



# EU LEGISLATION OF INSIDE INFORMATION IN THE AGE OF ARTIFICIAL INTELLIGENCE

## – ADDRESSING THE NEED FOR CHANGE

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*In the beginning the Universe was created. This has made a lot of people very angry and been widely regarded as a bad move.*  
– Douglas Adams

*As the financial world places more and more emphasis on advanced technologies, particularly artificial intelligence, the regulatory landscape faces new challenges. The aim of this paper is to show how the regulation of finance increasingly lags behind these new technological developments, using inside information and a certain algorithmic trading strategy as a concrete use case. Given the regulatory difficulties of capturing the nuances of information flow in algorithmic trading, it is essential to devise solutions that are adequate in the age of AI. Thus, solutions will be explored not only in the strictly legal sense but also in the relevant architectural layers, in this case the fundamental components of stock markets.*

### I. INTRODUCTION

For as long as stock markets have existed, there have been people who have acted on information not known to the public when buying or selling financial instruments such as stocks or bonds. Historically, one of the most prevalent techniques of this kind has been what is commonly referred to as front-running. The forementioned trading strategy exploits the vast asymmetry of information that sometimes exists between a financial intermediary and the rest of the market. Before the digitization of trading, financial markets were often dependent on human intermediaries that could facilitate transactions between buyers and sellers. For example, a prospective buyer of a certain stock would instruct said human intermediary to find a seller of that stock, and to execute the trade on his behalf at a certain price. Furthermore, in this example the buyer wants to purchase a significant amount of the outstanding shares of the stock, which could generate a vast increase in its price. As can be deduced from the above, before executing the buy order, the human intermediary has exclusive access to information that is highly likely to significantly affect the price of the stock if known by the market. If he or she were to act on this information, by purchasing

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shares of the stock for personal gain before executing the prospective buy order, he or she could thus stand to benefit greatly by running in front of the market in this sense.<sup>2</sup>

Front-running is illegal in the EU according to Article 14 Market Abuse Regulation (MAR), since the information acted upon constitutes *inside information*, and it is illegal to act on such information for e.g., private benefit. The most general definition of what constitutes inside information is found in Article 7(1)(a) MAR, which states that such information is: (i) information of a *precise nature*; (ii) which has *not been made public*; (iii) relating, directly or indirectly, to one or more issuers of financial instruments, and which, (iv) if it were made public, would be likely to have a *significant effect* on the prices of those financial instruments or on the price of related derivative financial instruments.

In the example mentioned above, it is evident that the broker is acting on information that has *not been made public*. However, the rise of certain algorithmic trading strategies,<sup>3</sup> fueled by the use of AI and machine learning,<sup>4</sup> has increasingly blurred the line when it comes to what constitutes inside information and not.

Front-running has thus far been portrayed as a problem arising due to the role of humans as financial intermediaries. In recent years, however, computers have practically rendered the need for such intermediaries obsolete. In light of this, consider the digital equivalent to the above scenario, also known as algorithmic front-running (AFR):<sup>5</sup> An investor sends an order to buy a large number of shares in a company. The order gets sent both to the London and Frankfurt stock exchanges due to the order being too large for each exchange to execute in full. Furthermore, imagine that the computer from which the investor sent the order is closer in proximity to the London rather than the Frankfurt exchange, by, say, 20 milliseconds. Thus, the order will arrive to London first and then (the remainder of the order) to Frankfurt 20 milliseconds later. In this example, the party that has the lowest sell price (and thus the party from which the investor will buy from) on both these exchanges uses an AI-fueled AFR algorithm. Upon executing the order on the London exchange, the algorithm infers that the order has not yet been fully executed, and thus adjusts its sell price on the Frankfurt

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2 Cf. Article 7(1)(d) Market Abuse Regulation.

3 Commonly referred to under the umbrella terms algorithmic trading (AT) and/or high-frequency trading (HFT).

4 Mangat, F., Reschenhofer, E., Stark, T., and Zwatz, C., (2022) *High-Frequency Trading with machine learning algorithms and limit order book data*, *Data Science in Finance and Economics*, 2(4), p. 437–463. See p. 452 ff.

