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THREE ESSAYS ON MARKET CONCENTRATION AND TECHNOLOGICAL CHANGE

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Three essays on market concentration and technological change

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Orientador: Prof. Dr. Rafael Saulo Marques Ribeiro

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ATA DE DEFESA DE DISSERTAÇÃO DE **ANA CAROLINA BOTTEGA DE LIMA** Nº. REGISTRO 2018651280. Às quatorze horas e trinta minutos do dia vinte e três do mês de junho de dois mil e vinte, reuniu-se, **por videoconferência**, a Comissão Examinadora de DISSERTAÇÃO, indicada "*ad referendum*" pelo Colegiado do Curso em 09/06/2020, para julgar, em exame final, o trabalho final intitulado **"Three essays on market concentration and technological change"**, requisito final para a obtenção do Grau de *Mestre em Economia,* área de concentração em Economia. Abrindo a sessão, o Presidente da Comissão, Prof. Rafael Saulo Marques Ribeiro, após dar a conhecer aos presentes o teor das Normas Regulamentares do Trabalho Final, passou a palavra à candidata, para apresentação de seu trabalho. Seguiu-se a arguição pelos examinadores, com a respectiva defesa da candidata. Logo após, a Comissão composta pelos professores: Rafael Saulo Marques Ribeiro, João Prates Romero, Gilberto Tadeu Lima e Esther Dweck se reuniu, sem a presença da candidata e do público, para julgamento e expedição do resultado final. A Comissão aprovou com distinção a candidata por unanimidade. O resultado final foi comunicado publicamente à candidata pelo Presidente da Comissão. Nada mais havendo a tratar o Presidente encerrou a reunião e lavrou a presente ATA, que será assinada por todos os membros participantes da Comissão Examinadora. Belo Horizonte, 23 de junho de 2020.

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"Enquanto, por efeito de leis e costumes, houver proscrição social, forçando a existência, em plena civilização, de verdadeiros infernos, e desvirtuando, por humana fatalidade, um destino por natureza divino; (...) em outras palavras, e de um ponto de vista mais amplo ainda, enquanto sobre a terra houver ignorância e miséria, livros como este não serão inúteis."
Victor Hugo, Os Miseráveis

Resumo

O declínio da competição em muitas economias avançadas e seus efeitos no investimento, na produtividade e na desigualdade ganharam atenção recentemente, mas a maioria dos trabalhos existentes relega alguns aspectos importantes desse processo. Esta dissertação visa retomar o estudo da concentração de mercado, argumentando que esse processo pode ser melhor compreendido por meio de sua relação central, embora intrincada, com a mudança tecnológica. Com isso, fornecemos contribuições para a literatura teórica e empírica. Com base na combinação de elementos da abordagem neo-Schumpeteriana da inovação tecnológica e da literatura pós-Keynesiana liderada pela demanda, formulamos dois modelos dinâmicos, um micro e um macro. O modelo micro envolve duas firmas e uma relação explícita de mão dupla entre concentração de mercado e mudança tecnológica. O modelo macro, por sua vez, incorpora evidências recentes sobre a concentração do mercado e sua relação com a acumulação de capital e a distribuição de renda. Na parte empírica da dissertação, investigamos se existe uma relação de determinação simultânea entre poder de mercado e capacidades tecnológicas para uma amostra de 131 países que se estende ao longo do período 1990-2017. Esta investigação é realizada com a metodologia Vetor Autoregressivo (VAR) em painel. Em geral, percebemos que a mudança tecnológica é uma adição importante à análise da concentração de mercado, ao permitir a identificação de nuances sobre como aumentar ou neutralizar as tendências de concentração de mercado. Uma característica comum dos modelos micro e macro é que sua estabilidade depende em grande parte das interações entre mudança tecnológica, imitação e concentração. Além disso, nossos resultados empíricos fornecem evidências apenas de que a inovação tecnológica afeta o poder de mercado, mas não o contrário. Assim, este estudo reforça que a concentração e o aumento do poder de mercado são tendências preocupantes que parecem não promover inovação e não são compatíveis com estratégias focadas no crescimento ou na distribuição de renda.

Palavras-chave: Concentração de mercado. Mudança tecnológica. Distribuição de renda. Markups. VAR em painel.

Abstract

The decline of competition in many advanced economies and its effects on investment, productivity, and inequality have recently gained some attention, but most of the existing work relegates some important aspects of this process. This dissertation aims to resume the study of market concentration arguing that it can be better understood through its central, although intricate, relationship with technological change. By doing so, we provide contributions to the theoretical and empirical literature. Based on the combination of insights from the neo-Schumpeterian approach to technological innovation and the post-Keynesian demand-led literature, we formulate two dynamic models, a micro and a macro one. The micro model involves two firms and an explicit two-way relationship between market concentration and technological change. The macro model, in turn, incorporates recent evidence on market concentration and its relationship with capital accumulation and income distribution. In the empirical part of the dissertation, we investigate if there is a simultaneous determination in the relationship between market power and technological capabilities for a sample of 131 countries that extends over the period 1990-2017. This investigation is carried out with the panel Vector Autoregressive (VAR) methodology. In general, we notice that technological change is an important addition to the analysis of market concentration, allowing us to identify nuances of how to boost or counteract concentration tendencies. A common feature of both the micro and macro models is that their stability depends largely on the interactions between technological change, imitation, and concentration. Besides, our empirical results provide evidence only that technological innovation affects market power, but not the other way around. Thus, this study reinforces that concentration and the increase in market power are worrisome trends that do not seem to promote innovation and do not match strategies focused either on growth or income distribution.

Keywords: Market concentration. Technological change. Income distribution. Markups. Panel VAR.

List of Figures

List of Tables

Contents

Introduction

Market competition has been a pillar of the capitalist economy. The general idea is that markets work more efficiently and competition is the selection mechanism that makes that happen, by rewarding success and punishing failure. Competition is assumed to be what creates dynamism in the economy and propels growth by creating jobs, rising wages, advancing technology, and encouraging investment. This argument has been extensively used to guide deregulation policies and reforms, such as tariff reductions, and recently has been appropriated by the neoliberal agenda related to most of the right-wing uprise in the last decade. However, if competition falls dramatically, what does this say about capitalism?

Competition has indeed been declining in several sectors of many advanced economies. The US case in the twenty-first century is the most pronounced one, with an average increase in measures of concentration reaching 90%, accompanied by market shares of the four largest firms in most industries and average firm size tripling (GRULLON; LARKIN; MICHAELY, 2019). Markups, a measure of market of power, have risen sharply since the 1980s, when they were 21% above marginal cost, reaching 61% in 2020, especially in the upper tail of the markup distribution (DE LOECKER; EECKHOUT; UNGER, 2020). Suddenly, the capitalist power of the world seems to have given up on free markets, as Philippon (2019) describes it. And similar although lighter trends have been reported for other advanced countries (BAJGAR et al., 2019). Apparently, competition has become a fragile basis in support of the system.[1]

The consequences of this decline are shown to be lower investment and productivity along with higher inequality, a worrisome combination for economic growth prospects. The increase in concentration has been appropriated as higher market power in the domain of a few large companies. Higher market power allows firms to keep a larger share of rents from production, leaving labor with increasingly smaller fractions of this output. These rents, however, are directed to shareholders through the payment of dividends, they are not used to invest or hire new workers. This general scenario has been named by Akcigit and Ates (2019) as the decline in business dynamism, but the process could have been worsened by a declining focus of public policy from the general well-being of the population to the gains of companies. Rent-seeking, lobbying practices, and weaker antitrust enforcement seemed to have had an important role, as supported by Bessen (2016), Grullon, Larkin and Michaely (2019), and Philippon (2019).

Nonetheless, technological change can be a key factor in understanding this scenario.

[1] The issue of higher market concentration and some of its damages and consequences have been discussed by some economists in the economics-related media. For some examples, see Govindarajan et al. (2019), The Economist (2019), Stiglitz (2019), Tepper and Hearn (2018), and Wolf (2019).

There is empirical evidence that concentration had the highest increases in industries with higher technological change indicators, what happened alongside a declining diffusion of technology from frontier to laggard firms, indicating a possible source of why general productivity has declined (AKCIGIT; ATES, 2019; AUTOR et al., 2020). Moreover, despite barriers to knowledge imposed by firms with high market power, the sluggish diffusion of technology associated with productivity growth is also related to investment. Since firms are not investing, they are not incorporating technological innovation embodied in new equipment and processes. Other studies are more skeptical that innovation has been a definite force, especially when a cross-country comparison of innovation and concentration trends shows marked differences (PHILIPPON, 2019). However, a broad view of the recent processes encompasses that very large firms have grown so much at least partly because of their productivity enhancements.

Thus, although technological change does not explain by itself the process of market concentration, it certainly has a role in it. The intricacies between competition and technological innovation are recognized and studied since the works of Schumpeter at the beginning of the twentieth century, which highlighted the role of innovation in promoting economic change. Technological innovation changes the dynamics of competition, be it price or non-price, by modifying and creating new processes and products. At the same time, it is also influenced by competition, which shapes the conditions, expectations, and strategies connected to firms' innovation-related decisions. By no means it is a straightforward relationship, but influences on both sides have been recognized, and understanding how these two processes relate is a path to comprehend and explain a bit of the recent problems of low growth and high inequality.

This dissertation aims to resume and proceed with the study of market concentration and its relationship with technological change, given the context of major changes involved with these processes. We also investigate their consequences for income distribution, investment, and economic growth. By doing so, this work contributes to the theoretical and empirical literature. The resulting formalizations and outcomes of this research fill gaps in the study of the competition dynamics, which can largely be explored by future works.

