve the same level of deterrence. Finally, if the reputation of the competition authority decreases (e.g. by moving from $\omega_0 = 0.1$ to $\omega_0 = 0$), the degree of substitutability between α and β also decreases. If a competition authority has a poor reputation, when the external signal is weak (low values of α) we would need much stronger interactions between market players (higher values of β) to compensate for a further decline in the external signal α.

Figure A2: Comparative iso-multiplier curves with different reputation effects



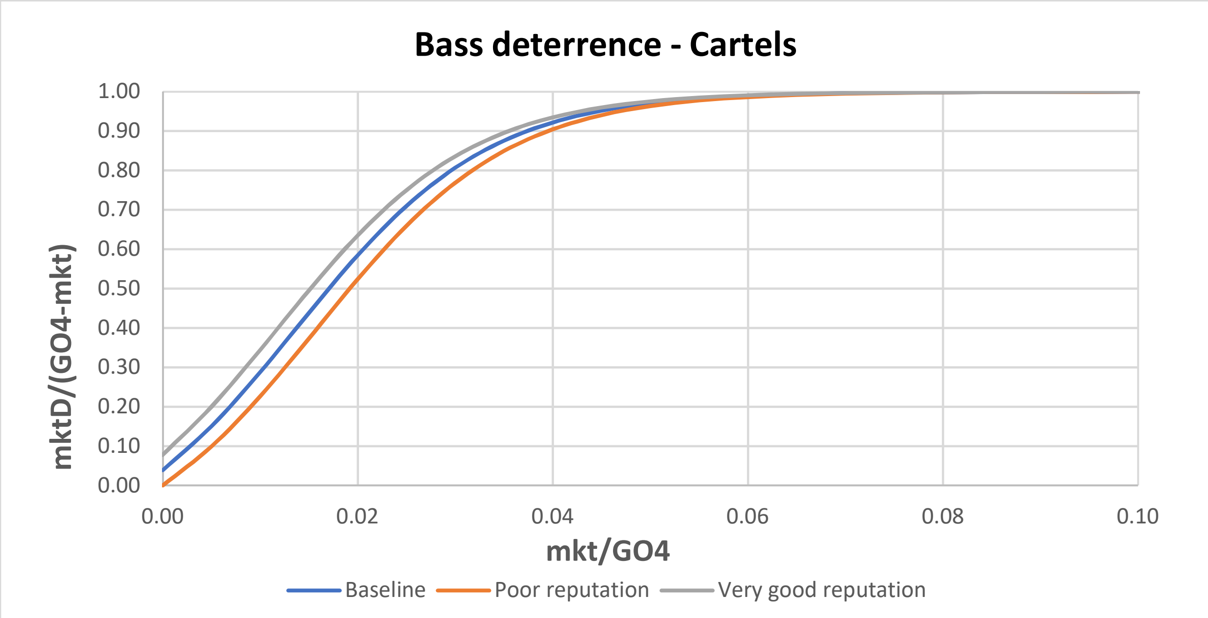
For the sake of simplicity, the argument on the iso-multiplier curve has been set out so far mainly looking at the merger cases. Nonetheless, results and observations hold true for the other competition policy instruments as well. In particular, Figure A3 presents the iso-multiplier curves for all competition tools and suggests that the proposed ratio $\beta/\alpha = 5$ is located in the median region of all the curves.