5 Lewis, M., (2015), *Flash Boys*, Penguin Books Ltd. See p. 174.

exchange ever so slightly (e.g. by 0.03 €). As long as this adjustment is made faster than the 20 milliseconds it will take for the rest of the order to be sent to Frankfurt, the investor will pay these extra 0.03 € for each remainder of the buy order.<sup>6</sup>

It is not as clear here, compared to the classic front-running case, that the algorithm has acted on non-public information. After all, the information that the algorithm acts on is an order that has de facto arrived at a stock exchange. However, accounting for the fact that it takes more than five times these 20 milliseconds for humans to blink once with their eyes, skepticism undoubtedly arises. Rather, an argument could be made that this information is just as opaque to the public as the information which led the human intermediary to trade on his or her own behalf. Thus, a question arises: Does the usage of AFR constitute use of inside information according to Article 7(1)(a) MAR?

Factoring in that these transactions occur innumerable times per day at significant costs to market participants,<sup>7</sup> it is essential to explore solutions for dealing with this trading strategy. In light of this, two further questions will be explored below: Are there changes that can be made to Article 7(1)(a) MAR or related case law which ensures that AFR is encompassed, if it turns out not to fall under the current scope? Can the architectural design of stock exchanges as such be altered in order to make the profitable deployment of AFR impossible?<sup>8</sup>

Consequently, this paper aims to analyze whether AFR trading involves utilization of inside information according to Article 7(1)(a) MAR and, if the answer is negative, to investigate both legal and architectural solutions. Since the non-public criterion of Article 7(1)(a) MAR is the most relevant requisite in this regard, this paper will primarily concentrate on said part of the Article.

## 2. THE LEGAL FRAMEWORK

### 2.1 THE MATERIAL CONTENT OF THE NON-PUBLIC CRITERION

In order to assess whether the AFR algorithm in the example under section 1 uses information which has not been made public, one must first define what is meant by non-public information in the context of Article 7(1)(a) MAR. The Article encompasses any information that changes the state of public knowledge

<sup>6</sup> Cf. Lewis, p. 173 ff.

<sup>7</sup> Daian, P., Goldfeder, S., Kell, T., Li, Y., Zhao, X., Bentov, I., Breidenbach, L., and Juels, A., (2019) *Flash Boys 2.0: Frontrunning, transaction reordering, and consensus instability in decentralized exchanges*. Available at ArXiv: <https://arxiv.org/abs/1904.05234>. See p. 3 f.

<sup>8</sup> Lessig, L., (2006), *Code: version 2.0*, New York: Basic Books. See p. 123 f.

at any given time.<sup>9</sup> In other words, as soon as there exists information that in some sense changes the total mix of information currently available, this new information principally falls under the non-public criterion.<sup>10</sup> Furthermore, the information has to be exclusive in the sense of not being available to a broad range of actors on the market.<sup>11</sup>

Under what circumstances, however, can the information be said to be unavailable to the broader market? In this regard it can be useful to examine the boundary of the non-public criterion, i.e., when the transition from non-public to public information occurs.

First of all, the information has to be widely disseminated in order to be considered public.<sup>12</sup> Nonetheless, the term “widely disseminated” is not defined, thus making it uncertain the amount of people the information must reach for the Article to be applicable.

Some claim that it is sufficient for the information to reach an indeterminate number of market participants.<sup>13</sup> The main argument in favor of this stance is that said participants will trade on the new information in such a way that the information will be factored into the price of the financial instrument, and thus effectively become public.<sup>14</sup>

Others assert that this is not sufficient, but rather that the information has to reach the general public at large. This argument consists of two parts: Firstly, an *e contrario* reading of Article 7(1)(a) MAR entails that the information has to be *made* public. This seems to demand some sort of activity from the entity holding the information, rather than it being enough for a number of market participants to conduct a sufficient amount of trade based on said information. Secondly, if it were enough for the information to reach a small subset of the market, this would risk being severely detrimental to private investors. This is due to the fact that said private investors would then be effectively unable to

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9 Neumann, M., Torggler, U., (2021), *Article 7: Inside information*. In: Kalss, S., Oppitz, M., Torggler, U., and Winner, M. (eds), *EU Market Abuse Regulation: A commentary on Regulation (EU) 596/2014*. Edward Elgar publishing. See p. 62.

10 Ibid.

11 Hansen, J., (2016) *Say when: When must an issuer disclose inside information?*, Nordic & European Company Law LSN Research Papers Series No. 16-03. Available at SSRN: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2795993](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2795993). See p. 17.