This research is pursued combining insights from two main theoretical frameworks: the evolutionary neo-Schumpeterian literature and the post-Keynesian demand-led approach. We argue that the two approaches can greatly benefit from one another. The neo-Schumpterian literature has a great understanding of technological change and provides microeconomic foundations for the firms' decisions on innovation and for specifying the dynamics of competition. For the post-Keynesian literature, in turn, the concept of effective demand is central to deal with the macroeconomics of growth and distribution. This approach highlights the role of income distribution in influencing aggregate demand and capital accumulation, especially when following the work of Kalecki (1971). These distribution and demand factors should also be considered in this analysis of market concentration, as they have been affected by these recent changes. The combination of these two approaches results in a unified comprehensive interpretation of the process of market concentration, one that highlights contributions from both supply and demand factors.

Furthermore, the reasoning behind choosing this theoretical background also relates to the different interpretations and elements that these two approaches bring to this analysis. The recent theoretical literature that deals with the changes in market competition mostly relies on mainstream endogenous growth theory (AUTOR et al., 2017; AKCIGIT; ATES, 2019). In these models, demand does not have a central role in constraining output growth when compared to the demand-led approach to growth. However, demand aspects should also be taken into account, as they have a role in determining the success of competing firms. For instance, market concentration implies that some firms were more successful than others in capturing a fraction of aggregate effective demand. Moreover, deficiencies of effective demand are less likely to negatively affect more concentrated markets. These issues are incorporated into this study with the proposed comprehensive analysis.

The investigation proposed in this dissertation extends through three chapters, besides this introduction and the conclusion. Chapter 1 develops a micro-dynamic model with two firms that formalizes the non-price competition dynamics and how it changes alongside technological progress. To do so, we rely on complementing the post-Keynesian theory of the firm with neo-Schumpeterian insights, defining a two-sided causality between market concentration and technological change. This formalization allows us to explore what influences the stability properties of the model and how it reacts to a technological innovation shock. Moreover, given the scarcity of micro models and the discussion of competition in the post-Keynesian literature, this model fills this gap and allows many new developments.

From the microfoundations constructed in Chapter 1, Chapter 2 develops a macro model that encompasses part of the aforementioned dynamics of advanced economies. The focus is on concentration and its relationship with capital accumulation and income distribution. The investigation of the dynamic system is divided into two parts. First, we consider concentration as exogenous and model a two-dimensional system that sets the dynamics between distribution and accumulation. Then we extend the model to a three-dimensional system that sets how concentration evolves endogenously with the other variables. With this framework, we reflect on the different effects of a higher degree of market concentration and what are other demand and supply-side factors that affect or even counteract these effects.

Chapter 3 is the empirical part of this dissertation. Relying on the theoretical discussions presented in the previous chapters, in this one we investigate empirically if there is a simultaneous determination in the relationship between market power and technological capabilities for a sample of 131 countries that extends over the period 1990-2017. The investigation of this simultaneity is carried out with a panel Vector Autoregressive (VAR) methodology, which is suitable because of its robustness to reverse causality. Finally, we close the dissertation with some conclusions.

1 Market concentration and technological change: a tale of two firms

1.1 Introduction

The two-way relationship between market structure and technological change has been remarked since the work of Schumpeter (1934) and is highlighted by the neo-Schumpeterian literature following Nelson and Winter (1982). It is known that market concentration affects the dynamics of technological innovation, but this effect seems to be ambiguous. On the one hand, a more concentrated market can induce innovation by conceding power to innovative firms to avoid or prevent imitation from competitors, assuring a larger appropriability of monopoly profits coming from successful innovation. An oligopolistic market also implies firms with more internal resources to invest in uncertain activities like innovation. On the other hand, firms in very concentrated markets feel less threatened and thus have fewer incentives to innovate (METCALFE, 1998). Despite the inconclusive results of most of the empirical literature, which are sensitive to industry-specific conditions and the simultaneous determination of these processes, a popular approach encompasses these two views suggesting that market concentration affects innovation following an inverted-U shaped relationship (AGHION et al., 2005; KAMIEN; SCHWARTZ, 1975; NEGASSI et al., 2019; SCHERER, 1967; TINGVALL; POLDAHL, 2006).[1] Accordingly, innovation would be higher for intermediate levels of concentration, while being lower for low and high ones.

The causality also runs in the opposite direction, that is, from innovation to market concentration. Following the notion of "creative destruction", firms that innovate successfully obtain competitive advantages that allow them to increase their market shares, concentrating the market as long as these advantages last (DOSI, 1988; NELSON; WINTER, 1978; NELSON; WINTER, 1982). The persistence of these advantages is related to barriers arising from the accumulation of knowledge, which makes imitation harder and enhances R&D expenditures that will generate innovations, and from a possible increase in the optimal scale of production (LEVIN, 1978; PHILLIPS, 1966). Still, if innovation-related entry is possible and occurs on a large scale, innovation could reduce the concentration of an industry (MANSFIELD, 1983). Thus, the impact of innovation on market concentration is also mixed and can go either way.

In this paper, we argue that the post-Keynesian theory can benefit from a neo-Schumpeterian inspired analysis of this dynamics between market structure and innovation. The outlined dynamics relies on the concept of "Schumpeterian competition", according

[1] See Kamien and Schwartz (1975), Gilbert (2006), and Cohen (2010) for comprehensive surveys of the empirical works that investigate the effects of market structure on innovation.

to which technological competition is more important than price competition. Therefore, technological enhancements like product differentiation, improvement, and variety yield decisive competitive advantages to innovative firms against its rivals. This non-price competition mechanism is similar to what the post-Keynesian theory has in mind regarding competition, as Lavoie (2014) summarizes. This literature offers a more realistic view of the firm proposing that firms aim at power in an environment with fundamental uncertainty. Firms also operate with planned excess capacity to respond to sudden demand shifts and prices are not market-clearing, which implies imperfect, oligopolistic markets. In this setting, non-price competition prevails. Competition is then driven not by the adjustment of prices, but by adjustments in different branches of innovation, branding, and advertisement. In light of this competition mechanism, Kalecki (1941), who precedes this theoretical perspective, highlights how technological change increases the degree of oligopoly of an industry as it propels market concentration. However, the effects of concentration on innovation also need to be considered to evaluate the micro and macro implications of this two-way relationship within this theoretical framework.

Although this microeconomic perspective is assumed in most post-Keynesian macroeconomic models, there are not many formal models of this competition dynamics and how it changes intricately with technological progress.[2] An exception is Lima (2000), who develops a post-Keynesian macro model of capital accumulation and distribution, in which the rate of technological innovation depends non-linearly on market concentration, while concentration is endogenous to capital accumulation and technological change. Yet, to the best of our knowledge, the post-Keynesian literature lacks micro models of this relationship.

Therefore, this paper contributes to the post-Keynesian literature by developing a dynamic model on the firm level in which there is a two-way relationship between market concentration and technological change. To encompass both ways of this causality, we extend the post-Keynesian theory of the firm accounting for the relationship between market share, technological change, and the growth of firms inspired by the neo-Schumpeterian approach to technological innovation. The model involves two firms that compete on technological factors. With our formalization, we notice that the stability properties of the system depend on the interactions between the dynamics of innovation, imitation, and market concentration. By exploring different configurations of these interactions, we cast light upon two scenarios of changes in market domain and technological advantage

[2] In the neoclassical branch of studies, the investigations relating innovation and market concentration have been conducted mainly through endogenous growth models following Aghion and Howitt (1992), like Aghion et al. (2001)'s growth model with step-by-step innovation, which is assessed with experimental economics in Aghion et al. (2018). Aghion, Akcigit and Howitt (2014) associate these attempts to the "Schumpeterian growth paradigm", referring to the formalization of the mechanism of creative destruction into growth models. According to the authors, that was done in two ways: by incorporating the microeconomic aspects of growth and by using more microdata than competing theories to investigate their predictions.

driven by an exogenous innovation shock and how these can be propelled or hindered by firm strategies. Moreover, given the relative scarcity of this discussion in the literature, this model can also serve as a basis for other post-Keynesian micro models and more comprehensive macro models of growth and distribution that aim to incorporate changes in the micro competitive structure.

The paper proceeds as follows. Section 1.2 describes the structure of the duopolist industry modeled. Section 1.3 looks at the behavior of the model in the short run, while Section 1.4 explores its long-run dynamics. Section 1.5 examines the effects of an exogenous innovation shock on this system and discusses the implications of the results. Finally, Section 1.6 concludes.

1.2 Framework of the duopoly model

The model developed here involves two competing firms A and B.[3] Both firms belong to the same industry and each produces a single good used for both investment and consumption. Each firm combines two factors of production, capital and labor, through a fixed-coefficient technology as the following production functions specify:

$$Y_A = \min\{L_A/a_A, K_A/b_A\}\,, \tag{1.1}$$

$$Y_B = \min\{L_B/a_B, K_B/b_B\}\,, \tag{1.2}$$

where for each firm $i = A, B$ - as indicated in the subscripts throughout the paper - Y_i is output, L_i is employment, and K_i is capital stock, while a_i and b_i are labor-output and capital-output ratios, respectively. The coefficient a_i is the reciprocal of labor productivity. Thus, it is constant in the short run, when technology remains constant, but it decreases in the long run as productivity grows with technological change. A fixed set of technical coefficients prevails as a consequence of the bureaucratic conventions and work rules that are formed over the most efficient combination of inputs (EICHNER, 1976, p. 28–37), as well as because of localized shifts in production derived from the cumulative effects related to the process of technological change (ATKINSON; STIGLITZ, 1969).

