The Efficient Market Hypothesis and Rational Expectations Macroeconomics. How Did They Meet and Live (Happily) Ever After?

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Abstract: This article contributes to the study of the historical relationship between macroeconomics and financial economics. We investigate the interactions, in the 1960s and 1970s, between two research programmes—"rational expectations macroeconomics" (or "new classical macroeconomics") and the efficient market hypothesis. We uncover the back-and-forth-dialogue between these two research programmes, which took place along the 1970s. We identify Sargent (1972a)'s contribution on the term structure of interest rates (and ensuing debates) as the starting point of this dialogue. We then highlight how rational expectations models reshaped the definition and assessment of the efficient market hypothesis in financial economics.

Keywords: term structure; macroeconomics and financial economics; Fama (Eugene); Lucas (Robert E.); Sargent (Thomas J.)

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1. Introduction

Very few contributions to the history of economics have been investigating the relationship between post-war macroeconomics and financial economics (or, in short, finance), although historians have recently produced a significant amount of scholarship about the respective evolution of these two fields. Our paper contributes to the study of the relationship between these two fields by documenting the historical interactions, in the 1960s and the 1970s, between two research programmes: "new classical macroeconomics" (an approach driven by Robert E. Lucas's and Thomas J. Sargent's contributions) and "market efficiency" (a research programme mainly led by Eugene Fama).

Stephen Ross, in his "Finance" entry to the *New Palgrave Dictionary of Economics*, makes a puzzling historical claim about the relationship between efficient market hypothesis and Lucas-Sargent's "rational expectations macroeconomics" (or "new classical macroeconomics," as we rather prefer to call it):

> *[T]he rational expectations school of macroeconomics was clearly influenced by the intuition of efficiency in finance. The original insight that prices reflect*

> *the available information lies at the heart of rational expectations macroeconomics. (Ross 2008, 6)* [1]

We consider this claim 'puzzling' since it gives rise to opposite reactions. From an economist' perspective, Ross refers to a theoretical relationship between two concepts (rational expectations and market efficiency) that is sensible, if not commonplace. From a historian's perspective, Ross suggests a historical relationship of influence from financial economics (namely, the efficient market hypothesis research programme) on macroeconomics (namely, new classical macroeconomics), which has found so far little supporting evidence in the history of both fields.

Like Ross, most contemporary scholarship in financial economics or macroeconomics *associates* the efficient market hypothesis and rational expectations, i.e. it claims that they are closely related (or even equivalent) equilibrium concepts. The efficient market hypothesis is usually summarized as the idea that "prices of financial assets fully reflect all available information" (see e.g. Lo 2008, 2)—although several other formulations and definitions exist (Walter 2006; Vuillemey 2013). Rational expectations are defined as "an equilibrium concept that attributes a common model … to nature and to all agents in the model," implying that "the forecasts made by agents within the model are no worse than the forecasts that can be made by the economist who has the model" (Sargent 2008, 1). The analytical affinity of these two

[1] Our paper relies on materials such as the *The New Palgrave Dictionary of Economics* or popular textbooks precisely because these materials are illustrative of stabilized, consensual knowledge and because they play a key role in structuring, showcasing and reproducing the scope and boundaries of a given field. This follows existing historiographical approaches to "self-produced", "standard", or "canonical" narratives (e.g. Jovanovic 2008; Duarte and Lima 2012; Sergi 2020).

equilibrium concepts, as understood today, can be easily grasped even by undergraduate students.[2]

It is way less trivial to identify Ross' second suggestions, i.e. the historical relationship between the two research programmes (new classical macroeconomics and the efficient market hypothesis), in which these two concepts played a distinctive role. New classical macroeconomics was developed by Lucas and Sargent between the late 1960s (Lucas and Rapping, 1969) and the early 1970s (e.g. Lucas 1972; Sargent 1976); these works later became the steppingstone of contemporary macroeconomics, after going through significant extensions and amendments in the 1980s and in the 1990s. In Lucas-Sargent new classical macroeconomics, the concept of rational expectations played a key role—alongside other assumptions. New classical macroeconomics was hence nicknamed, by its 1970s' contemporaries, "rational expectations macroeconomics," although the concept of rational expectations per se is usually attributed to John Muth (1961)—hence, predating Lucas-Sargent new classical macroeconomics.[3]

[2] For instance, the very popular financial economics textbook by Frederic Mishkin's associates the two concepts as follows: (i) rational expectations are expectations "identical to optimal forecast (the best guess of the future) using all available information" (Mishkin 2016, 192); (ii) in an efficient market, asset prices should reflect expectations on future returns (e.g., for stocks, the expected discounted sum of future dividends; Mishkin 2016, 190). Therefore, market participants will converge towards an "equilibrium price" reflecting the optimal forecasting, since all prices reflecting non-optimal (i.e. non-rational expectations) forecast on returns would lead to over-pricing or under-pricing of assets—i.e. the current price would imply higher or lower future return than that implied by "the best guess" (Mishkin 2016, 196-197). Market participants are assumed to act so, in order to avoid such unexploited profit opportunities (arbitrage).

[3] Literature on the history of rational expectations has already identified several potential 'precursors' to Muth. Keuzenkamp (1991) notably discusses Jan Tinbergen ([1932] 1933)'s

Literature in financial economics (see e.g. Lo 2008, 1) traditionally identifies Paul Samuelson (1965) and Eugene Fama (1965) as the contributions starting the efficient market hypothesis research programme. While the first original contributions appeared from the first half of the XXth century, the efficient market hypothesis, intended as a research programme, fully developed in the 1960s. This collective research endeavour combined empirical analysis of the dynamics of asset prices (based on stochastic processes) with a theoretical interpretation of such dynamics (based on the idea of market equilibrium).

Diverse claims about the relationship between these two research programmes have been made. Like Ross, Robert Merton (2006) suggests that the dissemination of Samuelson (1965)'s early drafts may have influenced Muth (1961) and new classical macroeconomics. However, macroeconomists disregard this genealogy.[4] Similarly, historians of macroeconomics did not notice any connection between the early works of new classical macroeconomists and previous contributions to the efficient market hypothesis (see notably Sent 1998; Louçã 2004; de Vroey 2016, chap. 9; da Silva 2017; Galbács 2020, chap. 2). Another narrative holds that the success

use of expectations that would be "rational, i.e. consistent with the economic relationships". Young et al. (2004, chap. 4) argued against this interpretation, since they rather see Tinbergen as a precursor of the "implicit expectations" program set in motion by Edwin Mills (on this program, see Young and Darity 2001). Lucas strongly objects against the idea of "precursors" to Muth, arguing that "we don't want to go back to all the people who used the words 'rational' and 'expectations' … no one had anything like [Muth] before" (Lucas in Hoover and Young 2011, 15).

[4] For instance, entries on "Rational Expectations" (Sargent 2008) and "New Classical Macroeconomics" (Fischer 2008) in the *New Palgrave Dictionary of Economics* do not mention at all the efficient market hypothesis. The same remarks apply to most macroeconomics textbooks (see e.g. Blanchard 2016).

of new classical macroeconomics deeply transformed research in financial economics and gave to the efficient market hypothesis is 'modern', 'scientific' form. For instance, Andrew Lo, in his "Efficient Market Hypothesis" entry to the *New Palgrave Dictionary of Economics,* argues that Lucas's work was crucial in shifting the focus of financial economics from sole "statistical descriptions" and "empirical testing" towards a fully-fledged "theory of efficient markets".[5] Our article intends to take seriously each of these diverse historical claims and to investigate rigorously the origins of the relationship between the efficient market hypothesis and new classical macroeconomics, from their development..

A few contributions in the history of economics have already investigated the relationship between financial economics and macroeconomics, broadly defined. Mehrling (2005; 2010; 2016) has illustrated the influence of financial economics on the real business cycle (RBC) approach (Kydland and Prescott 1982), which he considers as a 'macroeconomic version' of the capital-asset-pricing model (CAPM; Sharpe 1965). Mehrling (2005) and Young (2014) have notably shown that Fischer Black—one of the pioneers of option-pricing model (Black and Scholes 1973)—played a key role in the development of the RBC approach, through his comments on different drafts of Kydland and Prescott (1982) and Long and Plosser (1983). Hoover (1988, chap. 5) argues that Fama (1980) has provided the influential basis for the later extension to finance, money, and banking of Lucas-Sargent new classical macroeconomics. Mehrling's, Hoover's and Young's contributions documented the interactions between financial economics and the RBC approach at the turn of the 1980s, and its consequences on

[5] Stanley Fischer, in a piece celebrating Lucas' Nobel Memorial Prize, held a similar view: "Aside from its macroeconomics significance, [Lucas 1972] was influential also in providing a precise model that illustrates the information-conveying role of prices. It was common in the field of finance to say, without any great precision, that in an efficient market prices reflect all relevant information. Lucas's model shows exactly what that might mean" (Fischer 1996, 18). See also Hall (1996, 41-42).

macroeconomics. However, these contributions did not address two questions: How and when this dialogue between new classical macroeconomics and the efficient market hypothesis research programme actually started? What were the consequences of this dialogue on the development of *financial economics*?