12 Ferrarini, G., (2004) *The European Market Abuse Directive*, *Common Market Law Review* 41, p. 711–741. See p. 719 f.

13 Neumann et al., p. 63 f.

14 Ibid.

capture any of the potential profits arising from this new information, which would be at odds with the main purposes of MAR.<sup>15</sup>

The rulings of the European Court of Justice (ECJ) regarding Article 7(1)(a) MAR will be further explored in Section 3. Nonetheless, in this context it is valuable to note that the ECJ case law seems to be more aligned with the latter understanding. Namely, that the information needs to reach the broader public. Although not addressing the non-public criterion specifically, the Court has taken a more teleological view on Article 7,<sup>16</sup> emphasizing the importance of maintaining market integrity and investor confidence through its application.<sup>17</sup> In light of this it seems, if one were forced to choose between these two claims, that the information has to reach the public at large in order to lose its non-public character.

There are also differing views regarding if the medium (news, press conference etc.) through which the information is communicated bears any relevance on how fast said information can be considered widely disseminated. Some argue that information disclosed through stock-market related mediums gets publicly available at a faster rate than other mediums, such as press releases.<sup>18</sup> Others argue that the channel of communication is irrelevant, as long as the information reaches the public at large.<sup>19</sup> Since most EU member states have effectively acted in accordance with the latter view,<sup>20</sup> it is highly probable that this is what applies in the Union.<sup>21</sup>

Lastly, and of primary relevance for what will unfold in the coming sections, as regards the point in time when the information ceases to be non-public, there is no amount of delay between availability and perception.<sup>22</sup> In other words, as soon as the information is widely disseminated it is no longer non-public,

15 Neumann et al., p. 63 f. See also recitals 2–4 MAR.

16 Also in relation to Article 8 MAR on insider dealing (which relates to Article 7), which the case mentioned in footnote 16 deal with as well.

17 Case C-19/11 Markus Getl v. Daimler AG, 28 June 2012, ECLI:EU:C:2012:397. Klöhn, L., (2010) *The European Insider Trading Regulation after the ECJ's Spector Photo Group Decision*, European Company and Financial Law Review, 7(2), p. 347–366. See para. 33 in Getl and p. 364 in Klöhn.

18 Ferrarini, p. 719 f.

19 Staikouras, P., (2008) *Four years of MADness? – The new market abuse prohibition revisited: Integrated implementation through the lens of a critical, comparative analysis*, European Business Law Review, 19(4), p. 775–810. See p. 781.

20 Ibid f. Although this applies in relation to the Market Abuse Directive, which preceded MAR, it is highly probable that this is still applicable under the new regulation (see footnote 20).

21 Moalem, D., Hansen, J.L., (2008) *Insider dealing and parity of information – Is Georgakis still valid?*, European Business Law Review, 19(5), p. 949–984. See p. 958 ff.

22 Neumann et al., p. 62.

regardless of whether anyone has yet been able to interpret this information in some sense.<sup>23</sup>

## 2.2 AFR – INSIDE OR OUTSIDE THE SCOPE?

How do the statements above regarding the non-public criterion of Article 7(1) (a) MAR apply to the AI-fueled AFR algorithm demonstrated in section 1?

To begin with, the algorithm is clearly acting on information that changes the total mix of information available in relation to the company, in the form of an order to buy shares of stocks in said company. Thus, this new information principally falls under the non-public criterion.

However the more enticing question in this case is whether the information is still non-public at the specific time when the algorithm acts on it, by sending a signal from the London exchange to adjust the sell price on the Frankfurt exchange. As stated above, the medium through which the information is disseminated does not bear any relevance as regards *when the non-public information becomes public*.<sup>24</sup> In order to provide context to what will be discussed below, it is nonetheless useful to know that the buy order will be disseminated by appearing as a change on the ticker tape of the company on the London exchange. This is because it is the most common way of announcing a change in price of a particular financial instrument.<sup>25</sup>

The moment the algorithm sends the adjustment signal to Frankfurt, has the change on the ticker tape been widely disseminated? It would be counter-intuitive to conclude that information which is actively disseminated through the most customary channel would not be able to reach the public at large. Thus, at the time the AFR algorithm acts on the information (the change on the ticker tape), it is no longer non-public.