Total employment L is divided between the two firms, formally $L = L_A + L_B$. In the short run, the nominal wages w_i are fixed, for labor productivity is constant. However, we assume away wage-push inflation, so that nominal wages grow in the long run at the same rate as labor productivity. The nominal wage is heterogeneous in the industry, but both wages are fixed at levels that ensure consumption at least above subsistence. The wage heterogeneity implies that employed workers are also heterogeneous, which we take

[3] The model involves a duopoly because the aim was to study competition between firms in the simplest way possible. However, this structure could be easily extended to represent an oligopoly. More firms can be added to the model turning it into a larger scale model. Another option is to keep pursuing a leader-follower relationship between firms, as will be explored in this paper, but considering the follower firm as an average of the market that follows the leading firm, thus turning this duopoly structure directly into an oligopoly.

as a result of the training involved in each firms' production (ACEMOGLU; PISCHKE, 1999). Yet, labor supply is in excess, which along with the assured minimum wage level implies that there is an infinitely elastic supply of labor. This labor availability means that employment is determined only by production according to demand:

$$L_A = a_A Y_A \,, \tag{1.3}$$

$$L_B = a_B Y_B \,. \tag{1.4}$$

Regarding the relationship between production and demand, we assume that firms operate with excess capacity, which for the capital stock means the inequalities

$$K_A > b_A Y_A \,, \tag{1.5}$$

$$K_B > b_B Y_B \,, \tag{1.6}$$

while the equality relationships $K_A = b_A Y_A^{fc}$ and $K_B = b_B Y_B^{fc}$ indicate full capacity utilization, with Y_A^{fc} and Y_B^{fc} being each firm's full capacity level of output. As Steindl (1952) argues, planned excess capacity is necessary for firms to respond to demand shifts that cannot be foreseen. Firms want to exploit the opportunity of an increase in selling power, and they want to do it before their current or new competitors to create barriers to entry and prevent a future threat to their market. They also expect their market to grow as goodwill towards their brand gradually extends. However, there are technical reasons that prevent firms to expand their capacity suddenly or alongside the growth of the market. Those reasons relate to indivisibility, durability, scale specifications, and building time of machines and plants, justifying the maintenance of excess capacity.

Since the firms are dividing the sector's demand Y between themselves

$$PY = P_A Y_A + P_B Y_B \,, \tag{1.7}$$

where Y_A and Y_B represent the demand that each firm attends and the general price level P is an average of the firms' prices $P = \lambda_A P_A + \lambda_B P_B$, where λ_i is constant. Dividing equation (1.7) by P_B, we have

$$\theta Y = \psi Y_A + Y_B \,, \tag{1.8}$$

where $\theta = \lambda_A (P_A/P_B) + \lambda_B$ and $\psi = P_A/P_B$.

Previous dynamics determined which share of the market each firm attends given the size of demand, so that each holds a fraction of total demand

$$P_A Y_A = m_A PY \,, \tag{1.9}$$

$$P_B Y_B = m_B PY \,, \tag{1.10}$$

where m_A and m_B are the market shares of each firm and $m_A + m_B = 1$.

The firms determine prices P_A and P_B by applying a markup τ_i on average variable costs, which in this case are unit labor costs $w_A a_A$ and $w_B a_B$, as follows:

$$P_A = (1 + \tau_A) w_A a_A \, , \tag{1.11}$$

$$P_B = (1 + \tau_B) w_B a_B \, , \tag{1.12}$$

where $P_A/P_B > 0$. The rates of profit r_A and r_B are derived from the price relationship above

$$r_A = \frac{\tau_A w_A a_A Y_A}{P_A K_A} = \frac{\tau_A w_A a_A u_A}{P_A b_A} \, , \tag{1.13}$$

$$r_B = \frac{\tau_B w_B a_B Y_B}{P_B K_B} = \frac{\tau_B w_B a_B u_B}{P_B b_B} \, , \tag{1.14}$$

where u_i is the rate of capacity utilization, $u_i = Y_i / Y_i^{fc}$. Capital K_i is evaluated at different prices since we are considering that firms have different techniques of production that are reflected in each firms' capital stock.

Aligned with the standard Kaleckian view (KALECKI, 1971), average variable costs are assumed to be constant up to full capacity, while overhead costs are decreasing. Since firms operate with excess capacity, unit labor costs $w_i a_i$ are constant.[4] As proposed by Sylos Labini (1969),[5] the markup is assumed to be constant and determined to create barriers to entry, a possibility allowed by the high degree of concentration of this market.[6] Consequently, prices are set at a sufficiently low level to prevent the entry of potential competitors.

We also assume that relative prices P_A/P_B and the markups τ_i remain constant, which implies θ and ψ in equation (1.8) as also constant. This refers to the fact that in this model prices are not market-clearing, they only allow the reproduction of the firms by avoiding new entry and by generating enough profits to finance investments (LAVOIE, 2014, p. 167).[7] While the markup and prices are kept constant in demand shifts, an

[4] According to Lavoie (2014, p. 147) these characteristics (constant average variable costs until full capacity, decreasing overhead costs, and firms operating with reserves of capacity) are the main stylized facts of the post-Keynesian firm.

[5] Beyond Sylos Labini (1969), see Steindl (1952) and Bain (1956) for a more detailed explanation on the relationship between prices and barriers to entry.

[6] Although in this model the market structure is duopolistic, this pricing mechanism could work even in a much more competitive market. This argument is developed by Lavoie (2014, p. 126), who claims that the market does not need to be duopolistic or oligopolistic to be imperfect. He argues that all markets could be considered imperfect markets, where prevails some sort of administered pricing mechanism, even with higher degrees of competition. For example, as aforementioned, in the analysis of Kalecki (1971) the fact that many sectors (like the ones of finished and industrial products) fix prices rely on the firms operating with excess capacity with constant marginal costs, according to their degree of monopoly, which he calls a "semi-monopolistic price formation" (p. 45) mechanism. However, Means (1936) links this pricing mechanism with structural factors of modern technology, while Shapiro and Sawyer (2003) relate prices with the interests of firms, strategically determined.

[7] The simplicity of the post-Keynesian pricing procedures is criticized by Lee (1994) and Lee (1999). In these works, the author proposes a more complex pricing mechanism using a multisector model where industries have different price procedures between themselves. However, since prices in this model are not market-clearing, we consider that it is a good enough approximation to consider that firms fix prices over average variable costs.

assumption consistent with empirical evidence shown in Sawyer, Aaronovitch and Samson (1982), Chevalier, Kashyap and Rossi (2003), and Alvarez et al. (2006), the profit rates vary according to these changes in demand through alterations in the rate of capacity utilization. Therefore, firms would respond to possible demand shifts with adjustments in quantity, not prices.

Constant relative prices imply that firms do not compete on prices so that, in this setting, competition occurs through non-price factors, like quality, variety, and technology. Thus, we are assuming a neo-Schumpeterian approach to competition, where firms survive, grow, or die given how they differ regarding innovation, imitation, and how diffusion occurs (METCALFE, 1998, ch. 1). Market competition is crucial to Schumpeter (1934)'s concept of creative destruction, pressing firms to innovate, but it is also a dynamic mechanism of selection, as described by Nelson and Winter (1982). This selection process enhances the firms that have made the best choices - concerning investment, branding, advertisement, R&D, and the production process - under uncertainty. Hence, through innovation firms obtain decisive cost, quality, or variety advantages over their competitors that affect their profits and market shares, threatening the existence of other firms.

This view of competition focused on technological asymmetries between firms implies pronounced variability and inequality in the market. This variability suggests that firms should always be considered heterogeneous agents in their respective industries, as Dosi (1984) proposes.[8] The competition process itself is thus uneven and asymmetric, with a few firms leading the transformation of the economy, whereas the rest follows, trying to adapt.

The described Schumpeterian competition dynamics is incorporated into this duopoly model by taking the firms as technologically heterogeneous and, consequently, unequal in the market. The firms compete over the same type of good, but they supply it with different qualities, which reflect their different technologies. These differences in the level of technology and innovative knowledge between the firms are captured here by the technological gap. We are assuming that previous dynamics have made firm A the leader, which implies firm B as the follower. Firm A being the leader means that this firm is the one equipped with the most efficient techniques of production in this sector, so that we define the gap as

$$T = \frac{E_A}{E_B}\,, \tag{1.15}$$

where E_A and E_B are the stocks of technology and innovative knowledge of each firm and $T > 1$.[9] The measure E_i incorporates more than labor or capital productivity a_i and

[8] Lima (1996) highlights that taking this asymmetry into account from the start in models with innovation is a marked difference of the neo-Schumpeterian approach when compared to the neoclassical tradition, which starts from a point where all firms are identical, as in perfect competition.

[9] This feature of the model can be expanded to incorporate more firms. For instance, in an oligopolistic setting with three or more firms, T can be represented as $T = E_x/\bar{T}$, where E_i is the technological content level of each firm x, $x = [1, 2, \dots]$, and $\bar{T}$ would be the average technological content of the

b_i, also encompassing the intangible knowledge associated with each firm. However, as aforementioned, we do consider that productivity grows alongside technological change in the long run.

Being the leader gives firm A some liberty in making production and investment choices, while firm B awaits these decisions to make its plans. This leader-follower relationship implies that firm A is the only one able to make plans about its desired investment rate. Firm B only matches the sector's demand that the leading firm does not or cannot attend with its financial availability. In other words, firm B captures the residual market demand. For this reason, we define hereafter the financial constraints faced by both firms, but we only specify the desired expansion of the leading firm A.

Although in neoclassical economics firms decide to produce at the level that yields them the maximum rate of profit, here we follow the post-Keynesian view that firms aim at power, regardless of size and control scheme, as summarized by Lavoie (2014, p. 128). We follow Penrose (1959), Galbraith (1967), Wood (1975), and Aidar and Terra (2019) in relating power with growth. On the one hand, in a world with fundamental uncertainty, the larger the firm, the easier it is to respond to unpredictable events and to plan and control its operation and environment free from external influences. On the other hand, capacity expansion is important to obtain or maintain a competitive position in the market, since it allows firms to prevent entry by attending the growing demand and to innovate and diversify in production. Hence, it is not just a matter of ultimate control over the market, but how to survive in it. Power, growth, and survival are inevitably intertwined.