This article aims at investigating these two questions, by documenting the interactions between new classical macroeconomics and the efficient market hypothesis research programme in the 1960s and the 1970s. We highlight that there was indeed (as pointed out by Ross, among others) an interplay between these two research programmes, a cross-circulation of models and ideas; however, we argue (contrary to Ross) that this was rather a back-and-forth dialogue than a unidirectional influence of one programme over the other.

We begin with discussing the potential influence of the 1960s research on efficient markets on the early development of new classical macroeconomics (Section 2). After clarifying what we mean by "influence", and how it is usually documented by historians, we conclude that it remains difficult to assess the influence of the efficient market hypothesis on the inception of new classical macroeconomics. This issue remains an open question, requiring further investigations. We then discuss (Section 3) the first published evidence of an interaction between the two research programmes, which goes back to an early 1970s debate on the yield curve—a debate staging, as the main actors, Sargent, Franco Modigliani, Robert Shiller, and Fama. One of the main outcomes of this debate has been the methodological influence of new classical macroeconomics on the market efficiency research programme, leading to a reformulation of the efficient market hypothesis (Section 4). Furthermore, by the end of the 1970s, the debate on the yield curve had paved the way to new research questions in financial economics, inspired by new classical macroeconomics (Section 5).

2. Where Histories Begin and Research Paths Cross

2.1. The Development of Financial Economics and the Efficient Market Hypothesis (1965-1970)

Economic analysis of financial activities appeared at least from the late XIXth century on—for instance, with Irving Fisher's work (Dimand 2007). Nevertheless, a scientific academic community of economists interested in finance emerged only in the U.S. during the 1950s-1960s. Then, the development of the efficient market hypothesis contributed to establishing financial economics both as an autonomous academic discipline and as a subfield of economics (Walter 1996; Jovanovic 2008).

In the US, for the first half of the XXth century, finance had been traditionally taught in business schools by practitioners, rather than by academics (MacKenzie 2008; Fourcade and Khurana 2013). During the 1960s, US business schools went through significant changes. Under the aegis of several philanthropic foundations, business schools in US top universities gradually became closer to research departments, particularly those conducting research in economics. US post-war economics (see Morgan and Rutherford 1998) quickly became business schools' intellectual benchmark for building a 'science of finance', based on economics' distinctive concepts—equilibrium, competition and rationality. The new intellectual blueprint for finance involved both highly formalized models, econometric techniques, and market-oriented research (e.g. Jovanovic 2008; MacKenzie 2008, 74). The University of Chicago Graduate Business School (CGBS) played a leading role in this process (Fourcade and Khurana 2013).[6] Furthermore, leading economists, like Samuelson, Modigliani,

[6] A collective and organized empirical research in finance became possible because of the availability of the first computerized databases (Mehrling 2005, 88). The establishment of the

Merton Miller, or George Stigler, were enthusiastic contributors to such changes.[7] They participated, with their own work, to the renewal of financial research; some of them, like Miller and Modigliani, had also appointments in business schools.

One of the central issues to this renewal was to provide a theoretical explanation of asset price dynamics. Empirical observations about randomness of assets prices fluctuations had been raised long before in the US. However, theoretical explanations of these empirical observations gained momentum only in the early 1960s. Fama (1965) gave a verbal theoretical interpretation of asset prices' randomness, summarized with the expression "market efficiency". Fama's main insight was that asset prices result from information processed by market participants: if all current information is reflected in current prices, thus any change in prices should reflect new (and unpredictable) information—hence the random nature of asset price dynamics. The same year, Samuelson (1965) published a mathematical model explaining the randomness of futures prices.[8] Samuelson argued that, if we ignore risk aversion, economic agents will use accurately all information about past prices available at the current period (I_t) for determining the expected spot price for the period $t+j$ (S_{t+j}) of a commodity:

$$F_t^{t+j} = E[S_{t+j}|I_t] \quad (1)$$

This will lead the current futures price (F_t) at time t of this commodity at the horizon $t+j$ (F_t^{t+j}) to follow a martingale:

Center for Research in Security Prices in 1960, hosted at the CGBS, was at the forefront of such changes.

[7] See e.g., Nik-Khah (2011) for the role of George Stigler at CGBS.

[8] Contributions to this issue were obviously not limited to Fama, as a collective research effort had already emerged (see e.g. the contributions gathered in Cootner 1964). Cootner himself (1962) presented a model very similar to Fama's.

$$E\,[F_{t+1}^{t+j}|I_t] = F_t^{t+j} \quad (2)$$

If futures prices follow a martingale, then the current price represents the best estimation, given available information, of any price in the future.

In addition to this theoretical line of work, the efficient market hypothesis research programme developed econometric tests of price randomness, as well as alternative empirical tests of market efficiency, based on investment funds' performance (Jensen 1968) and on event studies (Fama *et al.* 1969). Fama (1970, 384) somehow sealed this early development by reviewing the 1960s research and formulating the definition of the efficient market hypothesis as when "prices fully reflect all available information".

2.2 Macroeconomics and New Classical Macroeconomics

"Schools of thought" and "revolutions" constitute a popular organising framework for recounting the history of macroeconomics (e.g. Snowdon and Vane 2005; Blanchard 2016, chap. 24). Historians of macroeconomics have recently challenged the ensuing "potted history" of macroeconomics, which portrays "battles" between "schools" bringing to "revolutions" and resolving in "consensus" or "syntheses" (e.g. Duarte and Lima 2012; Duarte 2016; Sergi 2020). In "potted histories," new classical macroeconomics usually refers to a set of contributions by Lucas, Sargent, and a handful of their co-authors; this "school" started with Lucas and Rapping (1969) and expanded throughout the 1970s, while facing rival schools ("Keynesians," "disequilibrium theory") and alternative schools ("monetarism"). According to the same narrative, new classical macroeconomics was followed, from the 1980s onwards, by various other schools, extending or amending the original new classical macroeconomics' contributions: "real business cycles" (RBC; e.g. Kydland and Prescott 1982), "new Keynesian

economics" (e.g. Mankiw and Romer 1991), and today's "dynamic stochastic general equilibrium" (e.g. Smets and Wouters 2003; Christiano et al. 2005).

Notwithstanding the flaws of the idea of school of thought, the label new classical macroeconomics is intended, in our paper, to characterize a set of authors having indeed worked together in the late 1960s and throughout the 1970s. The cradle of new classical macroeconomics has been the Carnegie Institute of Technology,[9] where Lucas, Sargent, and Edward Prescott worked in the second half of the 1960s.[10] There, as it is well documented (e.g. Sent 1998; Hoover and Young 2011), Lucas, Sargent, and Prescott became familiar with the rational expectations hypothesis formulated by their Carnegie Tech colleague John Muth (1961).[11] This hypothesis constituted for sure a theoretical flagship of new classical macroeconomics—hence the alternative label "rational expectations macroeconomics". And yet, rational expectations *per se* rapidly ceased to be a distinctive benchmark of new classical macroeconomics; as soon as, for instance, Fischer (1977) and Phelps and Taylor (1977), rational expectations were used by macroeconomists who, in potted history's terms, belonged to different schools.

[9] The Carnegie Institute of Technology ("Carnegie Tech") became in 1967 the "Carnegie Mellon University," after the merge of the Carnegie Institute of Technology with the Mellon Institute of Industrial Research.

[10] By the mid-1970s, all these authors had moved to the University of Chicago and to the University of Minnesota, which earned new classical macroeconomics yet another nickname, "freshwater macroeconomics."

[11] Before that, Muth's rational expectations concept (Muth 1961) had gone relatively unnoticed for almost a decade, remaining "a solution in search of a problem" (Young et al. 2004, xi; see also Sent 2002; McCallum 2016). The earliest application of rational expectations to a macroeconomics is actually to be found in Lucas ([1966] 1981)'s unpublished manuscript.

For historians, new classical macroeconomics is thus more distinctively characterised by two other principles. First, it relies on a particular dynamic general equilibrium methodology: namely, fluctuations in output, prices, and employment is represented as the market-clearing outcome of individuals' choices within an intertemporal optimisation problem.[12] This particular microfoundational programme (Hoover 2012) is combined with the idea that, within an incomplete information setting, changes in money supply drive changes in output, inflation, and employment.[13] The counterpart of this proposition is that, when complete information becomes available, changes in money supply result only in changes in the general price level—in short, predictable monetary policy is ineffective for altering output and employment level. This conclusion, strengthen notably by Sargent and Wallace (1976) and Lucas (1976), rapidly became the main fault line in the 1970s debates between new classical macroeconomics and the rest of the macroeconomic profession in the US. Indeed, since the 1950s, macroeconomists had invested their efforts in providing macroeconomic models (see e.g. Boumans and Duarte 2019), supporting and designing active stabilization policies, including monetary policies.[14] Such efforts culminated with the development the large-scale macroeconometric models, notably the Social Science Research Council (SSRC)-Brookings model (Acosta and Pinzon-Fuchs 2020) and the Federal Reserve-MIT-Pennsylvania (FMP) model (see e.g. Backhouse and Cherrier 2019; Rancan 2019).