Counterintuitive as it seems (since no member of the public has yet been able to observe the ticker tape change), this is the most likely answer within the context of Article 7(1)(a) MAR. The timeframe for the algorithm in this case was less than 20 milliseconds, but that bears no relevance, since the information ceases to be non-public at the exact same moment as it is widely disseminated.<sup>26</sup> In other words, this “notion of simultaneity” makes it irrelevant whether anyone has yet been able to observe the ticker tape change of the stock of the company,

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23 Cf. *ibid.*

24 Staikouras, p. 781 f. and Moalem et al., p. 958 ff.

25 <https://www.nasdaq.com/glossary/t/ticker-tape>

26 Neumann et al., p. 62.

as long as the change has been propagated in such a way that it will reach the public at large.<sup>27</sup>

In conclusion, the utilization of an AI-fueled AFR algorithm does not involve use of inside information according to Article 7(1)(a) MAR.

### 3. POSSIBLE SOLUTIONS GOING FORWARD

#### 3.1 THE UNSEEN EDGE

In any market, there will always be asymmetries in terms of interpretation ability. As long as the market is large enough (and that it at most only approximates perfect competition), some actors will necessarily conduct more profitable trades than others based on a given piece of new (public) information.<sup>28</sup> The problem with the AFR case, however, is that no human has yet been able to interpret, let alone even observe, the information which the AFR algorithm bases its actions on. The non-public criterion of Article 7(1)(a) MAR in general, and its “notion of simultaneity” in particular, thus seems to be outdated in the era of AI-driven algorithms.

#### 3.2 THE CONCEPT OF RINGA

One solution can possibly be found in the original Commission Proposal for a Market Abuse Regulation. There, the Commission laid out an additional definition of inside information apart from the ones that are applicable as of today (Article 7(1)(a–d) MAR). The definition is commonly referred to as RINGA (relevant information not generally available to the public):<sup>29</sup>

information not falling within paragraphs (a), (b), (c) or (d) relating to one or more issuers of financial instruments or to one or more financial instruments, which is *not generally available to the public*, but which, if it were available to a *reasonable investor*, who *regularly* deals on the market and in the financial instrument or a related spot commodity contract concerned, would be regarded by that person as *relevant* (my italics).<sup>30</sup>

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27 Cf. *ibid.*

28 Goolsbee, A., Levitt, S., Syverson, C., (2019) *Microeconomics*. 3rd ed. Worth Publishers. See p. 257 ff.

29 Hansen, p. 20.

30 COM(2011) 651 final. EU Commission, (2011) *Proposal for a regulation of the European Parliament and the Council on insider dealing and market manipulation (market abuse)*.



The introduction of RINGA would have functioned as a catch-all definition for information that did not fall under the other subparagraphs,<sup>31</sup> which could have been desirable in and of itself. Moreover, if implemented, RINGA would in all likelihood have affected AFR trading to some degree, which the following context makes evident. An ever-increasing amount of trade is executed through the use of sophisticated algorithmic trading strategies.<sup>32</sup> As more and more investors who regularly deal on the market implement these strategies, time horizons on the order of milliseconds become highly relevant. In other words, paraphrasing the RINGA framework, “[...] a reasonable investor, who regularly deals on the market”<sup>33</sup> would regard information relating to the algorithmic trade as “relevant”. Such an investor would thus deem the adjustment signal of the AFR algorithm to the Frankfurt exchange to be of primary relevance when forming an investment decision whether or not to, e.g., buy shares of that company.

In light of this, one could argue that the introduction of RINGA would be desirable in this algorithmic day and age. In a superficial sense, this certainly seems to be the case. Upon closer inspection however, the lack of a temporal dimension manifests itself with equal vigor compared to Article 7(1)(a) MAR, since RINGA only applies to “information [...] not generally available to the public”. Defining non-public information in such close proximity to the actual wording used in Article 7(1)(a) MAR implies, in my view, the absence of temporality. The main problem thus seems to remain since RINGA, like the non-public criterion in Article 7, lacks a temporal dimension between dissemination and availability. As nothing is said of this in the Commission Proposal and in light of the fact that this temporal aspect is otherwise absent in Article 7,<sup>34</sup> the introduction of RINGA would not resolve the AFR problem.

### 3.3 TOWARDS AN EFFECTUAL VIEW OF THE NON-PUBLIC CRITERION

The difficulty of equating AFR usage with inside information in a legal sense is thought-provoking, even more so in light of the case law of the ECJ concerning Article 7–8 MAR. As mentioned in Section 2.1, the Court has consistently viewed said Articles through a teleological lens, a view that is clearly demonstrated in *Spector*.<sup>35</sup> In the case, the Court states the primary essence of

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31 Hansen, p. 20 f.