In this setting there is no financial sector, which implies profits as the means that enable firms to grow. Therefore, firms finance their expansion with the retention of part of their earned profits. Following the financial frontiers proposed by Sylos Labini (1969) and Wood (1975), we establish a function of the financial constraint faced by the firms with growth as a positive function of profits

$$g_A^F = s_A r_A \,, \tag{1.16}$$

$$g_B^F = s_B r_B \,, \tag{1.17}$$

where g_i^F is the growth rate of each firm compatible with its financial constraint, r_i is the firm's rate of profit, and s_i is its retention ratio, $0 < s_i < 1$. Equations (1.16) and (1.17) indicate that an increase in the firms' growth rate demands a higher rate of profit, given an admissible retention ratio.[10] This assumption is also supported by empirical evidence

remaining sector. Therefore, firms with $T > 1$ would be more competitive than firms with $0 < T < 1$.

[10] See Stockhammer (2005-6) for a discussion on how financialization and the reported increase in shareholder's power have impacted the retention ratio, investment, and other related decisions of the firm, based on an extension of a standard post-Keynesian micro model and a Kaleckian macro model. He shows that the presence of high shareholder power reduces investment and output but increases profits. Rabinovich (2020) also elaborates on the effect of financialization on the detachment of firms' profitability and investment by analyzing the supply side of the investment-profit puzzle.

showing a significant role of availability of internal finance for investment (BROWN; FAZZARI; PETERSEN, 2009; FAZZARI; MOTT, 1986).

Since power is related to growth, the leader firm A can make decisions on how much it wants to grow, so that the desired expansion frontier of this firm can be defined as an investment function with the following configuration:

$$g_A^E = \gamma_0 + \gamma_1 r_A - \gamma_2 m_A + \gamma_3 T\,, \tag{1.18}$$

where γ_j are positive parameters, $j = [0, 3]$, with γ_0 representing animal spirits, g_A^E is firm A's desired rate of investment in capital stock, m_A is firm A's market share, and T is the technological gap between the firms. As we are dealing with a one-good sector, the same good can be used for consumption, investment, and innovation activities. This means that technological innovation is not taken a separate production process, similar to what is proposed in Lima (2004).

The assumption that investment depends positively on the rate of profit is derived from the formalization of Dutt (1984) following Robinson (1956). An upward shift in expected profits leads firms to decide to undertake a greater amount of investment. For simplicity, current and expected rates of profit are taken as equal, with the former assumed to be a good enough approximation of the latter.

Desired investment is also taken as a function of the market share firm A holds, implying that changes in the market structure affect the investment rate. Although market share could either be positively or negatively related to investment depending on the strategy of the firms, here we are assuming a negative relationship. This assumption indicates that firm A has a strategy of maintaining its market share. If firm A obtains a higher market share, it holds a better competitive position in the industry and feels less threatened, so that it does not need to keep expanding to increase its power. We also assume that this strategy does not change with changes in the concentration of the industry.[11] Nelson and Winter (1982) also propose in their model with oligopolistic competition that firms with large market shares realize that expansion can ruin their market since they need great financial resources to expand proportionally. In this case, higher investment would lead only to a bad use of resources. Gilbert and Lieberman (1987), reinforced by Wood (2005) and Scheibl and Wood (2005), provide empirical evidence of this pattern of investment consistent with market share maintenance for large firms, which would be the case for the leader firm in this duopoly. Thus, its strategy would be to increase investment if it encounters a significant reduction in its market share.

[11] Changes in firm's strategies due to interactions with the micro and macro environment are best incorporated in simulation models like Agent-Based Models (ABMs). For example, Possas et al. (2001) incorporate neo-Schumpeterian microfoundations into a macrodynamic model with effective demand along Keynesian lines. The authors propose a model in which feedback between agents' strategic decisions and the environment produces endogenous industrial dynamics that will determine market structure and innovative performances. One of the possible extensions of the present work is to insert the two-sided dynamics between market concentration and technological change in a more complex modeling approach.

Finally, in this model a higher technological gap T, which implies a higher relative level of technological content of firm A, increases firm A's desired investment rate. On the one hand, Kalecki (1971) claims that technological innovation would result in new machines and production routines more productive than the old ones. This causes the costs of the old methods to rise, which spurs new investment. On the other hand, technological innovation changing the dynamics of the economy and unfolding opportunities that influence investment is a central aspect of the theories of Schumpeter (1934) and the neo-Shumpeterians, as Nelson and Winter (1982), and is empirically supported by works such as Lööf and Heshmati (2006) and Corsino and Gabriele (2011).

1.3 Short-run equilibrium

The short run is a period in which the capital stock, the price level, the nominal wage, labor and capital output ratios, and the technological gap are all taken as given. Consumers of this industry choose if they prefer to consume the good from firm A or B according to their qualitative differences, but here we are assuming that firm A has the product that attracts a larger part of the demand. Demand, therefore, determines the success of competing firms. Each firm then holds a size of the market given by the size of demand that it attends, as shown in the equations (1.8), (1.9), and (1.10), which describe the sector's demand and define the market shares, respectively.

In this case, previous dynamics established that firm A was more successful than firm B is capturing a fraction of the aggregate effective demand of this market, thus, it has a larger market share and, as we assumed, has more liberty in setting its investment plans. In sum, the distribution of market shares is an outcome of the distribution of aggregate effective demand and hence capacity utilization across firms. This means that the market shares are endogenous in the short run along with capacity utilization in each firm.

Firm A will produce according to demand, matching its investment plans with the available financial funds through adjustments in its rate of capacity utilization. Thus, in the short-run equilibrium $g_A^F = g_A^E$, which reflects the firm's highest possible growth position. This equality can be solved for the short-run equilibrium value of the rate of capacity utilization u_A^* given in equation (1.13), obtaining:

$$u_A^* = \frac{P_A b_A(\gamma_0 - \gamma_1 m_A + \gamma_3 T)}{\tau_A w_A a_A(s_A - \gamma_1)} \,. \tag{1.19}$$

We assure stability for the short-run equilibrium value of capacity utilization assuming that the Keynesian stability condition holds. In formal terms, it means that the financial frontier is more responsive to changes in the capacity utilization than capital accumulation, that is, $s_A > \gamma_1$.

From (1.19), (1.13), and (1.16), we obtain the short-run equilibrium rate of growth of firm A:

$$g_A^* = \frac{s_A}{s_A - \gamma_1}(\gamma_0 - \gamma_2 m_A + \gamma_3 T)\,. \tag{1.20}$$

From expression (1.20), we can examine the impact of changes in market share and technological advantage on firm A's rate of growth through the following partial derivatives:

$$\frac{\partial g_A^*}{\partial m_A} = -\frac{s_A \gamma_2}{s_A - \gamma_1}\,, \tag{1.21}$$

$$\frac{\partial g_A^*}{\partial T} = \frac{s_A \gamma_3}{s_A - \gamma_1}\,. \tag{1.22}$$

Hence, a higher market share of firm A decreases its growth rate, following the firm's strategy. However, a higher technological gap implies higher investment as firm A incorporates the new technology.

In this framework, firm B would capture the residual demand of the market, the one that the leader firm A does not or cannot capture, considering a given total demand. Therefore, taking $\bar{u}$ as the constant and exogenously determined total capacity utilization of this industry, u_A^* will also determine the equilibrium rate of capacity utilization of firm B, u_B^*. We can formalize this mechanism by setting the sector's demand, in equation (1.8), in terms of capacity utilization:

$$u_B^* = \delta \bar{u} - \rho u_A^*\,, \tag{1.23}$$

where $\delta = \theta Y^{fc}/Y_B^{fc}$ and $\rho = \phi Y_A^{fc}/Y_B^{fc}$, and we assume both δ and ρ as constant.

Furthermore, since firm B's profit rate depends on its rate of capacity utilization, as given by (1.14), and the rate of profit will determine the retained funds that allow firm B to grow, as stated in (1.17), the short-run equilibrium growth rate of firm B will be determined by the rates of capacity of utilization of the sector and of firm A. Substituting (1.23) in (1.14) and (1.17) yields

$$g_B^* = \frac{s_B \tau_B w_B a_B}{P_B b_B}(\delta u - \rho u_A^*)\,. \tag{1.24}$$

Therefore, firm B expands to accompany the residual demand that it attends. For firm B, the effect of increase in the market share of firm A and technological advantage in g_B^* can be examined by the following partial derivatives:

$$\frac{\partial g_B^*}{\partial m_A} = \frac{s_B \tau_B w_B a_B}{P_B b_B} \frac{\rho P_A b_A \gamma_2}{\tau_A w_A a_A (s_A - \gamma_1)}\,, \tag{1.25}$$

$$\frac{\partial g_B^*}{\partial T} = -\frac{s_B \tau_B w_B a_B}{P_B b_B} \frac{\rho P_A b_A \gamma_3}{\tau_A w_A a_A (s_A - \gamma_1)}\,, \tag{1.26}$$

which indicates positive and negative effects, respectively. This follows the way that firm A's strategy works, implying that firm B has a chance of growing when firm A adopts a less aggressive investment plan as consequence of a higher dominance of the market. On the other hand, a higher technological gap increases the rate of growth of firm A, which necessarily decreases the one of firm B because of the general market size restriction.

The expansion of both firms is also restrained by the growth of the demand of this industry. Thus, the prevailing relationship between the growth of demand, the growth of firms, and their market shares is obtained by taking equation (1.8) in rates of change:

$$\bar{g} = m_A g_A + m_B g_B \,, \tag{1.27}$$

where $\bar{g}$ is the rate of growth of the sector's demand, taken as constant. As we are assuming short-run stability of the firms' rate of capacity utilization, we assure that the rates of change of the firms' product $\dot{Y}_i/Y_i$ are equal to their rates of growth of the capital stock g_i, as indicated by (1.27).

1.4 Long-run dynamics

In the described industry, it is reasonable to think that there will be mismatches between the growth rates of the firms as they enter a competitive process. In this case, in the long run, the industry will achieve the short-run equilibrium values of the variables by changes in the market shares m_A and m_B and the technological gap T. Therefore, we examine the dynamics of these variables in the long run to characterize the behavior of the system.