[12] See e.g. Hoover (1988); Louçã (2004); De Vroey (2016, chap. 9-12); Galbács (2020, chap. 4).

[13] This is *per se* not an original idea, but rather an insight shared with the monetarist school of thought—which resulted in new classical macroeconomics being also dubbed "monetarism mark II."

[14] "Potted history" usually identifies these modelling efforts as part of a "Keynesian" school of thought, since they were, theoretically, broadly inspired by John Hicks's IS-LM reinterpretation of John Maynard Keynes *General Theory*,.

The Sargent-Shiller-Modigliani debate addressed in our paper (section 3) belongs to this context of challenges towards large-scale macroeconometric models and monetary stabilization policies. Modigliani had been at the forefront of the construction of the FMP model and, more particularly of the development of its financial and banking sector (Acosta and Rubin 2019). Most of Modigliani's 1960s' work on the term structure of interest rates, which was criticized by Sargent (1972; section 3), was tightly connected to the FMP project and, more broadly, to a line of work pursued by macroeconomists in the 1950s and in the 1960s over financial issues (portfolio choice theory, corporate finance, asset pricing) (notably, Tobin 1958; Modigliani and Miller 1958).[15]

2.3. Muth's Legacy and the 1960s Interactions Between Rational Expectations and the Efficient Market Hypothesis

[INSERT Figure 1 here]

Figure 1: The Development of the Efficient Market Hypothesis and of New Classical Macroeconomics

Figure 1 summarizes our survey of the development of the two approaches. Figure 1 also clarifies the timeframe in which one could assess influences of one research programme over the other, as claimed by self-produced narratives (*cf.* Introduction). The efficient market hypothesis research programme clearly *predates* the development of the new classical macroeconomics approach: it would be then obvious, as Ross did, to see an influence of the

[15] See Ingrao and Sardoni (2019). However, these developments seem to have been parallel to those of the efficient market hypothesis research programme, as outlined above (2.1).

former on the latter. However, in order to properly discuss the matter, one should clarify what 'influence' means and how it could be documented by historians.

On the meaning of influence, two interpretations seem relevant in our case. One could consider influence as 'common ancestry' or 'intellectual legacy': if two approaches are inspired, to any degree, by the same set of works, they would henceforth share similar methodological or theoretical insights (Allisson and Missemer 2020). Alternatively, one could define influence as the cross-fertilization of ideas, resulting from intellectual dialogue between independently developing research programmes. We shall call such form of influence as an 'interaction'. Interactions are notably supported by interpersonal relationships, such as attending the same conferences or seminars, being trained in the same programmes by the same instructors, working at the same university or in the same department, etc. To document historically either concept of influence (common ancestry or interaction), historians rely usually on three different forms of evidence: co-citation in published writings, personal recollections (oral history, autobiographies), and archives (notably correspondence).

In the case of the efficient market hypothesis and new classical macroeconomics, influence as common ancestry shall be investigated by surveying the role of John Muth and his 1961 paper "Rational Expectations and the Theory of Price Movements".

Muth's influence on new classical macroeconomics is well-known.[16] And yet, there is little evidence of Muth's influence on the 1960s efficient market literature under the form of co-citation. Few articles in financial economics published before 1972 either cite Muth (1961), or

[16] All papers in new classical macroeconomics cite Muth (1961); Lucas and Sargent celebrated Muth as the pioneer of rational expectations in oral histories (Hoover and Young 2011) and autobiographies (e.g. Lucas 1996).

cite any other of Muth's works, or mentions "Muth" or "rational expectations". Most of these do not belong to the efficient market hypothesis research programme and most are found in four PhD dissertations (defended between 1961 and 1966); moreover, mentions of Muth are incidental and peripheral (see Appendix). These few mentions of Muth (1961) by PhD students point towards some very localised reception of rational expectations in the emerging financial economics, although this has not resulted in any fruitful line of publications.

Scarcity of citations does obviously not constitute, alone, sufficient evidence of the absence of influence.[17] Turning to other possible forms of evidence, we examined existing oral histories (interviews, autobiographies). These provide inconclusive evidence on the kind of common ancestry. Young and Hoover (2011, 22) have asked Lucas: "When rational expectations and the efficient market hypothesis were first connected?" The answer suggests that the two ideas were evolving independently:

> *Merton Miller was on both thesis committees. He was on Jack's [Muth] committee at Carnegie Tech; and when he moved to Chicago, he was in Gene Fama's committee. So I asked him that question once, and said "we didn't see*

[17] An author, or group of authors, could for instance purposefully avoid citing or mentioning works that are not in line with her/their own framework; alternatively, if an idea is common knowledge across a given community, citation or mention could also pass undetected a bibliometric investigation. However, these motives seem rather unplausible in our specific case, as Muth's framework is not inconsistent with the efficient market hypothesis framework: and indeed, Muth (1961) and rational expectations will be later cited and mentioned by financial economists (*cf.* section 4 and 5). Similarly, it seems unplausible that Muth's article had come to be considered common knowledge, undeserving citation, already in the 1960s—as already pointed out by secondary literature (e.g. Sent 2002; Young et al. 2004; Hoover and Young 2011).

> *it". He knew both theses, but he didn't see that they were saying very similar things. (Lucas in Hoover and Young 2011, 22)*[18]

Although not cited and not unambiguously remembered, it is still possible that a form of dialogue existed between Muth and the efficient market research programme, *via* interpersonal interactions—although such interactions have not been documented. In their detailed history of rational expectations, Young et al. (2004) have highlighted that Muth's individual work was part of a wider research network on expectations, spanning over a decade, and ultimately resulting in an influential collective volume, edited by Charles Holt, Modigliani, Muth and Herbert Simon (Holt et al. 1960). The Carnegie Graduate School of Industrial Administration (GSIA)[19]—where Muth had been a student then a professor—was the centre of this research network (Rancan 2009; Klein 2015), and Muth's (1961) idea of rational expectations resulted directly from the discussions summarized in Holt et al. (1960; see Young et al. 2004, chap. 3).

The University of Chicago Economics Department (through the Public Finance and Money workshop) was also involved with the research on expectations led by the Carnegie GSIA network (Young et al. 2004, 54).[20] However, Young et al. (2004) neither mention nor identify any interaction between this research network on expectations and the efficient market hypothesis research programme. Although undocumented, it remains plausible that Muth (or anyone aware of Muth's work) discussed Muth (1961)'s intuition with some financial

[18] Fama confirmed Lucas's narrative (Fama, personal communication, February 14, 2020).

[19] Carnegie GSIA constituted in many ways Carnegie Tech's "business school" (Klein 2015), although it was not literally a "business school"—at least not until 2004 (when it has been renamed "Tepper School of Business").

[20] Neil Wallace (in Hoover and Young 2011, 9) remembers that Muth's paper was well known since 1961-1963 to Chicago's *economics* graduates.

economists working at CGBS.[21] However, it is also true that GSIA and CGBS were developing their research activities following different paths. Few years after its foundation in 1949, GSIA, notably under Simon's leadership, had rapidly established a solid reputation in "management sciences," rooted in operational research, behavioural sciences, and engineering (co-sponsored by military funding, such as the Office of Naval Research; see Rancan 2009; Fourcade and Khurana 2013; Klein 2015). Changes at CGBS started later (at the end 1950s), were focused on financial economics, and somehow aimed at building an "anti-GSIA" business school (Fourcade and Khurana 2013, 146).

Without looking at direct interpersonal interactions, it is possible that Muth had been reading ongoing work in financial economics and that this (among other things) inspired him in writing his 1961 article. One possible lead to this connection is through literature in agricultural economics. Muth (1961) applied the idea of rational expectations to the cobweb theorem—a topic distinctive of agricultural economics. Like Muth's, early financial economists' research was also related to agricultural markets, in particular to the understanding of speculators' expectations in derivatives agricultural markets. Holbrook Working (1949; 1958) formulated a hypothesis of "ideal expectations" (statistically unbiased expectations) for explaining the behaviour of futures prices (Berdell and Choi 2019). Samuelson (1957)'s model of speculation on perishable commodities featured expectations that "as in Muth … are the predictions of the model itself" (Young et al. 2004, 20), although they rather relied on the (already existing) idea of "perfect foresight", i.e. a form of certainty equivalence (*ibid*.).[22] Samuelson's most famous

[21] Moreover, Richard F. Muth, an urban economist and John F. Muth's older brother, had been a PhD student, then an Associate Professor at CGBS until 1964 (Young et al. 2004, 78).