32 Sadaf, R., McCullagh, O., Grey, C., King, E., Sheehan, B., and Cunneen, M., (2021) *Algorithmic Trading, High-Frequency Trading: Implications for MiFID II and Market Abuse Regulation (MAR) in the EU*, available at SSRN: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=3846814](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3846814). See p. 1 f.

33 It goes beyond the scope of the paper to deal with the intricacies of the reasonable investor test.

34 Cf. COM(2011) 651 final.

35 C-45/08 (*Spector*). Case C-45/08 *Spector Photo Group NV and Chris Van Raemdonck v.*

the notion of inside information (and insider dealing, which are two closely related concepts):<sup>36</sup>

Owing to its non-public and precise nature and its ability to influence the prices of financial instruments significantly, inside information grants the insider in possession of such information an *advantage in relation to all the other actors on the market who are unaware of it*. It enables that insider, when he acts in accordance with that information in entering into a transaction on the market, to expect to derive an economic advantage from it *without exposing himself to the same risks as the other investors on the market [...] [thus] the undermining of the integrity of financial markets and investor confidence*.<sup>37</sup> (my italics).

As has been laid out in previous sections, the use of AFR does not encompass the utilization of non-public information under the current legal framework. Nonetheless, the above principled statement of the Court is rather interesting in light of AFR. If one, for the sake of argument, were to conceptualize the principled statement as a set of cumulative requisites, a very different legal picture would emerge in my view. Examining the principled statement in this way makes it all but abundantly clear that all of its main aspects practically *define* the use of algorithmic front-running. In order to see this, it can be useful to break the highlighted parts of the statement down and relate it to the AFR example from Section 1.

The moment the algorithm infers that the buy order is not fully executed and sends the signal to adjust its sell price on the Frankfurt exchange, it has an obvious advantage in relation to other market actors. As of this moment, the other market actors do not yet know that the investor will buy more stocks of the company on other exchanges.

Furthermore, the actor using the AFR algorithm does not expose himself to the same risks as other market actors. The algorithm can correctly infer (through the use of advanced machine learning techniques)<sup>38</sup> that the rest of the order will be sent to the Frankfurt exchange. Since it already has the lowest sell price for the company on said exchange, it can adjust its sell price in a sufficiently small way in order to ensure that it still has the lowest, although slightly higher, sell price. Thus, the investor will still buy the remaining stocks in the buy order from

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Commissie voor het Bank-, Financie- en en Assurantiewezzen (CBFA), 23 december 2009, ECLI:EU:C:2009:806. See primarily para. 47–50.

36 C-45/08, para. 50.

37 C-45/08, para. 52.

38 See e.g. Mangat et al., p. 452 ff.

the actor utilizing the AFR algorithm. Lastly, by implementing sophisticated strategies to minimize the latency of the adjustment signal,<sup>39</sup> the AFR algorithm will be able to adjust its sell price before the remainder of the buy order arrives. This is not far from taking zero risk and still generating profit, which does not apply to the other market actors.

For the investor buying the shares of the company, the use of the AFR algorithm effectively imposes a tax upon him. The mere fact that his buy order has to go through two exchanges instead of one effectively ensures that he has to pay a higher price for some of the shares than would otherwise be the case. In my view, this clearly undermines both market integrity and (if it were widely known) investor confidence.

Based on the Court's statement, one could argue that the AFR usage falls under the scope of inside information. However, there are significant calls for caution in this respect. First of all, the case does not deal with algorithmic trading strategies like AFR directly. Secondly, it primarily concerns questions regarding insider dealing which, although overlapping with inside information, bears important differences that cannot be overlooked. Among other things insider dealing, according to Article 8 MAR, concerns certain uses of inside information, rather than inside information as such. More importantly, this is reflected in the Court's statement, since the non-public nature is already taken as a given ("[o]wing to its non-public [...] nature").<sup>40</sup> Viewing the principled statement as a set of requisites in line with the above provides valuable insight into the overlap between some important characteristics of AFR and inside information. Implying that the principled statement as is could be interpreted as stating that the non-public criterion of Article 7 necessitates a temporal dimension is something else entirely. Thus, until a more concrete case emerges, the above declaration alone cannot erase the conclusions drawn in previous sections.