From the definition of firm A's market share in (1.9), we take rates of change obtaining the following state transition function for m_A:

$$\dot{m_A} = m_A(1 - m_A)[g_A(m_A, T) - g_B(m_A, T)] \,, \tag{1.28}$$

where $m_A \in (0, 1)$, expressing that the model developed here does not involve the case where one firm drives the other completely out of the market and becomes monopolist. This function reflects the already established view that firms aim at growing and they do so to keep or increase their share of the market. We see that if firm A has a higher growth rate than firm B, it obtains a larger share of the market.

Given (1.15), the technological gap T expressed in rates of change yields

$$\dot{T} = T(\dot{E}_A/E_A - \dot{E}_B/E_B) \,, \tag{1.29}$$

from which we define the dynamics of the innovative knowledge stocks in the following way:

$$\dot{E}_A/E_A = \alpha_A + \beta_A g_A - \sigma_A T \,, \tag{1.30}$$

$$\dot{E}_B/E_B = \alpha_B + \beta_B g_B + \sigma_B T \,, \tag{1.31}$$

where α_i, which designate the autonomous component of technological progress, β_i, and σ_i are positive parameters. Each growth rate has a positive impact on the respective technological change through a Verdoorn channel. Investment expands and renews the capital stock with new and more productive capital goods. In that way, it introduces innovations in the production process, while also uncovering other possibilities of innovation, according to how the knowledge inherent to the firm allows further improvements in productivity and the final quality of production, as claimed by Palley (1996, p. 124) and Possas (2008, p. 290). The level of the technological gap bears different signs for each firm conveying a common view that nonetheless affects the firms differently. Following Abramovitz (1986), a larger gap means that the leader is closer to the technological frontier, making innovations harder to be achieved. At the same time, a larger gap also gives more opportunities for the follower to catch up through imitation, slowing down the technological change of the leader while increasing the one of the follower.

We substitute (1.30) and (1.31) in (1.29) obtaining:

$$\dot{T} = T[\alpha + \beta_A g_A(m_A, T) - \beta_B g_B(m_A, T) - \sigma T]\,, \tag{1.32}$$

where $\alpha = \alpha_A - \alpha_B$, $\sigma = \sigma_A - \sigma_B$, and we take α and σ as positive parameters without loss of generality. The parameter α represents the autonomous component of relative technological change. Since the gap illustrates the relative technological positions of the firms, favoring firm A, changes in both the growth rates of firms and the level of the gap result in the same causalities for the dynamic changes in the gap as for the individual technological change, but now those causalities are taken as relative. Thus, both an increase in g_A and a decrease in g_B are related to a more rapid expansion of the gap as the investment process brings more innovations to one firm and makes the other lag behind, respectively. Besides, a decrease in the level of the gap reflects at the same time the two aforementioned mechanisms of innovation and catching up that also accelerate the expansion of the gap.

Equations (1.28) and (1.32) form a two-dimensional plane autonomous system of differential equations in which the rates of change of m_A and T depend on the levels of these variables and the parameters of the system. Solving (1.28) for the long-run equilibrium with $\dot{m}_A = 0$ yields a locus of points relating the firm A's market share and the technological gap:

$$T = \frac{Q - (h+Z)\gamma_0 + (h+Z)\gamma_2 m_A}{(h+Z)\gamma_3}\,, \tag{1.33}$$

where $Q = s_B \tau_B w_B a_B \delta \bar{u}/P_B b_B$, $h = s_A/(s_A - \gamma_1)$, and $Z = s_B \tau_B w_B a_B \rho u_A^*/P_B b_B$. Thus, we obtain an isocline with a positive slope, so that along the $\dot{m}_A = 0$ locus a higher market share of firm A is associated with higher levels of the technological gap.

On the other hand, solving (1.32) for the locus $\dot{T} = 0$ yields

$$T = \frac{-\alpha - (\beta_A h + \beta_B Z)\gamma_0 + \beta_B Q + (\beta_A h + \beta_B Z)\gamma_2 m_A}{(\beta_A h + \beta_B Z)\gamma_3 - \sigma}\,, \tag{1.34}$$

which is an isocline either upward or downward sloping according to the values of the parameters.

The local stability of the unique non-trivial long-run equilibrium (m_A^*, T^*) in the loci $\dot{m}_A = 0$ and $\dot{T} = 0$ is examined with the Jacobian matrix of partial derivatives given by:

$$J_{11} = \frac{\partial \dot{m}_A}{\partial m_A} = m_A^*(1 - m_A^*) \left(\frac{\partial g_A^*}{\partial m_A^*} - \frac{\partial g_B^*}{\partial m_A^*} \right) < 0\,, \tag{1.35}$$

$$J_{12} = \frac{\partial \dot{m}_A}{\partial T} = m_A^*(1 - m_A^*) \left(\frac{\partial g_A^*}{\partial T^*} - \frac{\partial g_B^*}{\partial T^*} \right) > 0\,, \tag{1.36}$$

$$J_{21} = \frac{\partial \dot{T}}{\partial m_A} = T^* \left(\beta_A \frac{\partial g_A^*}{\partial m_A^*} - \beta_B \frac{\partial g_B^*}{\partial m_A^*} \right) < 0\,, \tag{1.37}$$

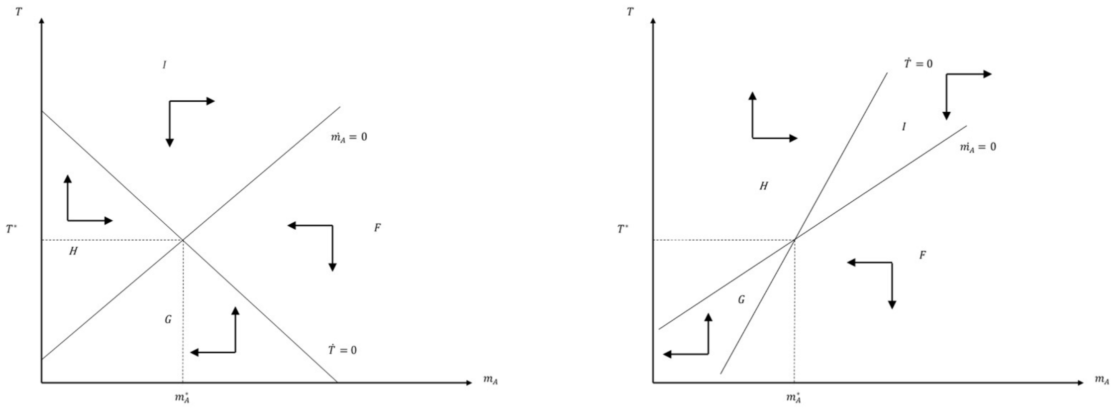
$$J_{22} = \frac{\partial \dot{T}}{\partial T} = T^* \left(\beta_A \frac{\partial g_A^*}{\partial T^*} - \beta_B \frac{\partial g_B^*}{\partial T^*} - \sigma \right) \lesseqgtr 0\,. \tag{1.38}$$

Only the last partial derivative is ambiguously signed. Equation (1.35) shows that an increase in the concentration of the industry with firm A, by decreasing the growth rate that this firm will pursue, will slow down the rate of increase of its market share. Equation (1.36), in turn, shows that the market share of firm A will raise with a higher rate when there is an increase in the technological gap since this gives firm A a competitive advantage that raises its rate of growth. This causality describes a sort of "creative destruction" competition mechanism according to which a higher technological advantage leads to a higher rate of change of concentration of the market with the leader. However, equation (1.37) indicates that when firm A obtains a higher market share it will invest less, thus slowing down the rate of relative technological change. This result is compatible with Geroski (1990)'s findings using different measures of market concentration and the empirical evidence that shows an inverted-U relationship between concentration and innovation, such as Blundell, Griffith and Reenen (1999), Aghion et al. (2005), Tingvall and Poldahl (2006), and Negassi et al. (2019).[12] Since this market is already concentrated, it would be located at the downward part of the curve, where a higher concentration discourages innovation.

Finally, equation (1.38) indicates that an increase in the technological gap can either raise or reduce the rate of relative technological change depending on the values of the parameters. For instance, if the parameter σ, that measures the sensitivity of the relative

[12] As Metcalfe (1998, p. 100–103) highlights, although small firms with in highly competitive markets have larger incentives to innovate since they need innovation to gain power, most of the times they lack the resources to do so. Firms with larger shares of the market, however, have little or no incentive to innovate, because they do not need to obtain any more competitive advantage. This argument is reinforced by Lima (2000), as he points out that although this empirical evidence needs to be relied on with caution, most studies suggest that an intermediate market structure, between monopoly and perfect competition, would promote higher innovative activity. With that in mind, he proposes a concentration-quadratic innovation function in his macroeconomic model dealing with technological innovation and market concentration.

Figure 1: Long-run dynamics: stable equilibria



(a) Panel 1 (b) Panel 2

Source: Author's elaboration.

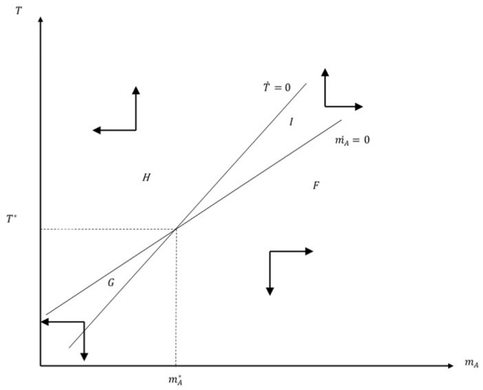
technological change to the level of the technological gap, measuring the potential for imitation and catching up by the follower, is high enough the effect is negative. Therefore, a higher gap would slow down the relative rate of technological change both because of the difficulties of innovation and the large space to catch up through imitation. However, if investment is more responsive to the gap than the catching up, the effect is positive, and a higher gap indicates higher technological advantages that stimulate growth, which will increase the rate of relative technological change.