[22] Muth (1961, 322-330) did indeed refer to the problem of speculation (in the case of inventories) and did present his rational expectations hypothesis as describing a situation where

extension of this preliminary work was precisely his 1965 martingale model. In his account of Samuelson's contribution to financial economics, Merton (2006) suggests that early versions of Samuelson (1965) are likely to have had an impact on Muth's rational expectations, through Samuelson's talks presenting his paper, including one held at Carnegie (Merton 2006, 14).[23] The connection between Working (1958), Muth (1961), and Samuelson (1957) had been noticed already in the mid-1960s by Samuelson's PhD student F. Helmut Weimar, in his dissertation "The Dynamics of the World Cocoa Market" (Weimar 1966a); but Weimar's idea went unnoticed.[24]

In a nutshell, any early encounter between Muth's rational expectations idea and the efficient market hypothesis research programme remains for the moment a possibility, with no decisive evidence available so far (either in form of co-citation, oral history, or archives), though both concepts seem known to at least few people in both communities—setting the stage for a later association. The thesis that the efficient market hypothesis and new classical macroeconomics are related through common ancestry (Muth) remains then uncorroborated.

"there would be no opportunities for the 'insider' to profit from knowledge" (*ibid*., 318). However, Muth does not refer to Samuelson's article or any other work in this vein.

[23] However, Samuelson claimed that he had no influence on Muth (Letter to Bernstein, 01/02/1991. Correspondence with Peter Bernstein, Box 16, 1948-2009. Paul A. Samuelson Papers, 1933-2010 and Undated. David M. Rubenstein Rare Book and Manuscript Library, Duke University). See Boianovsky (2020) for a comprehensive account of Samuelson's thought about economic dynamics.

[24] Weimar (1966b)'s short "Comment" in the *American Economic Review*, based on his dissertation, scores only 3 citations between 1966 and 1973, all by agricultural economists. Moreover, Weimar left academia after his PhD, to work for a private corporation, the National Biscuit Company (Weimar 1966a, 378); he never published any other academic paper after 1966.

Conversely, a direct (and later) interpersonal interaction between new classical macroeconomics and the efficient market hypothesis is attested by individual recollections. This interaction started with the arrival at Carnegie GSIA of Richard Roll, in September 1967. Roll came from CGBS, where he had just completed his PhD dissertation under Fama's supervision.[25] Roll's dissertation (Roll [1968] 1970) applied the idea of efficient markets to the bond market.[26] Lucas, in his Nobel Memorial Prize autobiography, recalls that "Dick Roll, a student of Eugene Fama's at Chicago, brought the ideas of efficient market theory to GSIA" (Lucas 1996). Sargent mentioned as well that he became aware of the work of Fama when he met Roll at Carnegie GSIA (Sargent in Sent 1998, 167; Sargent 1996, 17-18). Roll confirms this in his own recollection (Roll, personal communication, 20/02/2020; see also Sent 1998, fn. 7).

3. When Rational Expectations Met the Efficient Market Hypothesis: The Term Structure Debate (1972-1975)

Although we are unable to document the details of the interaction between Roll and his new colleagues at GSIA, we can easily document its outcomes. Several published articles discussing explicitly rational expectations and the efficient market hypothesis appeared from 1972 on.

[25] As mentioned by Fourcade and Khurana (2013, 144), it was not uncommon for students trained at University of Chicago Economics department to join GSIA (Lucas, for instance, joined GSIA in 1963 after completing his PhD in Chicago). However, Roll seems to be one uncommon instance of someone joining GSIA while coming from CGBS (and not from the Chicago Economics Department).

[26] In the published version of Roll's thesis, no explicit mention is made of Muth (1961) or of "rational expectations"; however, note that Roll (personal communication, 20/02/2020), conversely to Fama (*cf. supra),* argues retrospectively that he was already well-aware of Muth's rational expectations while writing his PhD—and so were his colleagues at CGBS.

"Discussing explicitly" means to us two things: (i) the two terms are mentioned in the article (and eventually a reference to Muth 1961 and/or Fama/Samuelson 1965 is made); and (ii) the association of rational expectations and the efficient market hypothesis is paramount to the core argument of the article.[27] Chronologically, the first article fulfilling these criteria is Sargent's "Rational Expectations and the Term Structure of Interest Rates" (1972a).[28]

Sargent (1972) opened a renewed phase of the long-lasting debate on the determinants of the term structure of interest rates (or "yield curve", i.e. the observed relation among the interest rates of bonds that differ only in their maturity). Different theories aiming at explaining the shape of the yield curve have been originally devised by Fisher (1896), John Hicks (1939), and Friedrich Lutz (1940).[29] In the 1960s, the topic was reinvigorated by the flourishing of

[27] This is to say that the two terms are not simply mentioned incidentally, as it is the case, for instance, in a footnote by Lucas (1972): "The assumption that traders use the correct conditional distribution in forming their expectations, together with the assumption that all exchanges take place at the market clearing price, implies that markets in this economy are efficient, as this term is defined by Roll (1968). It will also be true that price expectations are rational in the sense of Muth (1961)." (Lucas 1972, 110, fn.7) Another paper by Nicholas Gonedes, published in *The Accounting Review* in 1972, refers explicitly to Muth (1961)'s rational expectations hypothesis, as the relevant assumption for understanding why systematic forecast errors cannot lead to market inefficiency in Fama's sense (Gonedes 1972, 18). Gonedes was an Assistant Professor in Finance at CGBS since 1969, working alongside Fama and Roll (Gonedes 1972, 11); however, Gonedes's knowledge of Muth's work originated from his sabbatical to Carnegie GSIA in 1971-1972 (Gonedes, Personal communication, 21/09/21).

[28] Laffer and Zecher (1976) followed closely Sargent (1972a)'s argument; although Laffer and Zecher's paper was probably completed in 1971 or 1972 at University of Chicago, it was published only 4-5 years later; we henceforth excluded it from our analysis.

[29] See Brillant (2019) for a historical perspective on these contributions.

econometric testing of these theories.[30] The main point of contention of the 1960s debates on the yield curve was the explanatory power of the so-called "expectations theory" of the term structure. The expectations theory states that, if there are no arbitrage opportunities on the bond market, the current short-term interest rate r_t , and the long-term (time-horizon n) interest rates R_{t+n} should be related by the expected interest rates r^e_{t+n}:

$$r^e_{t+n} = R_{t+n} - r_t \qquad (3)$$

Although very simple, the expectations theory constituted an obvious challenge in terms of econometric testing since it entailed producing some sort of measurement of r^e_{t+n}. In the 1960s, this generally were derived from the adaptive expectation hypothesis (Modigliani and Sutch 1966), in which the expected interest rates were estimated as a function of m past interest rates:[31]

$$r^e_{t+n} = \beta_0 r_t + \sum_{i=1}^{m} \beta_i r_{t-i} + \varepsilon_t \quad (4)$$

Alternative theories of the term structure had suggested that the interest rate differential between long-term and short-term bonds should reflect both expectations *and* a premium for liquidity and/or risk (Hicks 1939). Modigliani and Sutch (1966) developed this intuition into the "preferred habitat theory", which stated that the risk premium varies according to agents' preferences regarding their investment horizon.

The testing of alternative theories of the term structure had already caught the attention of the first generation of financial economists (Malkiel 1966; Roll [1968] 1970). In his PhD

[30] See notably Meiselman (1962); Wood (1964); Modigliani and Sutch (1966; 1967; 1969); Hamburger and Latta (1969).

[31] Meiselman (1962) suggested that expectations are formed through a learning process from past errors; Kane and Malkiel (1967) used questionnaires to measure interest rate expectations directly. However, they also concluded that their measurements supported Modigliani and Sutch's formulation of adaptive expectations.

dissertation, Roll was the first to apply Samuelson's martingale model to the expectations theory.