However, the Court's effectual view seems to capture the problems with AFR in a way that Article 7(1)(a) MAR does not (effectual in the sense that it makes it of primary importance what effects the use of the information will have). Another purely argumentative exercise demonstrates this, if one assumes that the Court also comments on the nature of the non-public criterion specifically (which it does not). Given the forementioned vantage point, my view is that the Court's statement would correspond to the following question as regards its applicability in the AFR use case: When the AFR algorithm sends its adjustment signal to the

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39 Manahov, V., (2016) *A note on the relationship between high-frequency trading and latency arbitrage*, *International Review of Financial Analysis*, vol. 47, p. 281–296. See p. 283 ff.

40 C-45/08, para. 52.

Frankfurt exchange, how many market actors have actually observed the change on the ticker tape for shares of the company?<sup>41</sup> This would thus achieve what RINGA does not, which is to introduce an appropriate temporal dimension. By viewing the non-public criterion in this way, one basically asserts that a sufficient proportion of market participants has to perceive the new information before any action can be taken in relation to said information. Necessarily, then, in order for that to happen some amount of time has to pass.

Contrasting this to the Court's teleological view of Article 7–8 MAR,<sup>42</sup> it is clear that the Court places a lot of emphasis on protecting the integrity of financial markets and to enhance investor confidence (also the main purposes of MAR).<sup>43</sup> Due to the constantly evolving nature of financial markets, it cannot be stated ahead of time what constitutes threats with regards to market integrity and investor confidence. For example, if one were to go back 15 years in time, algorithmic trading strategies like AFR were close to non-existent.<sup>44</sup> In other words, what was a non-issue in the past might become severely detrimental to market integrity and investor confidence at a later point in time. Thus, it can be argued that defining the non-public criterion in this effectual manner would be more in line with the purposes of MAR, compared to Article 7(1)(a) MAR.<sup>45</sup> In addition, this view is also likely to be more future proof with regard to upcoming algorithmic trading strategies.

However, if the principled statement were to be interpreted as is (and as stated above), one cannot draw this conclusion. To summarize, then, *if* the Court's statement could be read as outlining this effectual view of the non-public criterion, *then* it would in all likelihood encompass algorithmic front-running.

### 3.4 CHANGING THE ARCHITECTURAL DESIGN OF STOCK EXCHANGES

Awaiting appropriate changes to the legal framework, are there changes that can be made to the architecture<sup>46</sup> of stock exchanges that would achieve the same legal effect, which is the prohibition of the use of AFR algorithms?<sup>47</sup>

41 Primarily as regards the following passage of the above quoted statement: "... an advantage in relation to all the other actors on the market who are unaware of it". See C-45/08, para. 52.

42 Hellgardt, A., (2013) *The notion of inside information in the Market Abuse Directive: Getl*, Common Market Law Review 50, p. 861–874. See p. 866.

43 See e.g. C-19/11 (*Getl*), para. 33–35. Although addressing MAD, almost certainly this applies in relation to MAR as well, given that the relevant recitals are practically equivalent. See recitals 2 and 12 MAD and recital 2 MAR.

44 Lewis, p. 16 f.

45 Primarily recital 2 MAR.

46 Lessig, p. 123.

47 Since, if use of AFR would constitute use of inside information, it would be illegal according to

In order to answer this question, one must first understand what aspects of stock exchanges current architecture enables the profitable deployment of AFR. In this regard, two components are fundamental: The fact that stock exchanges treat time as continuous, and that orders are processed in a serial manner.<sup>48</sup>

The forementioned aspects are made evident by contrasting them against the AFR use case. Firstly, the user of the AFR algorithm is effectively guaranteed that his adjusted, slightly higher, sell price on the Frankfurt exchange will be executed. This is due to the fact that, since time is treated as continuous, orders are executed at *every given instant of time*, no matter if that instant constitutes seconds, milliseconds or even microseconds.<sup>49</sup> Thus, as long as the algorithm's adjustment signal arrives to the Frankfurt exchange before the remainder of the investor's buy order, no matter by how small a margin, this is what will happen.

Secondly, since the AFR algorithm has the lowest sell price, every single share that the sell order contains will be matched against the investor's buy order before any other actor can sell shares of the company to said investor. Since orders are processed serially, the AFR algorithm's outstanding sell order on the Frankfurt exchange will thus be processed *in its entirety* against the remainder of the investor's buy order.<sup>50</sup> To put it differently, these two aspects of stock exchanges architectural design are what enables both the logical possibility as such and the profitable deployment of AFR algorithms.