Figure A3: The proposed ratio β/α for different competition policy instruments



Annex 4: Detection and deterrence for cartel and antitrust enforcement actions

Figure A4: Reputation sensitivity analysis for cartels



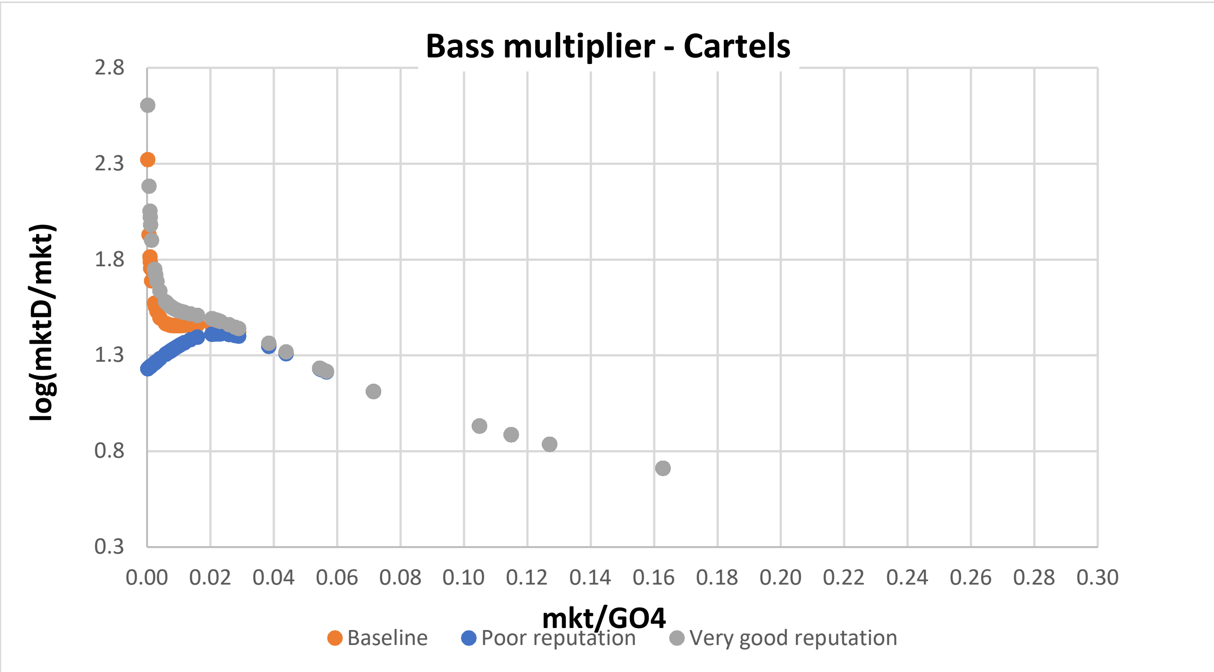
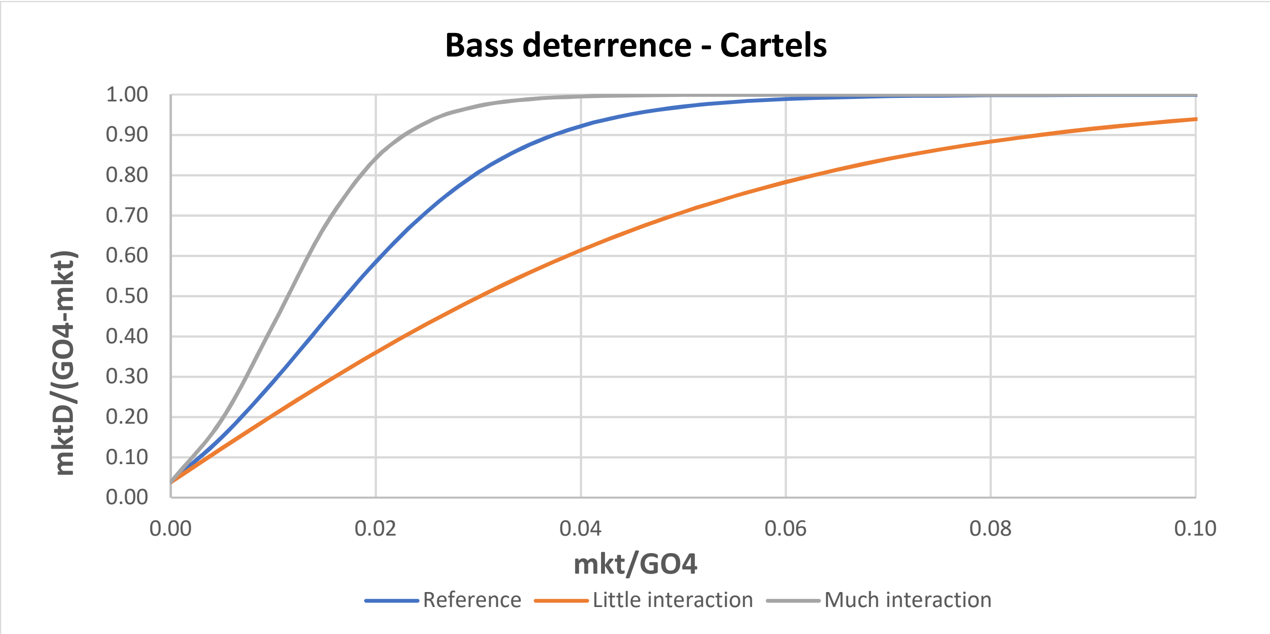