Following Roll's contribution, Sargent (1972a, 74) suggested two ideas: an alternative way of testing the expectations theory of the term structure ("expectations hypothesis" in Sargent's words); and a reformulation of the expectations theory using rational expectations *a la* Muth (1961). For Sargent, the two "hypotheses" (the expectation theory of the term structure on the one hand, and rational expectations on the other hand) had one single and testable implication, i.e. that the bond market was "efficient":

> *This paper reports some tests of two important hypotheses ... The first is the "expectations hypothesis" ... The second hypothesis is that expectations of investors are rational in the sense of John F. Muth. ... A convenient way to characterize a market that satisfies both of these hypotheses is as an "efficient market". (Sargent 1972a, 74)*

For Sargent, it was straightforward to test this outcome, following the many examples developed in the previous decade by the literature on the efficient market hypothesis: in short, both hypotheses would be corroborated if forward interest rates were proven to follow a martingale.[32]

Sargent (1972a) applied Samuelson (1965)'s relation between forward and spot commodities prices and martingale model (*cf. supra*, equation 1 and 2). The value of the future spot interest

[32] Hence, Sargent used the efficient market hypothesis as a way of econometrically testing the rational expectations hypothesis embedded in new classical macroeconomic models. The same path was taken later by others, e.g. Mishkin (1978; 1983), as one way of shielding the rational expectations hypothesis against criticisms—see e.g. Modigliani (1978)'s attack on Mishkin (1978).

rate (r_{t+n}) should be equal to the forward interest rate F_t^{t+n}(determined at t, for a bond maturing at $t+n$), conditionally to information currently available I_t:

$$F_t^{t+n} = E[r_{t+n}|I_t] \text{ (5)}$$

Following Samuelson's argument, Sargent showed that (5) implies that forward interest rates follow a martingale:[33]

$$E[\, F_{t+1}^{t+n}|I_t] = \, F_t^{t+n} \text{ (6)}$$

Unlike Samuelson and Roll, Sargent presented explicitly equation 5) as an assumption about rational expectations. Henceforth, by applying Samuelson's model to the debate on the expectations theory of the term structure, Sargent brought into this debate more than just an econometric procedure: it introduced the theoretical interpretation of forward prices as entities reflecting information—an interpretation rooted in the efficient market hypothesis. Then, instead of measuring or proxying expected interest rates (as in Modigliani and Sutch 1966), forward interest rates could be treated as reflecting available information about such expectations.

However, Sargent (1972a)'s estimations rejected the martingale hypothesis and therefore the efficiency of the bond market. Nevertheless, Sargent was reluctant to take this result as a rejection of either rational expectations or of the expectations theory of the term structure. Nor did he consider as valid alternatives any "diluted form of the expectations theory", since adding variables as the liquidity premium, although practical in fitting the data, was also "arbitrary" (Sargent 1972a, 94). Abandoning rational expectations was equally unacceptable: to Sargent, this would entail violating the no-arbitrage condition (embedded in the expectations theory), since "suboptimal" (i.e. non-rational) expectations would result in unexploited profit opportunities (*ibid*.).

[33] Assuming a probability distribution with infinite variance. Sent (1998, 33-35) already noticed Sargent's early discussions with Roll on this issue.

Shiller (1972b) wrote the first response to Sargent (1972a).[34] He notably argued that Sargent's information set from equation (5) included only past interest rates and hence neglected "many other factors in talking about the outlook for future interest rates." (Shiller 1972b, 856) A longer reply to Sargent came later, by Modigliani and Shiller (1973).[35] The objective of their paper was to improve the habitat preference theory by discussing the rational expectations hypothesis and the role of inflation in forming expectations. Modigliani and Shiller defined rational expectations simply as "optimal forecasts" or "best guesses". However, they considered that "extrapolative expectations" did abide by this definition, i.e. that expectations based on a weighted sum of past rates did minimize the prediction error for future rates.[36] Modigliani and

[34] Shiller had just completed his PhD dissertation, "Rational Expectations and the Structure of Interest Rates" (1969-1972, under Modigliani's supervision at MIT). Moreover, Sargent was Shiller's colleague at University of Minnesota from 1972 on.

[35] Note that Shiller (1972b) and Modigliani and Shiller (1973) mostly relied on two ideas developed in Shiller (1972a)'s dissertation.

[36] In Shiller dissertation (1972a), the main model represented the interest rate for the n-th period (long run interest rate) as a linear combination of the future one-period rates, which are "forecasted on the basis of any subset of the forecasting variables used by the market plus an error term" (Shiller 1972a, 11). This meant that the relation forecasted *by the econometrician* could rely only on a *subset* of what was used by actual market participants. Typically, such subset would include only past one-period interest rates (as discussed in Shiller 1972a, 36-39**)**. Despite this asymmetry between the econometrician and market participants, the forecast obtained was proven to be "optimal" (in an ordinary least-square sense; Shiller 1972a, 12-14). The idea that there was an asymmetry between the information used by the econometrician and the information used by economic agents was obviously in contrast with the usual definition of rational expectations in new classical macroeconomics. However, Shiller did not discuss this latter issue in his dissertation—which, for instance, did not mention Muth (1961), or, even more relevantly, Muth's early (1960) paper that established the forecast optimality of weighted sum of past variables.

Shiller suggested that Sargent's negative result about the martingale indicated precisely the importance of *past* inflation. While neglected by Sargent, past inflation rates represented, with past interest rates, the main relevant variable to predict long-term interest rates (Modigliani and Shiller 1973, 29).

Sargent remained unconvinced. To him, a model of expectations based on past interest rate and/or on past inflation) was "ad hoc"; such hypothesis was inconsistent with expectation theory and the no-arbitrage condition (Sargent 1972a, 94). Sargent (1973) traced back this mistaken view to Fisher (1930) explanation of the so-called Gibson Paradox. The Gibson paradox refers to the empirical positive correlation between the price level and the interest rate. Such a relationship was viewed as a contradiction of the quantity theory of money that claimed that interest rates are determined by real variables. Fisher (1930) suggested that the Gibson paradox might be explained by a model of inflation expectations with distributed lags. Sargent was sceptical with such an explanation because expectations based on lagged inflation had to be explained: "why people's anticipations of inflation are apparently so slow to adjust?" (Sargent 1973, 447) Sargent argued that past inflation rates (or inflation levels) were not a relevant variable for determining interest rates. Such relation, as estimated by Modigliani-Shiller, relied on the idea that inflation rates causally determined interest rates: for Sargent, on the contrary, causality was "two-way", as current interest rates also contain information about inflation (Sargent 1973, 447; Sargent 1969; 1972b). Following the efficient market 'style of reasoning', he argued that current nominal interest rates contained better information about the expected inflation than past inflation rates.

Sargent's study of the Gibson paradox attracted Fama's attention, getting him involved with the ongoing discussion about the relation between interest rate and inflation. Fama (1975),

applying the market efficiency methodology, restated Sargent (1972a)'s argument: in an efficient bond market, nominal interest rates reflect market information on expected variables. Nominal interest rates can thus be used to extract information about the evolution of inflation expectations: if the real interest rate is constant, all changes in the nominal rate reflect change in the expected inflation. Hence, rather than trying to determine the expected interest rates through past inflation (as Modigliani and Shiller did), Fama reversed the argument and used current nominal interest rates R_t as predictors of future inflation (π_{t+n}):

$$\pi_{t+n} = \beta_0 + \beta_1 R_t + \varepsilon_t \quad (7)$$

As emphasized by Campbell (2014), Fama (1975) provided henceforth an original estimation methodology. In subsequent contributions to financial economics, Fama (1976b; 1980; 1984) and others, will *assume market efficiency* and use market prices for inferring information on expected variables.[37]

Fama (1975) contained another innovation: a reformulation of the efficient market hypothesis 'in the language' of rational expectations. The earlier definitions of the efficient market hypothesis were rather elusive about the equilibrium mechanisms at work. Fama (1965, 94) defined efficiency as a situation where asset prices "represent best estimates of the intrinsic values"—the latter depending on "earnings prospects of the company, which in turn are related to economic and political factors" (Fama 1965, 36). In further refinements, Fama (1970, 384) suggested that asset prices on an efficient market might, for instance, be understood as the equilibrium outcome of the CAPM ("the two parameters model" in Fama's words).[38] Fama

[37] Modigliani and Shiller had a similar intuition, although, for them, "there is little a priori reason for holding that [the nominal rates] should, in fact, have significant informational content" (Modigliani and Shiller 1973, 35).

[38] However, the definition embedded into the CAPM relied on a one-period analysis, where expectations were exogenous and not rational (Sharpe 1965).

(1975) laid down the foundations of a new definition of the efficient market hypothesis as a rational expectations equilibrium: "an efficient market correctly uses all relevant information in setting prices" (Fama 1975, 269) or "correctly uses all available information" (Fama 1975, 270); such "correct" use of information is formalized as the expected probability distribution of a variable equating the true probability distribution of that variable (Fama 1975, 270, eq. 6). This definition was then use by Fama in his textbook *Foundations of Finance* (1976a), and still remain unchanged since (Fama 2014).[39]

4. Lucas' Contribution to the Efficient Market Research Program

The previous section illustrated how, by the beginning of the 1970s, Sargent was aware and familiar with the market efficiency research programme, using it in his own work on rational expectations macroeconomics. However, we concluded, this was not a unidirectional influence from financial economics to new classical macroeconomics. Sargent (1972a)'s original combination of rational expectations and market efficiency, and the ensuing debates, led Fama to reformulate his definition of market efficiency, whose theoretical foundations were still tenuous.