However, there are other ways of designing stock exchanges than what is currently prevalent. One such alternative design is commonly referred to as frequent batch auctions (FBA).<sup>51</sup> A complete outline of the architecture goes beyond the scope of this paper, but two particular aspects of FBA are worth considering in relation to the present architectural issues mentioned above.

First of all, FBA treats time as discrete instead of continuous,<sup>52</sup> meaning that trades cannot be executed at every given instant of time but instead once per discrete time unit. Views differ as to which discrete time unit that would be

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Article 14 MAR.

48 Budish, E., Cramton, P., Shim, J., (2015) *The High-Frequency Trading Arms Race: Frequent Batch Auctions as a Market Design Response*, *The Quarterly Journal of Economics*, 130(4), p. 1547–1621. See p. 1586 f.

49 Budish et al., p. 1549.

50 Cf. Budish et al., p. 1553 f.

51 Manahov, V., (2021) *High-frequency trading order cancellations and market quality: Is stricter regulation the answer?*, *International Journal of Finance and Economics*, 26(4), p. 5385–5407. See p. 5403 f.

52 Budish et al., p. 1549.

optimal,<sup>53</sup> but for the sake of argument, in the example below trades can be executed once every 300 milliseconds.

Secondly, instead of orders being processed serially, they are processed in uniform-price batches.<sup>54</sup> Since these concepts are quite technical, it can be useful to break them down, using a fictitious stock as an example. At every discrete time unit (in our case 300 milliseconds), all of the outstanding buy and sell orders of the stock are collected into a single batch. Once collected into said batch, they will all be executed *simultaneously*. In other words, every outstanding buy and sell order within this batch will be executed at the exact same time. Furthermore, the price at which these outstanding orders will be executed is determined by a uniform-price auction. Such an auction works by simultaneously computing two separate mathematical functions in order to determine *one common price* for all of the outstanding buy and sell orders of the stock.<sup>55</sup> Stated otherwise, regardless of whether one buy order bids 10.05 € for the stock and another bids 10.10 € for that same stock, both orders will be executed at one specific price. It goes without saying that there are more technical intricacies involved here, but the above passage is merely meant to give a conceptual understanding of these two aspects.<sup>56</sup>

Replacing the current design of stock exchanges with the FBA architecture would severely lower the prospects for the users of AFR strategies. Firstly, as stated above AFR demands a continuous and serial execution of orders. Since every order in this new architecture is processed in batches at discrete time intervals, the deployment of AFR effectively becomes impossible. Moreover, even if it *were* possible, it would no longer be profitable. Since all orders in a given batch are executed at a single price, that cannot be known beforehand,<sup>57</sup> whether one profited from the use of AFR in such a setting would at best be entirely random.

To conclude, then, changing the architectural design of stock exchanges in accordance with the FBA model would achieve the same legal effect as a prohibition of the use of AFR.

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53 Manahov, p. 5404.

54 Budish et al., p. 1549.

55 *ibid.*

56 Cf. Budish et al., p. 1595 f.

57 Budish et al., p. 1596 f.

#### 4. CONCLUDING REMARKS

A market where investors are effectively forced to pay a hidden tax on their transactions, as soon as said transactions have to be processed through two or more exchanges, is a market that does not function properly in my view. The current legal framework seems unable to reign in the algorithmic strategy that brings these hidden taxes into existence, and thus seems outdated at a time when trading is becoming increasingly reliant on advanced technology.

Going forward, two possible solutions emerge at the end of the AFR-tunnel. The first is effectively an attempt to align the legal term inside information with its common-sense counterpart, in the context of finance. The everyday notion of inside information has, at its core, a temporal dimension built into it. By being able to act on information before anyone else has yet been able to see it, one is in this respect in possession of inside information. So, by viewing the legal term inside information through its common-sense lens, which to some extent is what the Court's principled statement in *Spector* does, this alignment could be achieved. The second solution would constitute a case where technology regulates technology. By altering the architectural design along the lines of the FBA model, no investor would have to pay tribute to the algorithmic demon, embodied in the shape of AFR.

Douglas Adams' quote on the frontpage of the paper questions the purpose of the universe, the answer to which probably lies far into the future, if ever. Awaiting that however, by prohibiting the use of algorithmic trading strategies like AFR, either directly through law or indirectly through technology, my hope is that we can at least re-establish the purpose of financial markets.