Figure A5: Interaction sensitivity analysis for cartels



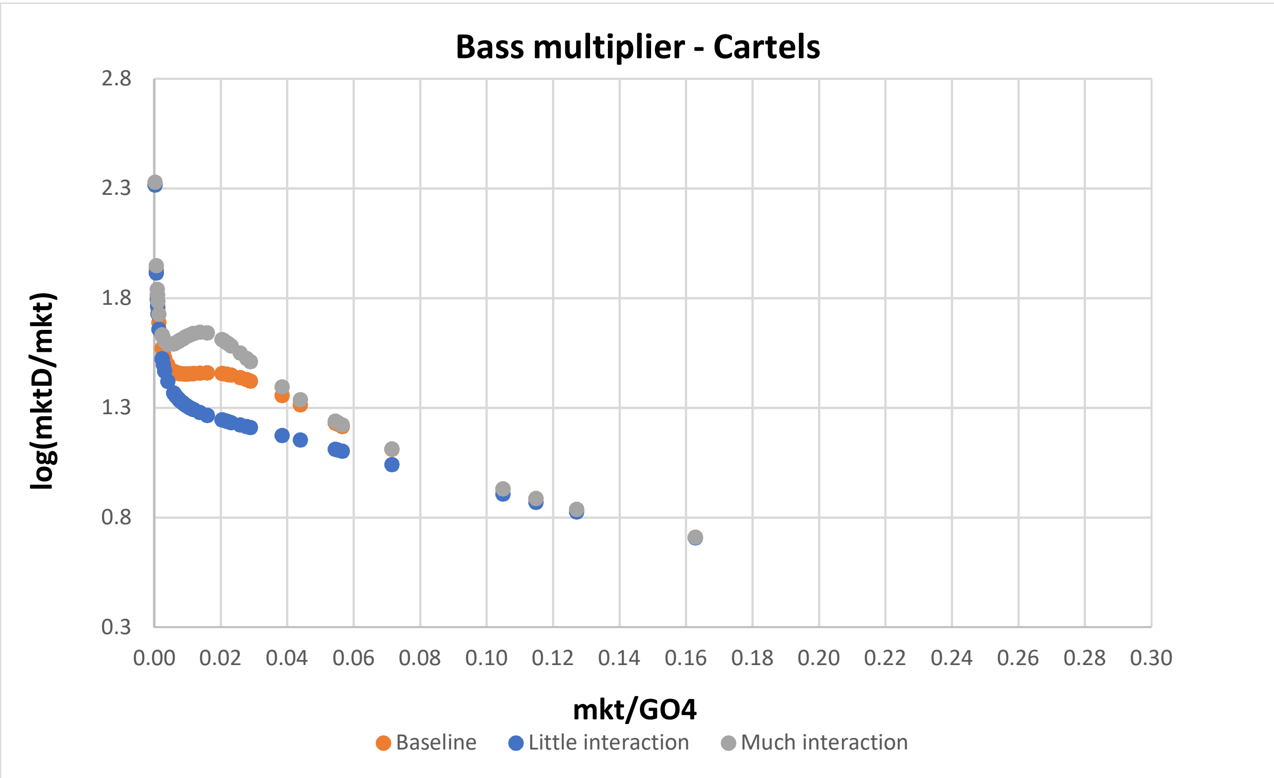
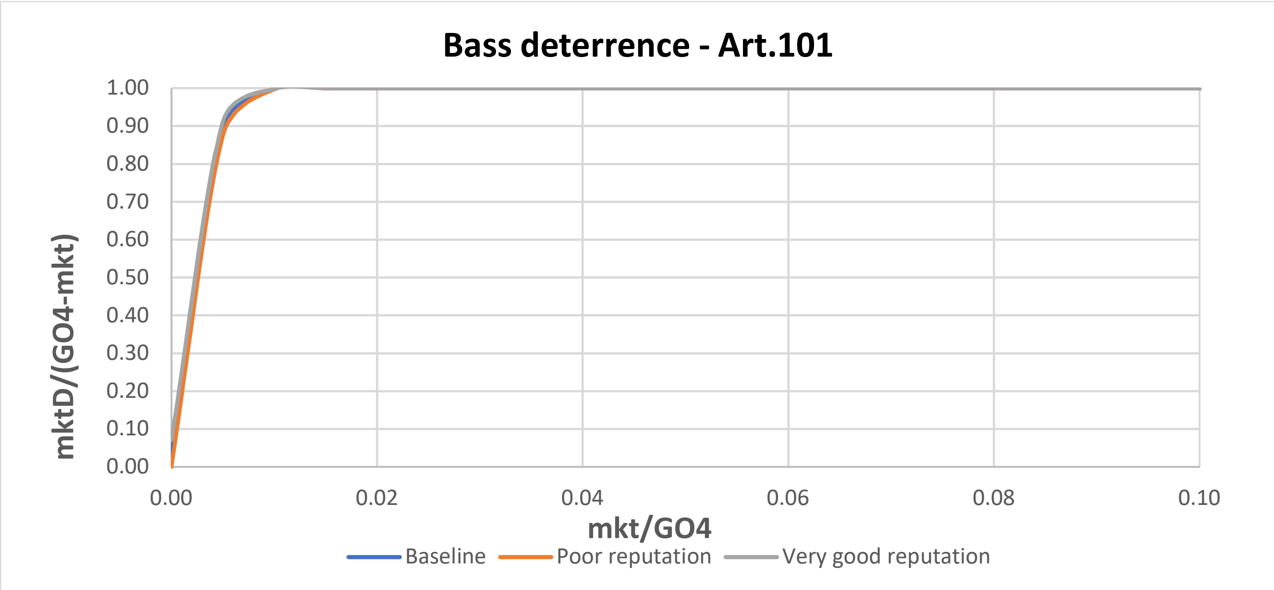