Like Fama (1975), Lucas' "Asset Prices in an Exchange Economy" (1978[40]) aimed at providing new theoretical foundations for the efficient market hypothesis, foundations based on rational expectations equilibrium models. Lucas explicitly set his article as a contribution to financial economics and to the literature on the efficient market hypothesis. In this respect, he connected

[39] Fama (1976c) also used this new formulation to answer LeRoy (1976)'s criticism of Fama (1970)'s definition of the efficient market hypothesis.

[40] Note that the article was completed in September 1975 (Lucas, 1978, 1444).

both his result and his assumptions to Fama *and* Muth;[41] however, the formal model developed by Lucas was not inspired by Fama (1975) but, like the model in Sargent (1972a), by Samuelson (1965)'s formulation of the efficient market hypothesis as a martingale, and LeRoy (1973)'s refinement of Samuelson's model (as explicitly acknowledged; Lucas 1978, 1444, fn. 10).

In his model, Lucas discussed the price dynamics for a financial asset, in a single-good pure exchange economy where productivity of firms varies stochastically. In this model economy, the financial asset represents "claims on part of the output", which is produced exogenously (i.e., with no inputs) by a large number of heterogeneous firms. Households (which were assumed identical) purchased assets in a "competitive stock market". The problem set by Lucas was thus to determine the dynamic price sequence for the financial asset and the single consumption good, assuming that such prices were market clearing prices (i.e., the prices for which, at each period, households consume all the current output while holding all the existing assets). Equilibrium prices for each asset (p_t) correspond to the current (discounted at rate β) value of the expected return (y_{t+j}), conditionally to available information I_t:

$$p_t = E(\sum_{j=1}^{n} \beta_i y_{t+j} | I_t) \quad (8)$$

In this framework, the equilibrium (efficient) asset prices might either follow a martingale process, or they might not: when household are risk-neutral ($\beta = 1$), (8) corresponds precisely to Samuelson's martingale model (*cf. infra*, equations 1-2); but, without this restrictive assumption, (8) does not follow a martingale—and yet, markets are efficient. In other words,

[41] "The analysis is conducted under the assumption that, in Fama's terms, prices 'fully reflect all available information,' an hypothesis which Muth (1961) had earlier termed 'rationality of expectations.'" (Lucas 1978, 1429)

any observed statistical characteristic of a sequence of prices was not a *sufficient* condition to draw inference on the efficiency of markets:

> *With respect to the random character of stock prices, it is evident that one can construct rigorous economic models in which price series have this characteristic (a martingale) and ones with equally rational and well-informed agents in which they do not. This would suggest that the outcomes of tests as to whether actual price series have the Martingale property do not in themselves shed light on the generally posed issue of market 'efficiency'. (Lucas 1978, 1444, Lucas's emphasis)*

A more explicit claim about the *intentions* of the paper was to be found few lines later, where Lucas clarified his methodological aspirations:

> *In the main, however, this paper is primarily methodological: an illustration of the use of some methods which may help bring financial and economic theory close together. (Lucas 1978, 1444).*

The bottom line of Lucas's paper was therefore that efficient markets were rather characterized by the equilibrium nature of asset prices (based on rational expectations) than by any particular statistical distribution.[42] We can therefore interpret Lucas's methodological ambition, as a new classical macroeconomist, to push financial economics further towards formalizing a general equilibrium model of asset pricing.

In this respect, Lucas's paper contributed to the process (started earlier, *cf. supra*, 2.1) of 'anchoring' the efficient market hypothesis, as a field of research, into a theoretical 'rigorous' concept of equilibrium and into a practice of mathematical modelling (e.g. Hall 1996, 42).

[42] Note that similar arguments were raised later by Sims (1980)'s working paper "Martingale-Like Behavior of Prices".

Moreover, as already shown by Andrada (2016), Lucas (1978) remains today Lucas's most-cited article alongside Lucas (1976). This high-citation counts seems directly related with the immediate echo of Lucas (1978) in financial economics (see Appendix, Table A.3). Our story emphasizes how Lucas (1978) actually came as a further (or, even, final) step into a sequence of debates and interactions that dates back to Sargent (1972).

5. Rational Expectations Equilibrium Models and Challenges to the Efficient Market Hypothesis

In the previous sections, we documented how the debate about the term structure materializes the first interaction between new classical macroeconomics and the efficient market hypothesis research programme. The historical significance of this interaction needs, though, to be assessed by considering its broader legacy in the following years. This last section illustrates that a growing dialogue between macroeconomics and financial economics had developed at the turn of the 1970, as a result of the interaction between new classical macroeconomics and the efficient market hypothesis research programme. In short, this section answers the second question outlined in the Introduction: What were the consequences on the development of financial economics of the dialogue with new classical macroeconomics?[43]

One consequence was definitional: following Fama (1975) and Lucas (1978), the renewed definition of the efficient market hypothesis (*cf. supra*) started to be routinely employed in surveys (e.g. Jensen 1978; Kantor 1979), books (e.g. Mishkin 1983; Sheffrin 1983) on both rational expectations and the efficient market hypothesis. One example is Steven Sheffrin's

[43] As discussed in the Introduction, the efficient market hypothesis remained in the background of new classical macroeconomics and of the later approaches it inspired, all of which implicitly or explicitly assumed efficient financial markets (e.g. Mehrling 2016).

Rational Expectations (1983), a detailed exposition of the rational expectations literature, in which the efficient market hypothesis was presented as an application of the rational expectations hypothesis to financial markets.[44] This change in the definition of the efficient market hypothesis is still current today (*cf.* Introduction).

There is however a second set of consequence: that is, the opening of the intellectual boundaries between financial economics and macroeconomics at the turn of the 1970s. It is well known (e.g. Wang 2008) that, during this period, the market efficient hypothesis came under intense scrutiny and criticism, leading to the emergence of alternative research programmes. What has gone unnoticed so far by is how these criticisms fuelled broader discussions on the content and methods of financial economics, and its place within economics (e.g. Merton and Fischer 1984; Merton 1987; Summers 1985; Ross 1987).[45] In this section, we briefly outline two key examples, illustrating the fruitfulness, for financial economics, of the early 1970s interaction with new classical macroeconomics.

5.1 Rational Expectations and the Empirical Challenge to the Efficient Market Hypothesis

[44] Sheffrin argues that, by this time, the association between rational expectations and market efficiency "was widespread. We often would talk about using regression models for rational predictors, so that the error terms in prediction were orthogonal to the regressors. For efficient markets, the 'regressors' would include publicly available information. We realized that rational expectations was a deeper, model based concept but some of its immediate implications applied to efficient markets." (Sheffrin, personal communication, February 14, 2020)

[45] Moreover, an institutional shift had occurred. Contributions to financial economics (such as those scrutinized in this section) were increasingly produced by 'outsiders'—that is, scholars mostly trained in economics departments, and not in business schools.

It is widely acknowledged that the 1980s have been characterized by several empirical challenges against the efficient market hypothesis (e.g. Wang 2008). The formulation of efficient market hypothesis based on rational expectations (as in Fama 1975) became the benchmark, against which "anomalies" of market efficiency were detected (Jensen 1978, 95).[46] Among the most influential contributions in this line of work are Shiller's twin papers "The Volatility of Long-Term Interest Rates and Expectations Models of the Term Structure" (Shiller [1979] 1981a) and "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?" (Shiller [1980] 1981b).[47] Shiller's participation to the debate on the term structure had already set the path for these two contributions.

Shiller's methodology for testing the efficiency of the bond market was original, insofar as it did not start, as in Roll ([1968] 1970) and Sargent (1972a), from a statistical assessment of the random character of the interest rate. Conversely, Shiller began with developing a simple class of linear rational expectations models of the long-term interest rate. In Shiller's model, the current (t) long-term interest rate for a bond maturing at time n (R_t^n) should be equal to the present expected value of the sum of one-period interest rates (r_t):

$$R_t^n = \frac{1-\gamma}{1-\gamma^n} \sum_{k=0}^{n-1} \gamma^k E_t(r_{t+k}) \quad (9)$$

[46] Although empirical analysis remained highly fashionable in finance, the shift towards a more formal and theoretical approach implied a reassessment of the methods for testing the efficient market hypothesis. Somehow relating to Lucas (1978) intuition, traditional tests asset prices as random walks or martingales were progressively complemented with tests about "above-average profitability" (Summers 1986: 591-592) or "excessive volatility" (*cf. infra*).

[47] For the stock market, LeRoy and Porter (1981) provided similar results to Shiller's (1981a [1979]).

with γ the inverse of the discount factor.[48] As the reader will note, the core of Shiller's formalisation was simply a rational expectations version of the expectations theory of the term structure, precisely as suggested by Sargent (1972a).