The direction of this relationship between the level of the gap and its rate of change is also important to determine the local stability properties of the equilibrium solution. Since the determinant of the Jacobian matrix, given by $Det(J) = J_{11}J_{22} - J_{12}J_{21}$, is always positive, the stability depends on the respective trace, given by $Tr(J) = J_{11} + J_{22}$. The higher the catching-up parameter σ, the smaller the value of J_{22} and, hence, the more likely it is that the system is stable.

The trace of the matrix is negative suggesting local stability both when $J_{22} < 0$ and $J_{22} > 0$ but $|J_{11}| > J_{22}$. In the first case we have a downward-sloping $\dot{T} = 0$ isocline, so that in this locus a higher market share of firm A is associated with a lower technological gap. In the second one, the $\dot{T} = 0$ isocline has a positive slope, associating higher market shares of firm A with higher technological gaps. These two cases are depicted in the phase diagrams in Figure 1.

The stability refers to the following dynamics. If the equilibrium solution shifts to a point in the area F of Figure 1a, given that $\partial \dot{T}/\partial m_A$ is negative $\dot{T}$ undergoes a steady fall as m_A increases, because this firm has now fewer incentives to invest and innovate. However, the smaller technology gap means that firm B is catching up through imitation, which would decrease firm A's market share again, reversing its incentives to innovate. This innovation occurs in phase H, increasing again the technological gap, which increases

Figure 2: Long-run dynamics: unstable equilibrium



Source: Author's elaboration.

firm A's market share. This process continues until the equilibrium m_A^* and T^* is reached again.

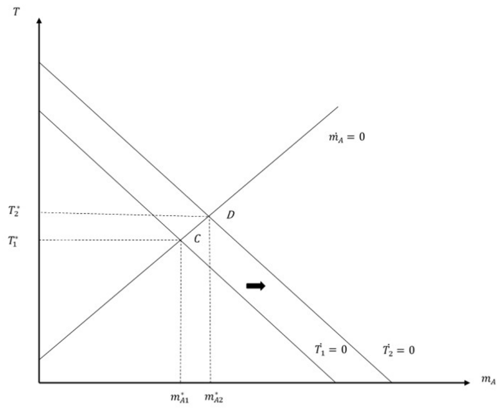
However, if σ is low enough, the upward-sloping $\dot{T} = 0$ isocline is flatter. Since in this case J_{22} is smaller, when $|J_{11}| < J_{22}$ the trace is positive, so that the system becomes locally unstable. Thus, the equilibrium will be unstable if the decrease in the rate of change of firm A's market share, given by a slow down of this firm's growth rate when faced with an increase in its market share, is not large enough to offset an increase in its growth rate caused by a larger technological gap. In this case, a deepening of the technological gap leads to such a great increase of the rate of growth of firm A when compared with firm B as to create a vicious circle of increases in technological advantage, firm growth and market share that asymptotically tends to concentrate the market with firm A. This happens because the catching up parameter is too small, so that firm B cannot accompany the leader and catch up, which allows the market to concentrate. The phase diagram in Figure 2 illustrates this dynamics.

Therefore, the equilibrium will be stable or not depending of the interaction between the processes of market concentration, technological change, and catching up. The equilibrium will be locally stable, maintaining the system as a duopoly, only if the follower firm has enough catching up and imitation capacity to overcome the tendencies of the market to concentrate with the leader. On the other hand, a sufficiently low catching-up capacity reduces the survival chances of firm B.

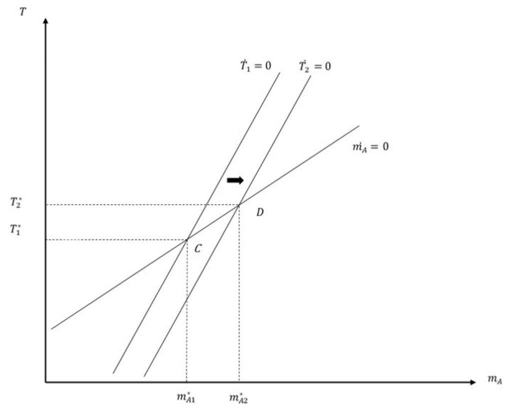
1.5 Comparative statics of an innovation shock

Let us now analyze the effects on the system of an "innovation shock". An innovation shock is taken as an exogenous shock in the autonomous component of relative technological

Figure 3: Effects of an innovation shock



(a) Panel 1



(b) Panel 2

Source: Author's elaboration.

progress, which is the parameter α in equation (1.32). This exogenous innovation shock can be defined as an innovation that is independent of the firms' resources. An example is technological innovation coming from the public sector, most likely derived from university R&D. However, in this setting firm A can absorb it better than firm B, or even only firm A has the capabilities to absorb it at all.

An increase in the parameter α_0 raises the intercept of the $\dot{T} = 0$ isocline when it is downward sloping and decreases the intercept when the isocline is upward sloping. In the unstable case, any deviation of the equilibrium makes the system diverge in a direction that depends on the parametric conditions of the system. The increase in the rate of change of the technological gap could increase the rate of growth of firm A faster than firm B can imitate and catch up, allowing firm A to continually expand its advantage in the technology race, eventually being able to cast firm B completely out of the market.

However, in both stable cases, this shock will shift the $\dot{T} = 0$ isocline along the $\dot{m}_A = 0$ isocline, as depicted in Figure 3. In both configurations, along the path to the new equilibrium, the exogenous increase in the rate of change of the gap leads to an increase in firm A's market share. This power gain decreases the rate of growth of this concentration, allowing firm B to do some catching up, although not enough to reach firm A. Therefore, firm A maintains its acquired advantage so that the new equilibrium point is marked by increases in both the technological gap and the market share of firm A.

These results agree with most of the theoretical work on innovation and competition, which suggests a dynamic of market concentration with the leading firm after a technology shock as the typical one in a capitalist economy. Despite that, it is interesting to notice how even different configurations of the system provide the same competition dynamics following a technology shock. In either case, if firm B could seize this catching-up opportunity and imitate fast enough, it could reduce its market share distance from firm A and its technological backwardness.

This long-run result is reflected in how the firms' growth rates are subject to innovation-related changes. The exact effect of the innovation shock on the growth of the firms is given by how changes in the technology gap and the market shares affect these rates. Formally, the total magnitudes of these changes are given by the following total derivatives:

$$\Delta g_A = \frac{\partial g_A}{\partial T}\Delta T + \frac{\partial g_A}{\partial m_A}\Delta m_A\,, \tag{1.39}$$

$$\Delta g_B = \frac{\partial g_B}{\partial T}\Delta T + \frac{\partial g_B}{\partial m_A}\Delta m_A\,, \tag{1.40}$$

so that the net change of this result depends on the parametric conditions of this industry and the magnitude of the changes in the technological gap and the market share of firm A. Therefore, the exact effect of innovation on growth depends on these conditions and it is related to which of the two possible described dynamics prevail.

After an exogenous innovation shock, there will be a disequilibrium between the growth rates of both firms, with different possible consequences. In the unstable case, firm A could keep growing more than firm B, asymptotically dominating the market. In this scenario, this extreme concentration could lead to stagnation. When firm A dominates the market by maintaining $g_A > g_B$, if it keeps growing at one point we will have $g_A > \bar{g}$, where $\bar{g}$ represents the rate of growth of the demand as specified in equation (1.8). This implies a different dynamics for firm A than the one described in this model. This firm will need to change its strategy towards innovation since the demand constraint will prevent it to increase its growth rate further. Therefore, in this case, demand could restrict growth possibly leading to stagnation, unless innovation becomes related to purposes other than competitive gains.

However, in the stable case, the long-run stability of the system of differential equations (1.28) and (1.32) requires that variations in g_A and g_B be compensated by adjustments in m_A and T to keep $\dot{m}_A = 0$. Thus, eventually, the growth rates equalize again. In this case, after the shock the growth rate of firm A increases. If demand continues to grow at a constant rate, the greater growth rate of firm A necessarily implies firm B growing at a smaller rate. But since the system tends to equilibrium, it eventually shifts to a new combination of T and m_A that equalizes both growth rates. To reach this new point, the growth rate of firm A decreases, while the rate of growth of firm B increases as the latter catches up. The speed of the catching-up process of firm B will limit how much more market share firm A will obtain while it maintains a higher growth rate.

Therefore, the process of market concentration that can come along with technological change can be counteracted by a higher imitative capacity of the follower, given that the effects of innovation on concentration are not so great as to offset these attempts. If the heterogeneity and specific capabilities of firm B allow it to copy the new technologies fast enough, fewer competitive gains would come from innovation for firm A. In the scope of our model, parameter σ in equation (1.32) indicates the amount by which the rate of technological change decreases with an increase in the level of the gap. A higher absolute value of σ would mean a greater decrease in the rate of technological change, thus giving firm B a greater opportunity to pursue imitation. Imitation is what then makes the system go back to an equilibrium, as depicted in Figure 3.

In sum, the two situations show how the processes of innovation, imitation, and market concentration are closely related, being their interplay responsible to make the system unstable or stable. This pattern agrees with some predictions of the neo-Schumpeterian approach. For instance, Iwai (1984a)'s evolutionary model is focused on analyzing the interactions between the disequilibrating effects of innovation and the equilibrating effects of imitation and how these interactions determine the pattern of evolution of an industry. Meanwhile, Iwai (1984b) also proposes how firms grow comparatively faster with innovative and imitative success. In the simulation model of Nelson and Winter (1982), weaker appropriability derived from the rival's higher ability to imitate the other's advances can also attenuate market concentration. We observe the same patterns with our much simpler model.

Innovation implies disequilibrating forces, following Schumpeter (1934)'s concept of creative destruction. The firm that implements innovation increases its market power and obtains monopoly profits, changing the landscape of the market. Imitation, in turn, is equilibrating since it mitigates the previous increase in market power, lowering the technological gap, which brings the system back to a stable path. Thus, the success of the follower firm in imitation, not the success of the leading firm to pursue advantages, is crucial for the industry to settle down to a static equilibrium. Nonetheless, as Lima (1996) highlights, as innovations are constantly being introduced, consequently upsetting the equilibrium tendency, the system could be permanently being put in a state of disequilibrium.