Figure A6: Reputation sensitivity analysis for Art.101



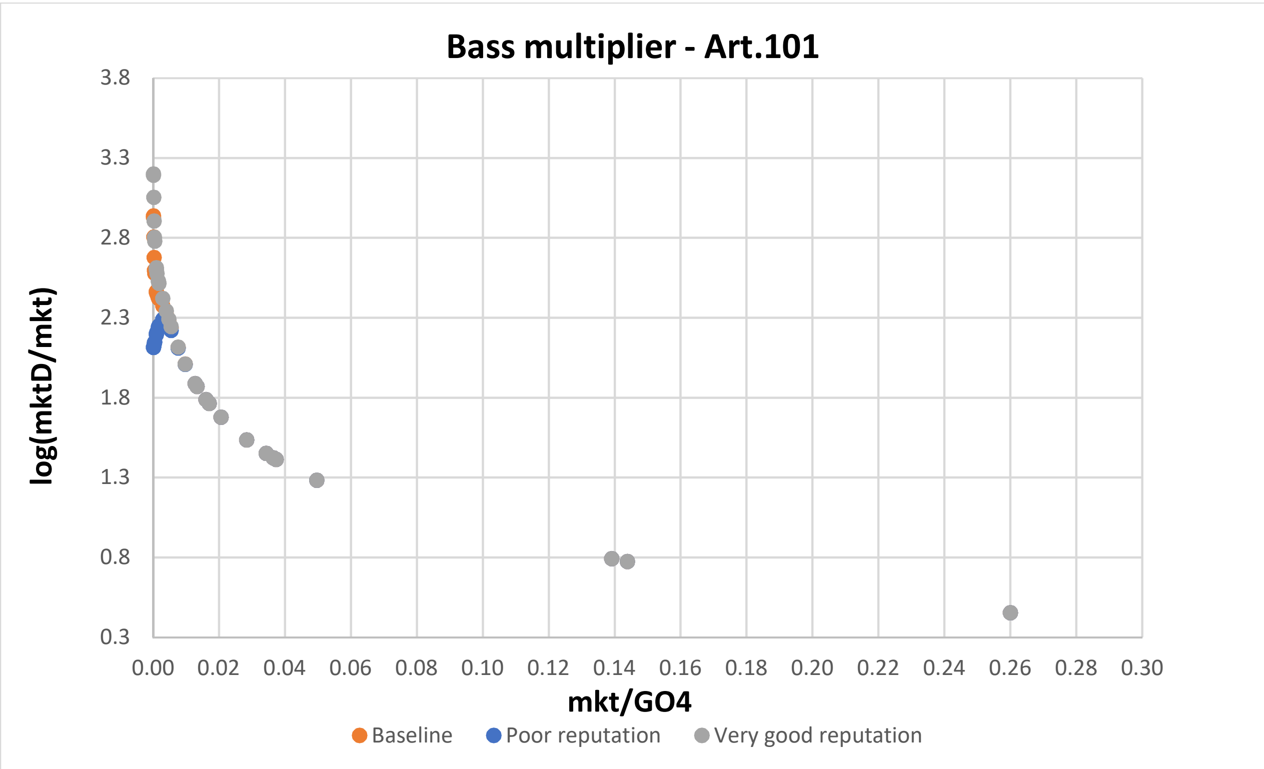
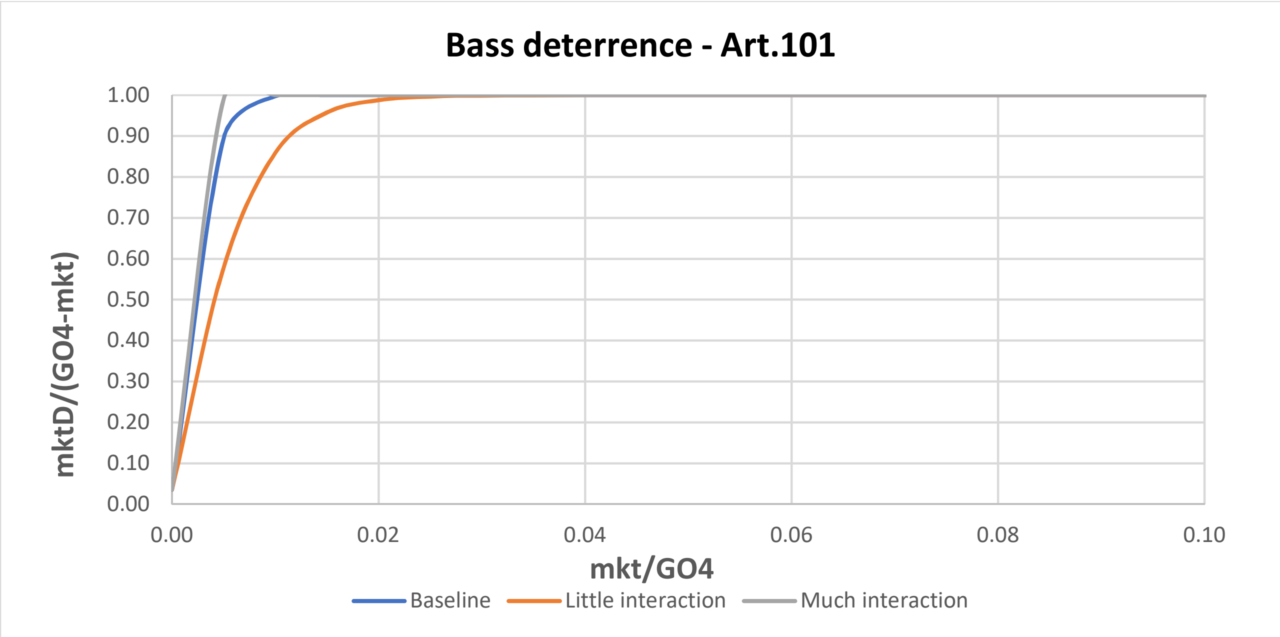