Shiller noted then that long-term interest rates, as defined by the above equation, could be computed retrospectively (ex-post) using observed short-term interest rates (r_t^*) and assuming a value of $\gamma = 0.98$. Such "ex-post rational rates" (R_t^{n*}) are:

$$R_t^{n*} = \frac{1-\gamma}{1-\gamma^n} \sum_{k=0}^{n-1} \gamma^k (r_{t+k}) \quad (10)$$

When comparing the series of ex-post rational rates above with the actual (observed) series of long-term interest rates for 1966-1977, the discrepancy was apparent: the observed long-term rates were much more volatile than the ex-post rates predicted by the rational expectations model (Shiller [1979] 1981a, Figure 1 and Figure 3). This disqualified an explanation of long-term rates as the "averaging, implicit in rational expectations models," of short-term rates (Shiller [1979] 1981a, 1192). Although the integration of "new information" into expectations could eventually justify the observed volatility, Shiller argued that it was unlikely that such "new information" would appear that often, and that long-term rates seemed rather "disturbed by transient effects unrelated with expectations" (Shiller [1979] 1981a, 1214).

Shiller's paper ended with a statistical analysis of the discrepancy between the ex-post rates and observed rates. Notably, Shiller introduced for the first time a set of zero-covariance restrictions on observed long-term and short-term rates, in order to test the efficiency of the

[48] The original version of the model also included a constant liquidity premium, which was omitted here for sake of simplicity.

bond market. These restrictions were violated by the data: non-null covariance, implying the 'forecastability' of interest rates, contradicted the efficient market hypothesis.

Shiller ([1980] 1981a) extended this reasoning to the volatility of stock prices. Again, he highlighted how the observed volatility of these prices was inconsistent with a rational expectations model equating the equilibrium price of stocks with their expected returns (measured as the ex-post observed dividends). Like for bonds, the excess volatility of the observed stock prices was combined with a violation of zero-variance restrictions, therefore implying the existence of profit opportunities (Shiller [1980] 1981a, 423-424).

Like Shiller's, several other contributions (e.g. Summers 1986; De Bondt and Thaler 1985; Poterba and Summers 1988) relied on rational expectations models to produce new tests of market efficiency—although with different angles.[49] Their findings on the 'inefficiency' of the bond and stock market have not been the end of the line for these authors. Conversely, their goal became, as Shiller put it, to find alternative answers to a "more interesting (from economic standpoint) question: what accounts for movements of real stock prices?" (Shiller [1980] 1981b, 424) Price valuation became indeed the central issue for the rise of behavioural finance (Shiller 1984; De Bondt and Thaler 1985). This entailed the development of several explanations of asset prices determination, all relying on assumptions about individual behaviour that clearly departed from the optimizing rationality implicit in the rational

[49] Summers and Poterba focused on the mean-reversion phenomenon, as further evidence of possible misevaluation of assets prices. De Bondt and Thaler focused on market "overreaction" (i.e. the tendency of market participants to overweight new information and underweight prior information) as a possible explanation of the excessive volatility highlighted by Shiller. However, several other contributions actually criticized Shiller's method and result (for a short summary see Fama 1991, 1586; Shiller 2003, 84-90).

expectations hypothesis. Shiller's test of volatility, based on a rational expectation model, introduced thus a new framework for testing the empirical implications of the efficient market hypothesis, while paving the way to new theoretical developments in financial economics (the price valuation research programme). It can be considered as a major legacy of the early 1970s term structure debate.

5.2 Rational Expectations and the Theoretical Challenge to the Efficient Market Hypothesis

As we just suggested, the development of behavioural finance (bringing alternative theoretical insights to the efficient market hypothesis) actually arose from an empirical criticism of the predictions of the efficient market hypothesis. Rational expectations models, as in Shiller's work, were paramount to this development.

A different research path resulted from a rather theoretical criticism, as for instance in the literature on "rational bubbles" (Blanchard 1979; Blanchard and Watson 1984; Tirole 1982; Tirole 1985). Like the new research program on price valuation, the literature on rational bubbles illustrated that, within dynamic rational expectations models, asset prices could depart from their efficient price (defined as the sum of future returns).

Another example of this line of theoretical criticism is the literature that used rational expectations models to discuss the dissemination of information in financial markets. The seminal paper for this line of research was Grossman and Stiglitz's "On the Impossibility of Informationally Efficient Markets" (1980), famously rebranded the "Grossman-Stiglitz paradox".[50] The model developed by Grossman and Stiglitz relied explicitly on Lucas (1972)

[50] Note that the paper draws on the authors' previous work on the role of information in determining market equilibrium (Grossman and Stiglitz 1976).

incomplete information model (the seminal model for new classical macroeconomics). Grossman and Stiglitz used Lucas's model to investigate whether efficient prices (i.e. "prices reflecting all available information") were a property of a rational expectations equilibrium model (Grossman and Stiglitz 1980, 393).

Grossman and Stiglitz's model described a market featuring two types of individuals: "informed traders", who have acquired, at a fixed cost, information on the future returns of a financial asset; and "uninformed traders", who did not to pay for information. The latter, from observing the asset price on the financial market, are only able to infer (with no cost whatsoever) information about future returns. However, this inference is not perfect: even if the asset price reflects some of the information about future returns (acquired by informed traders), the price also reflects noise generated from a stochastic component.[51] Market participants will acquire information only if its marginal cost is less than its expected returns. The equilibrium (i.e. the absence of profits opportunities) occurs when the expected utility of the informed traders equals the expected utility of the uninformed traders. If the expected utility of informed traders is greater than those of uninformed traders, then some of the uninformed traders switch to the informed traders group. If the population of informed traders increases, their expected utility decreases since the relative gains of informed traders on uninformed traders decrease. Furthermore, if the population of informed traders increases, information has a greater impact on price (relatively to noise) and then more information is available to the uninformed.

[51] Like in Lucas (1972)'s model agents observing individual prices are not able to distinguish changes in relative prices from changes in nominal prices.

After proving the existence of an equilibrium of this economy, Grossman and Stiglitz investigated notably the case where the price "fully reflects all information," as defined by the efficient market hypothesis. Their model showed that, if the price "fully reflect[s] all information" and information is costly, then the market collapses. Indeed, since the price reveals all the information, informed traders would stop acquiring it. Since all traders behave identically, they should all become uninformed; however, if all agents are uninformed, there is then a profit opportunity for those that would decide to purchase information. Hence, Grossman and Stiglitz showed that freely available information is not only a *sufficient* condition for the efficient market hypothesis to hold, but that it is a *necessary* condition. However, if the information is freely available, then, the authors argued, financial markets and competitive prices become purposeless, since their role should be precisely to convey information.

Grossman and Stiglitz did not aim at challenging the efficient market hypothesis, although they did want to redefine it under less restrictive conditions (incorporating inefficiency and costly information). This contributed to the development of a new literature, analysing the information transmission in financial markets: see, for instance, the no-trade theorems (Milgrom and Stokey 1982; Tirole 1982), the noise traders (Black 1986; De Long et al. 1990), and the issue of information aggregation (Hellwig 1980; Diamond and Verrecchia 1982; Admati 1985; Kyle 1985).

6. Conclusion

Is it then true that "[t]he rational expectations school of macroeconomics was clearly influenced by the intuition of efficiency in finance" (Ross 2008, 6)? This paper has nuanced the existing claims on the influence of the efficient market hypothesis on new classical macroeconomics,

by presenting an historical appraisal of the interactions between these two research programmes.

We discussed how each research programme seems to have been developing independently in the 1960s: for the moment, no decisive evidence can credit the thesis of a "common ancestry," going back for instance to Muth. The arrival of Roll at Carnegie Tech (1967) seems to be the only firmly documented starting point of an interaction between new classical macroeconomics and the efficient market research programme. We have then assessed the first outcomes of this interaction, i.e. Sargent (1972a)'s article and the ensuing debates with Shiller, Modigliani, and Fama. Sargent (1972a) is the first recognizable instance of a published work explicitly and consistently articulating the rational expectations hypothesis with the efficient market hypothesis. Despite this crucial role, this contribution by Sargent had been so far overlooked by historians interested in the relationship between financial economics and macroeconomics. Finally, historians have mostly investigated and argued about the impact of the efficient market hypothesis on macroeconomics, especially on the RBC approach. The final section of our paper took the alternative perspective: we uncovered how the term structure debate had a lasting influence on the literature in financial economics at the end of the 1970s, reshaping its boundaries with macroeconomics. Two examples (Shiller's volatility paradox and the Grossman-Stiglitz paradox) illustrate how new classical macroeconomics' models were used for extending research in finance beyond the original boundaries of the efficient market hypothesis research programme.