However, the effects of innovation and imitation are relative since their outcome still depends on how the concentration of the industry is evolving. As we have seen in the unstable case of our industry, the instability caused by innovation could prevail if imitation is not strong enough to offset the effects of technological advantage on market concentration. If the effects of technological change in market concentration are high, and the effects of concentration is slowing down the rate of change of concentration with the leading firm are low, it would be more difficult for imitation to succeed. Hence, the interaction between the processes of growth, concentration, innovation, and imitation, not each process individually, is responsible for either maintaining the relative configuration of the sector or making it change rapidly.

1.6 Concluding remarks

This paper develops a duopoly model based on the post-Keynesian theory of the firm that incorporates the neo-Schumpeterian double-sided relationship between market concentration and technological change. Firms are taken as technologically heterogeneous in the competitive scenario and their growth is restrained by the growth of demand. This specification implies a leader-follower relationship between the firms, with the follower capturing the residual demand of the market. Concentration and relative technological advantage determine the growth of the firms negatively and positively, respectively. In the short-run equilibrium, firms will produce and invest according to demand through adjustments in the rate of capacity utilization, which also responds to changes in market share and technological advantage in the same direction as their investment rates.

Market share and technological change have an explicit and two-way relationship in the long-run dynamics of this industry. The paper's investigation of the two-dimensional system featuring market share and the technological gap conveys that in the long-run equilibrium a higher market share slows down technological change, whereas a higher relative technological advantage leads to a faster concentration of the industry with the leading firm. The stability properties of the system depend on the direction and relative strength of the innovation effects compared to the effects of imitation and catching up, as well as on the rate of concentration of the market. In sum, the system is more stable, the higher the imitative capacity of the follower firm.

The interplay between innovation, imitation, and market structure is seen in the comparative statics exercise, which results in two different scenarios for the industry following an exogenous innovation shock. The sudden technological advantage for the leader could asymptotically concentrate the market with the leading firm when imitation is relatively so weak as to allow the leader to keep innovating and growing. However, the market could also remain a duopoly, although a more concentrated one with a larger technological advantage with the leading firm. If the follower firm can do some catch up to accompany the greater advantage of the leader, it can prevent a higher increase in concentration. Therefore, according to this model, the concentration implied by technological change can be partially counteracted if the follower firm has high imitative and catching-up capacities, so that developing these capacities can be a strategy for such firms to survive.

However, these conclusions apply only to this industry and cannot be extrapolated to the macroeconomic scenery with this formulation. Yet, as we are implicitly arguing that post-Keynesian macroeconomic models should be grounded in sound microeconomic theory, this model can serve as a basis for more complex micro models and more comprehensive macro models that incorporate changes in the micro competitive structure. On the one hand, further works could rely on flexibilizations and extensions of this simple model into the micro setting. Other aspects of firms' decision to innovate can be incorporated and firms' strategies can be taken as interactively determined, as altered by changes in the competitive landscape of the market. On the other hand, the relationship between technological change and market concentration outlined in this model can also be extended to analyze how this dynamics affects certain macroeconomic variables, such as income distribution.

2 The decline and fall of competition in a demand-led dynamic model

2.1 Introduction

In recent decades there has been a noticeable fall in the so-called economic and business dynamism of many advanced economies. A fall in the labor or wage share of GDP and the investment rate alongside an increase in market concentration and average markups and profits has been noticed. The decline in the wage share is well documented for the US and many other countries (AUTOR et al., 2020; DAO et al., 2017; KARABARBOUNIS; NEIMAN, 2014; PIKETTY, 2014).[1] There is also sound evidence that the investment rate has decreased across advanced economies (GUTIÉRREZ; PHILIPPON, 2017a; IMF, 2015). Moreover, labor productivity trends, mainly for the US, show an increase in the productivity gap between frontier and laggard firms, which is also related to weaker aggregate productivity performance (ANDREWS; CRISCUOLO; GAL, 2015).

There is a recent literature that associates the salient increase in market concentration across many industries as one of the main causes of the observed trends in wage share, investment, profits, and productivity. Grullon, Larkin and Michaely (2019) report this increase in concentration and find that it is robust to the use of different measures of concentration. They also find that firms in industries with the largest market concentration indexes also presented higher profit margins, which are associated with higher returns to shareholders. Similar findings are also reported in Autor et al. (2017), Autor et al. (2020), Akcigit and Ates (2019), Eggertsson, Robbins and Wold (2018), Gutiérrez and Philippon (2017a), and Gutiérrez and Philippon (2017b), all of which relate market concentration with one or more of the other observed trends.[2]

The drivers of market concentration, in turn, are diverse. Demographic changes, the nature of new technologies, and looser regulations have all been highlighted as important causes. However, a neo-Schumpeterian analysis would point to the role of higher labor productivity induced by technological change in increasing market concentration (DOSI, 1984; NELSON; WINTER, 1982). This argument is extended, for instance, by Autor et al. (2017) and Autor et al. (2020), which investigate the relationship between productivity, concentration, and the decrease in the wage shares focusing on "superstar" firms. These

[1] This decline contradicts the idea of constant macro-level stability of the wage share, a phenomenon noticed through the twentieth century that became one of Kaldor (1961)'s stylized facts of growth.

[2] However, this is not the only reasoning put forward. Stansbury and Summers (2020) propose that a better explanation for this macroeconomic scenario of rising profits and lower wages and wage shares relies on the reduction of worker power, rather than increases in firms' market power. The authors provide evidence that measures of reduced worker power are indeed related to lower wage levels, lower wage shares, and reductions of the NAIRU measures. They argue that this proposal explains simultaneously all the trends involving firms' market power and has direct support from the data.

firms would be the ones with high productivity and low labor shares, that have dominated the industries where they operate, thus concentrating economic activity in their hands. These studies, as well as Diez, Leigh and Tambunlertchai (2018), also find evidence that industries with the highest concentrations, with market power determining higher markups and profit margins, present the largest declines in the wage share. Hence, there is evidence of a relationship between productivity, market concentration, and income distribution between profits and wages that needs to be further assessed.

However, these approaches do not consider the role of aggregate effective demand as a constraint on output production, which is a feature of this scenario of increasing market concentration that needs to be taken into account. On the one hand, by definition market concentration means that some firms were more successful than others in capturing a fraction of aggregate effective demand. On the other hand, demand constraints could play different roles in more concentrated markets, like being less able to negatively affect output while also influencing technological diffusion.

These demand aspects are better analyzed by the post-Keynesian demand-led growth literature, which has as an important feature how it incorporates the role of income distribution in the dynamics of capital accumulation. Regarding the role of the decrease in competition, Lima (2000) incorporates the relationship between market concentration and technological change within this framework to access the long-run dynamics between concentration and income distribution. Rabinovich (2020) also appoints the rise in market concentration as one of the explanations for the puzzle of the low investment-high profits configuration of financialized firms highlighted by this literature. Despite these efforts, the post-Keynesian literature has not yet incorporated these recent trends and lacks a model that integrates the role of market concentration in influencing the dynamics of the economy through its effects on investment, productivity, and income distribution.

Thus, this paper contributes to the post-Keynesian literature by building a macrodynamic model that describes part of the dynamics of advanced economies in the last decades, highlighting the role of concentration and its relationship with capital accumulation and income distribution. This is done in two steps. First, we model a two-dimensional system that sets the dynamics between the wage share and the capital-effective labor supply ratio, which constitutes a baseline scenario in which concentration does not evolve endogenously. We extend the model, in the second step, to a three-dimensional system that incorporates the state transition function of concentration. With this framework, we can reflect on demand and supply-side factors affecting this system.

The remainder of the paper is organized as follows. In section (2.2) we describe the model and how concentration influences markups, capital accumulation, and productivity growth in this framework. Section (2.3) concerns itself with the short-run dynamics and equilibrium of this model economy. Section (2.4) focuses on the long-run dynamics between income distribution, capital accumulation, and market concentration, the latter being considered to evolve at first exogenously and then endogenously, and the implications of these relationships. Finally, section (2.5) concludes.

2.2 Framework of the model

The model deals with a closed economy with no government that produces a single good used for both consumption and investment. Production is carried out combining homogeneous capital and labor as the only two factors of production through a fixed-coefficient technology:

$$Y = \min\{aL, bK\}\,, \tag{2.1}$$

where Y is output, L is employment, and K is the capital stock, while a and b are technical coefficients. Labor productivity a varies endogenously with technological change. Firms operate with planned excess capacity to meet unexpected demand shifts. Thus, since firms produce according to demand, employment is then determined by production:

$$L = \frac{Y}{a}\,. \tag{2.2}$$

The economy comprises two classes, firm-owner capitalists and workers, who earn profits and wages, respectively. This implies the following functional distribution of income:

$$Y = \frac{W}{P}L + rK\,, \tag{2.3}$$

where W is the nominal wage, P is the price level, and r is the profit rate. The classes also differ in their savings behavior, with the capitalists saving a constant fraction s of their profits, while workers consume all of their wages (KALDOR, 1956; KALECKI, 1971; ROBINSON, 1956). From equations (2.2) and (2.3), the share of labor in income σ is given by

$$\sigma = \frac{W}{Pa}\,, \tag{2.4}$$

and the profit rate is

$$r = u(1-\sigma)\,, \tag{2.5}$$

where u denotes the rate of capacity utilization. The capital-potential output ratio is assumed to be constant and normalized to unity so that capacity utilization u is given by the output-capital ratio, Y/K.