Figure A7: Interaction sensitivity analysis for Art.101



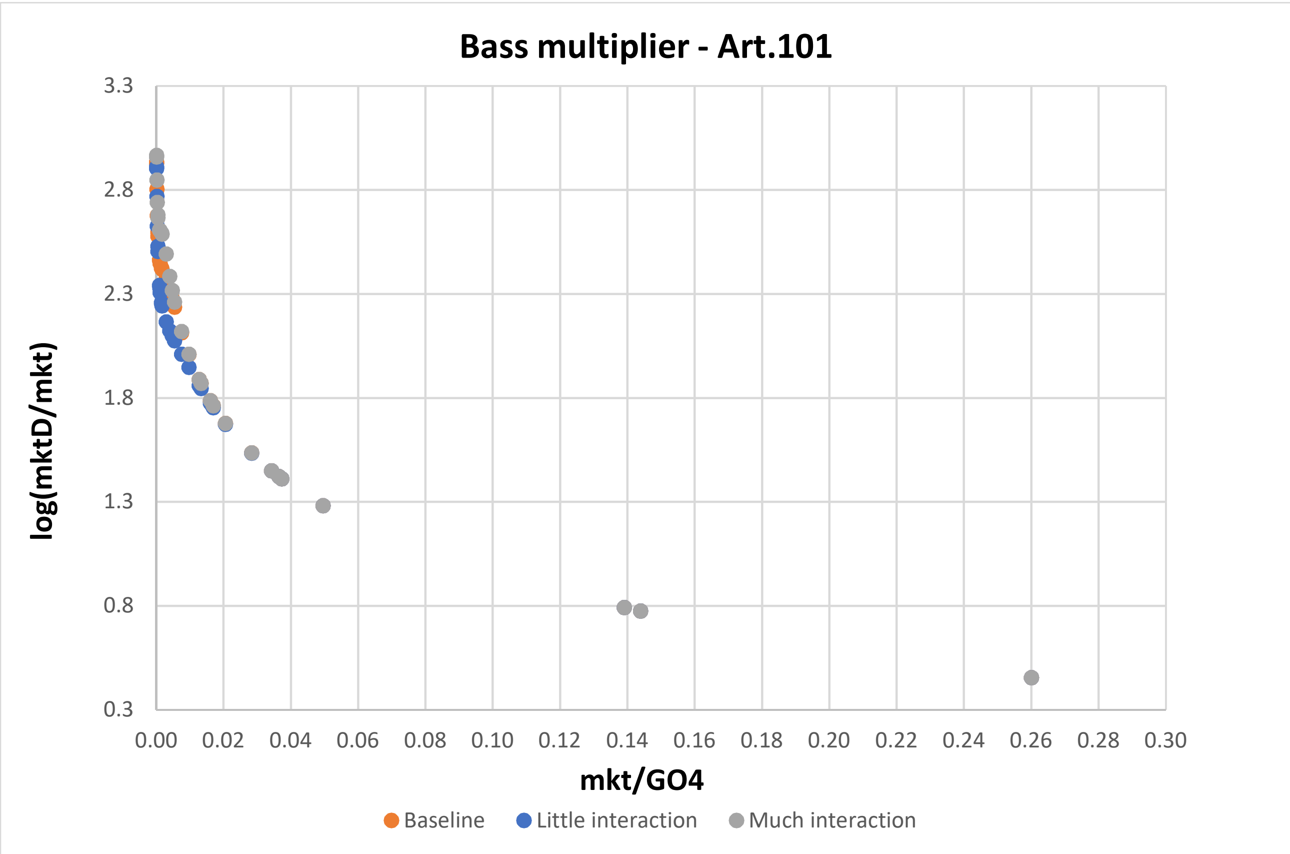
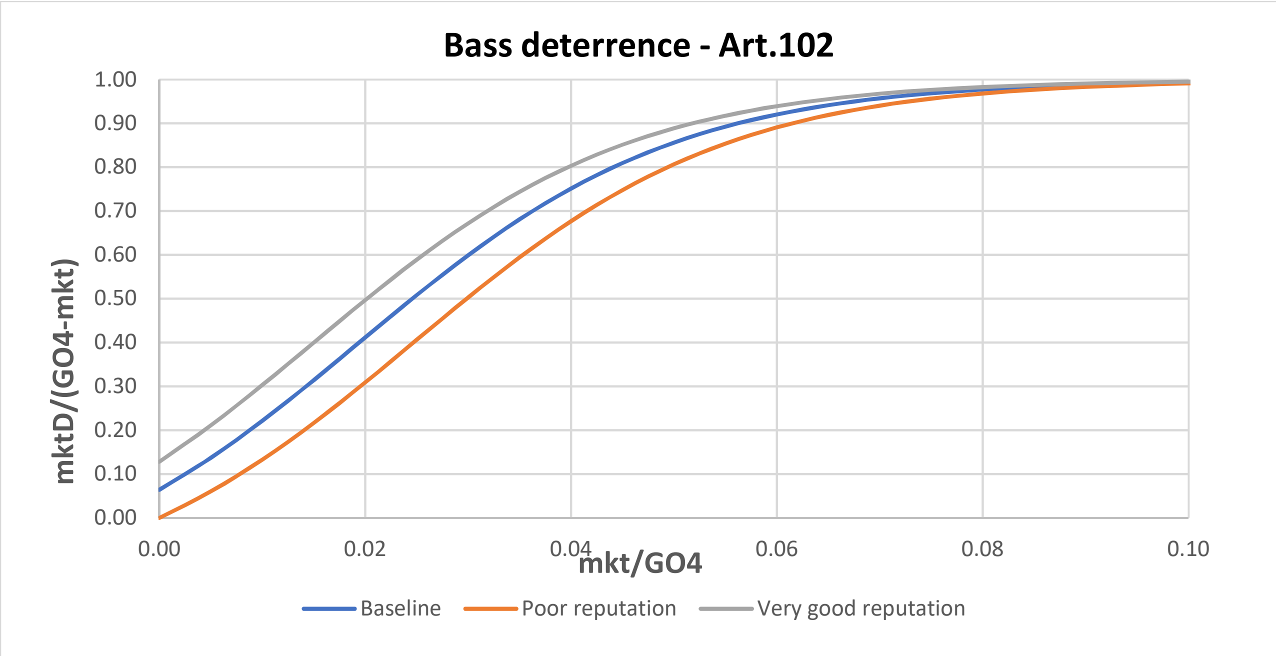