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Figures

Figure 1

Insert Figure 1

Appendix – Bibliometric Analysis

Table A.1 - Co-occurrences of "rational expectations" and "efficient market hypothesis" (1961-1972)

	Author	**Date**	**Title**	**How published**
1	J. B. Bossons	1962	On the Specification of the Time Structure of Economic Relationships	PhD Dissertation, MIT
2	W. L. Steiger	1963	Non-Randomness in the Stock Market: A New Test on An Existent Hypothesis	PhD Dissertation, MIT
3	W. L. White	1964	The Debt-Equity Ratio, the Dividend Payout Ratio, Growth and the Rate at which Earnings are Capitalized: An Empirical Study	PhD Dissertation, MIT
4	M. F. Tuite	1966	An Analysis of Variables Which are Associated with the Sensitivity of Common Stock Prices to News	PhD Dissertation, University of Indiana
5	G. J. Benston	1967	Published Corporate Accounting Data and Stock Prices	*Journal of Accounting Research*
6	P. M. Laub	1971	The Dividend-Earnings Relationship: A Study of Quarterly Corporate Panel Data	PhD Dissertation, University of Chicago, CGBS
7	R. E. Lucas	1972	Expectations and the Neutrality of Money	*Journal of Economic Theory*
8	T. J. Sargent	1972	Rational Expectations and the Term Structure of Interest Rates	*Journal of Money, Credit and Banking*
9	N. J. Gonedes	1972	Efficient Capital Markets and External Accounting	*The Accounting Review*

Table A.1 presents research results of co-occurrences, between 1961 and 1972, of terms relating to rational expectations and to the efficient market hypothesis in *Google Scholar*.[52] Different combinations of these terms have been tested, to ensure robustness of the results. Incomplete, duplicated or simply erroneous bibliographical records have been cleaned manually, as well as "false" occurrences (such as, for instance, citations of other authors by the name of Muth).

These results point to only six documents before 1972 including wording connected to rational expectations and to the efficient market hypothesis, and three documents published in 1972 (on which we commented already *supra*, section 3). Five out of six documents published before 1972 are PhD dissertations. The only article published before 1972 and fulfilling our co-occurrence criteria is a piece by George J. Benston, published in the *Journal of Accounting Research* (Benston 1967). This article belongs clearly to the efficient market hypothesis research programme, as it studies the informational content of corporations' accounts for stockholders. However, Benston only cites Muth incidentally, without using the rational expectations hypothesis in the core of his analysis.

Similar peripheral mentions of Muth (i.e. mentions that lie outside the main scope of the document) are found in four out of five dissertations. The dissertation by William Steger, defended at the MIT in 1963 under the supervision of Cootner, refers to Muth (1961) on a

[52] The list of keywords for rational expectation is: "Muth", "rational expectation*", "expectations * rational". The list of keywords for the efficient market hypothesis is "Eugene * Fama", "Paul * Samuelson", "Paul * Cootner", "efficient market", "random walk hypothesis", "efficient * market". The stars ensure that any variation in wording is included in the search: for instance, "efficient * market" will match "efficient capital market," "efficient bond market," "efficient stock market," …

footnote (page 3 of the Introduction), as one example about how economists formulate expectations. Muth or rational expectations are neither mentioned nor used later. A similar mention of Muth *en passant* is found in White's dissertation, also defended at the MIT, under Cootner's supervision. Moreover, although White does engage with the efficient market literature, his dissertation rather belongs to the subfield of corporate finance. Like Steger and White, the dissertation defended by Matthew Tuite at University of Indiana in 1966 mentions only incidentally Muth (1961), while surveying the literature on expectations in economics (Tuite 1966, 22). Here, again, the analytical affinity between the two concepts does not seem to be clearly grasped by the author.

Conversely, the dissertation by Michael Laub, defended in 1971 at CGSB (under the supervision of Arthur Zellner, Fama and Merton Miller; Laub 1971, ii), does discuss more substantially the connection between Muth's rational expectations and the efficient market hypothesis (Laub 1971, 33-35). However, this still remained peripheral to the topic of the dissertation. The same remark applies to John Bossons's 1962 dissertation, defended at the MIT under the supervision of Cootner. This is a dissertation rather focused on econometrics, applied to the "random walk hypothesis" (or the "perfect market" hypothesis here) formulated in financial economics. Bossons does refer to Muth at several occasions, most strikingly when arguing that: "the time series formed by the movement through time of a price which is determined in a perfect market will thus be a random walk if expectations are 'rational' [in the Muthian sense] … this condition is sufficient but not necessary" (Bossons 1962, 23).

Table A.2 - Muth (1961)'s citations in finance (1961-1972)

Author	**Date**	**Title**	**How published**	**Field in financial economics**
M. H. Miller and F. Modigliani	1961	Dividend Policy Growth and Valuation of Shares	*The Journal of Business*	Corporate finance
M. H. Miller	1962	Further Comment [on Credit and Risk Rationing]	*The Quarterly Journal of Economics*	Corporate finance
W. L. Steiger	1963	Non-Randomness in the Stock Market: A New Test on An Existent Hypothesis	PhD Dissertation, MIT	Efficient market hypothesis
W. L. White	1964	The Debt-Equity Ratio, the Dividend Payout Ratio, Growth and the Rate at which Earnings are Capitalized: An Empirical Study	PhD Dissertation, MIT	Corporate finance
D. T. Crary	1966	An Analysis of Interrelationships of Leverage Taxation and the Cost of Capital	PhD Dissertation, Ohio State University	Corporate finance
F. H. Weymar	1966	The Dynamics of the World Cocoa Market	PhD Dissertation, MIT	Speculation and futures on agricultural markets
F. H. Weymar	1966	Supply of Storage Revisited	*American Economic Review*	Speculation and futures on agricultural markets

O. H. Poensgen	1966	Valuation of Convertible Bonds: Empirical Results and Conclusions	*Industrial Management Review*	Options pricing
M. F. Tuite	1966	An Analysis of Variables Which are Associated with the Sensitivity of Common Stock Prices to News	PhD Dissertation, University of Indiana	Efficient market hypothesis
G. J. Benston	1967	Published Corporate Accounting Data and Stock Prices	*Journal of Accounting Research*	Efficient market hypothesis
M. Keenan	1970	Models of Equity Valuation: The Great Serm Bubble	*The Journal of Finance*	Asset valuation
P. M. Laub	1971	The Dividend-Earnings Relationship: A Study of Quarterly Corporate Panel Data	PhD Dissertation, University of Chicago, CGBS	Efficient market hypothesis
R. E. Lucas	1972	Expectations and the Neutrality of Money	*Journal of Economic Theory*	Efficient market hypothesis
T. J. Sargent	1972	Rational Expectations and the Term Structure of Interest Rates	*Journal of Money, Credit and Banking*	Efficient market hypothesis
N. J. Gonedes	1972	Efficient Capital Markets and External Accounting	*The Accounting Review*	Efficient market hypothesis

Table A.2 presents all documents published between 1961 and 1972, citing Muth (1961), and belonging, broadly, to the field of financial economics. The classification into fields of financial economics was carried out through our own reading of each paper. We used two main sources to collect the citations of Muth: the bibliographic database of *Web of Science* and the query service Google Scholar. *Web of Science* has reliable indexing information, insofar as all

the documents citing Muth (1961) are also indexed in the *Web of Science* database. However, Web of Science data remains partial, especially for the 1960s. We have supplemented this first source by collecting citation data from *Google Scholar*. If these data are more comprehensive, they are also less reliable, insofar as they contain incomplete, duplicated or simply erroneous bibliographical entries. From Google Scholar data, we have retained four categories of documents whose source are clearly identifiable: documents published in journals (articles, comments, etc.), working papers from known depositories platform (e.g. NBER Working Paper Series), books, and PhD dissertations.

A.3 Lucas (1978)'s citations (1978-1988)

Field	**Number of documents**	**%**
Financial economics	77	66.5 %
Others	53	33.5%

Table A.3 presents the share of documents published between 1978 and 1988, citing Lucas (1978), and belonging to the field of financial economics or management. Citations were collected following the same procedure as for Muth (1961; *cf. supra*). Documents were assigned to one of the two fields by applying a double filter. For articles published in peer-review journals, we assigned to them to the field of "Financial economics" when the journal obviously belongs to this field (e.g. the *Journal of Finance*, the *Journal of Financial Economics*, etc.). For other documents (dissertations, working papers) and for peer-review articles published in generalist journals (e.g., the *American Economic Review*) we applied a

second filter, based on titles' wording: we assigned then to "Financial economics" those articles whose title obviously suggests a relation to financial economics (i.e., asset prices).[53]

[53] The exact list of titles' wording used is: asset*, securit*, speculati*, stock*, share*, futures, shareholder, financ*, portfolio, mutual funds, capital market, efficient market, premium, martingale, present value, variance bound. Again, stars indicate that the search covered any similar wording (e.g. "speculati*" will include both "speculative" and "speculation").