Figure A8: Reputation sensitivity analysis for Art.102



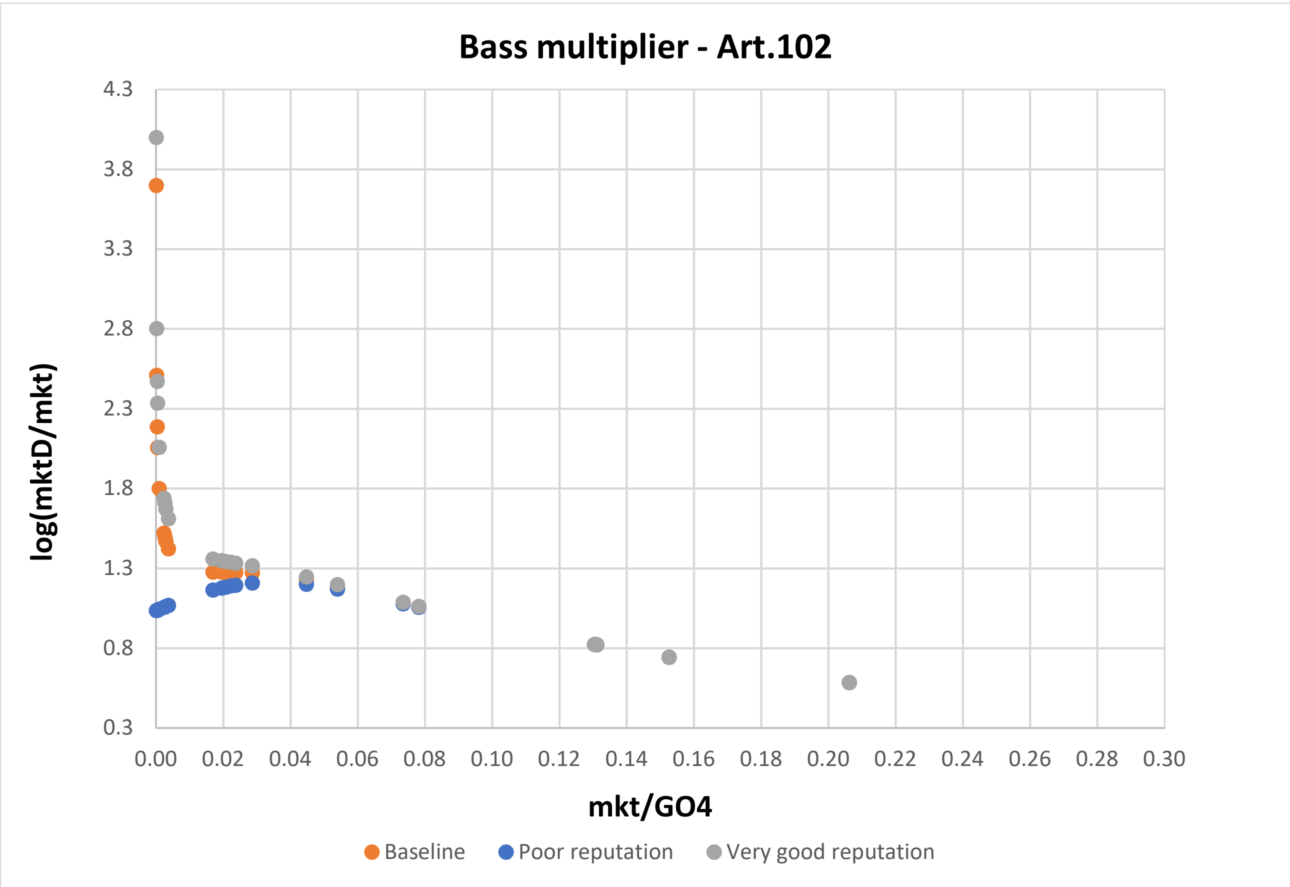
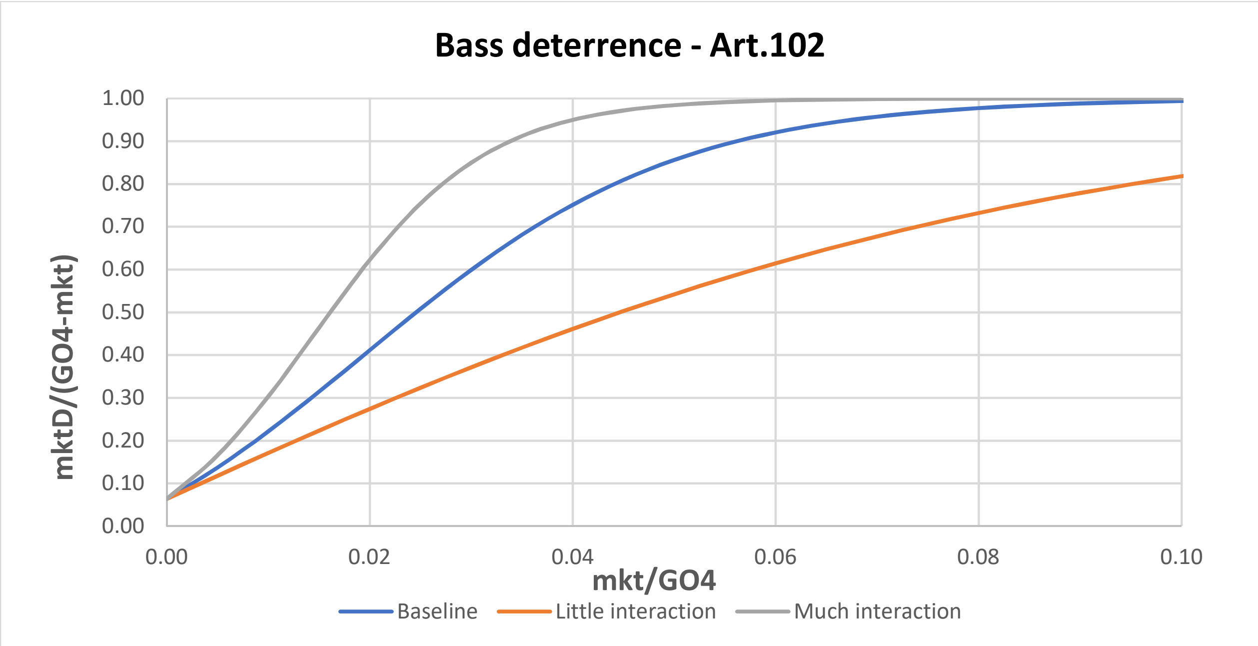
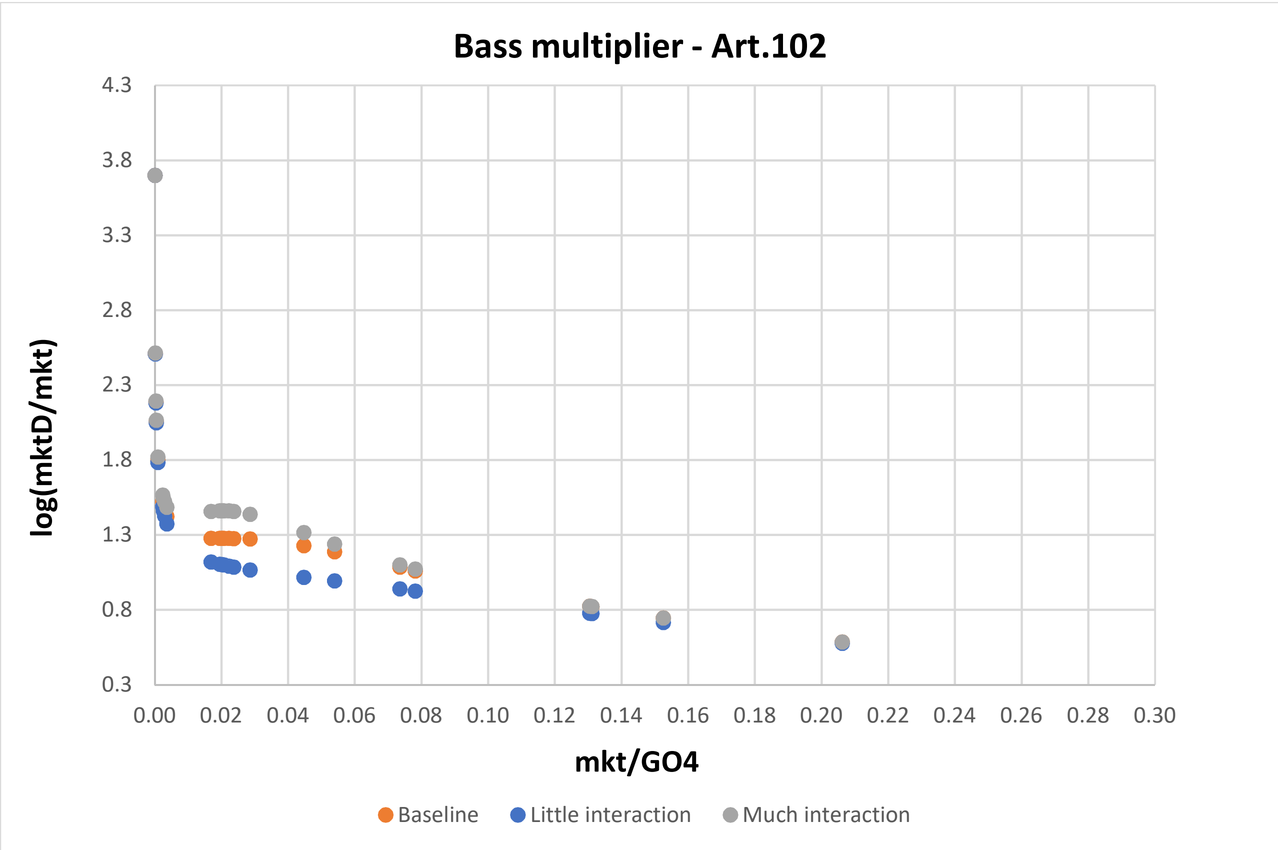


Figure A9: Interaction sensitivity analysis for Art.102





GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

— at the following standard number: +32 22999696,

— via the following form: european-union.europa.eu/contact-eu/write-us_en.

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

Open data from the EU

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
joint-research-centre.ec.europa.eu

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

EU Science