The market is oligopolistic such that firms determine prices by applying a markup on unit labor costs, aligned with the standard approach of Kalecki (1971), as follows:

$$P = z\frac{W}{a}\,, \tag{2.6}$$

where P is the price level and z is the markup factor (one plus the markup rate). Price and wage inflation, in turn, are determined within a conflicting claims approach.[3] Inflation

[3] Lavoie (2014, p. 549–551) argues that the basic widespread post-Keynesian conflicting claims model of inflation, like Dutt (1992)'s, follows Kalecki (1971) view that inflation and the degree of monopoly are endogenous to the distributional conflict, later summarized by Rowthorn (1977).

then arises from inconsistencies between the income shares demanded by workers and firms given the available income. Firms want to increase prices whenever the prevalent markup is below their wished markup. The larger the difference between these markups, the higher the rate of price inflation. From equations (2.4) and (2.6), the markup is the reciprocal of the wage share, so that price inflation can be formally represented in terms of a difference between the actual wage share σ and the one targeted by firms σ_f,

$$\hat{P} = \tau(\sigma - \sigma_f)\,, \tag{2.7}$$

where $\hat{P}$ is the rate of change in price, $\hat{P} = (dP/dt)(1/P)$, and $0 < \tau \leq 1$ is the speed of adjustment. When firms aim at lower wage shares, they hasten the rate of price inflation, given the actual wage share and their bargaining power. The firm-targeted wage share, in turn, is given by:

$$\sigma_f = \theta_0 - \theta_1 u - \theta_2 c\,, \tag{2.8}$$

where θ_i, $i = 0, 1, 2$, are constant positive parameters and c is the level of concentration of the market. Demand impacts firms' desired wage share since the level of capacity utilization u impacts the threat other competitors present to the firm, this thread being more important the lower the capacity utilization, discouraging price increases (DUTT, 1992; LIMA, 2004; ROWTHORN, 1977). Similar to Lima (2000), a higher concentration implies higher market power, which leads firms to desire a higher markup and a lower wage share, following Kalecki (1971) and Steindl (1952) and consistent with evidence found in Autor et al. (2020) and De Loecker, Eeckhout and Unger (2020).[4] As concentration increases market shares, it reduces the price elasticity of demand so that firms with larger market shares will set higher markup rates.

Wage inflation follows the same pattern as price inflation, depending on the gap between the workers' wage share target σ_w and the actual one:

$$\hat{W} = \beta(\sigma_w - \sigma)\,, \tag{2.9}$$

where $\hat{W}$ is the rate of change of the nominal wage, $\hat{W} = (dW/dt)(1/W)$, and β accounts for the speed of adjustment, which reflects the institutional framework of the wage settlement process. Therefore, the rate of wage inflation speeds up when, given the actual wage share, workers' target a higher wage share, depending on their bargaining power. Following Rowthorn (1977), Dutt (1992), and Lima (2004), workers targeted wage share is influenced by demand conditions as it increases with the employment rate $e = L/N$, where N is the supply of labor, as follows:

$$\sigma_w = \lambda_0 + \lambda_1 e\,, \tag{2.10}$$

[4] Autor et al. (2020) provide empirical support, using micro firm-level panel data, of market concentration being a cause of the fall in the labor share observed in the US and other advanced economies. They relate market concentration to the rise of superstar firms, which are characterized by high markups and a low labor share of value-added. These results are consistent with the ones found by De Loecker, Eeckhout and Unger (2020) using firm-level data for the US since 1955. Their empirical results also relate higher market power, measured by markups, with lower labor shares.

where λ_j, $j = 0, 1$, are positive parameters. A higher employment rate then allows workers to seek and obtain higher wage inflation, as it increases their power in the bargaining process. Moreover, the employment rate is related to the state of the goods market because of the fixed-coefficient characteristic of the production function - according to which a short-run increase in output is necessarily accompanied by an increase in employment when labor productivity stays constant. Consequently, the employment rate can be taken as $e = uk$, with k being the ratio of capital stock to labor supply in productivity units (or capital-effective labor supply ratio), $k = K/Na$.

Firms make accumulation plans despite their current savings so that firms' desired growth rate of the capital stock g_I is given by:

$$g_I = \alpha_0 + \alpha_1 r + \alpha_2 u - \alpha_3 c \,, \tag{2.11}$$

where α_h, $h = [0, 3]$, are all positive parameters, with α_0 representing animal spirits. Following the Kalecki-Steindl tradition, desired investment depends positively on the rate of capacity utilization, encompassing accelerator effects, and the profit rate, considering the current profit rate as a good index of what to expect in future earnings.

Desired investment is also taken to depend negatively on the degree of market concentration c. This implies that market power that comes with concentration affects investment decisions. In this case, we state that this effect is negative, as with less competition firms have fewer incentives to invest. This link has been empirically supported by works that investigate the weakness of capital investment in advanced economies, especially in the US. For instance, Gutiérrez and Philippon (2017a), Gutiérrez and Philippon (2017b), and Crouzet and Eberly (2019) provide empirical evidence that declining competition has an important role in the decline of investment in many industries.

The technological parameters are given at a point in time as a result of previous dynamics. Yet, they change over time with the growth of labor productivity, with the following specification:

$$\hat{a} = \gamma_0 + \gamma_1 c + \gamma_2 d \,, \tag{2.12}$$

where γ_i are positive parameters, $\hat{a}$ is the growth rate of productivity, and d is the rate of technological diffusion of the industry. Equation (2.12) indicates that the positive effect that concentration has on productivity can be reinforced or counteracted by how the diffusion of technology from leaders to laggards occurs.

We are considering the "Schumpeterian effect" of competition on productivity through technological innovation, following recent evidence of how firms that became more concentrated also presented an increase in productivity, as showed by Autor et al. (2020). However, there is also evidence that this firm-level productivity did not increase overall levels of productivity, which has slowed down in West advanced economies (SYVERSON, 2017). In this model, we encompass this trend by incorporating the possibility of declining diffusion of technology as an explanation for the lack of productivity gains from concentration. This declining diffusion argument is consistent with empirical evidence present in Andrews, Criscuolo and Gal (2015) and has been highlighted by the literature that incorporates Schumpeterian insights (AKCIGIT; ATES, 2019; DOSI, 1984; NELSON; WINTER, 1982). Diffusion d is thus defined as

$$d = \delta_0 + \delta_1 g \,, \tag{2.13}$$

where δ_j are positive parameters, with δ_0 encompassing the body of regulations (antitrust, patenting policies, incentives) and relevant technological characteristics that affect the level of diffusion. On the one hand, a weakening in antitrust enforcement law has been documented, especially in the US (GRULLON; LARKIN; MICHAELY, 2019). On the other hand, many sectors have become intensive in data-dependent processes and focused on "intangible capital" (CROUZET; EBERLY, 2019). Both processes contribute to a smaller level of diffusion. Also, we follow Lima (2000) in relating diffusion with growth since, from the demand side, diffusion would depend on income and its rate of growth.

Since firms operate with planned excess capacity, the equality between desired investment and savings will be assured by adjustments in the rate of capacity utilization. The available savings will determine the growth rate of the capital stock, such that assuming away capital depreciation we obtain:

$$g_S = sr \,, \tag{2.14}$$

where g_S is aggregate savings normalized by the capital stock. Finally, since the rate of capacity utilization equals the output-capital ratio, the growth of capital accumulation also stands for the growth rate of this economy.

2.3 Short-run equilibrium

In the short run, the stock of capital K, the nominal wage W, the price level P, concentration c, and labor productivity a are constant. Since adjustments in the rate of capacity utilization ensure the equality between investment and savings, in the goods market short-run equilibrium we have $g_I = g_S$. Substituting (2.5) in (2.11) and (2.14), from the equilibrium condition we solve for the short-run equilibrium value of the rate of capacity utilization u^*, obtaining

$$u^* = \frac{\alpha_0 - \alpha_3 c}{(s - \alpha_1)(1 - \sigma) - \alpha_2} \,. \tag{2.15}$$

We ensure short-run stability assuming a positive denominator in equation (2.15) above, $(s-\alpha_1)(1-\sigma)-\alpha_2 > 0$. This implies aggregate savings being more responsive than desired investment to changes in capacity utilization to eliminate rather than exacerbate excess demand or supply. Also, $u \in (0, 1)$ implies a positive numerator in (2.15), that is, $\alpha_0 > \alpha_3 c$.

From expression (2.15), everything else held constant, the partial effect of changes in the wage share and market concentration is given by:

$$u_\sigma^* = \frac{\partial u^*}{\partial \sigma} = \frac{(s-\alpha_1)u^*}{(s-\alpha_1)(1-\sigma)-\alpha_2} > 0\,, \tag{2.16}$$

$$u_c^* = \frac{\partial u^*}{\partial c} = \frac{-\alpha_3}{(s-\alpha_1)(1-\sigma)-\alpha_2} < 0\,. \tag{2.17}$$

The partial derivative (2.16) shows that an increase in the wage share affects the capacity utilization positively, that is, raises the level of activity. This means that the modeled economy operates in a wage-led effective demand regime, as is standard in Kaleckian models. According to (2.17), in turn, a higher concentration implies a lower capacity utilization, following the investment dynamics in which, given u, when the market becomes more concentrated investment declines.

The short-run equilibrium rate of capital accumulation g^* is obtained substituting (2.15) into (2.14), which results in

$$g^* = su^*(1-\sigma)\,. \tag{2.18}$$

Expression (2.18) allows for obtaining the following partial derivatives:

$$g_\sigma^* = \frac{\partial g^*}{\partial \sigma} = s[u_\sigma^*(1-\sigma) - u^*] > 0\,, \tag{2.19}$$

$$g_c^* = \frac{\partial g^*}{\partial c} = s(1-\sigma)u_c^* < 0\,, \tag{2.20}$$

both of which indicate how the accumulation and growth rates, as well as the profit rate - following the assumption that workers do not save and capitalists save a positive fraction of their income - move in the same direction as the rate of capacity utilization when faced with changes in the wage share and concentration.

2.4 Long-run dynamics

We now explore the dynamical feedback effects that relate income distribution, capital accumulation, and market concentration in the long run. This section is then divided into two. First, we model the dynamical interaction between income distribution and capital accumulation, when the degree of concentration is kept constant. Second, we relax this hypothesis and consider how the degree of concentration varies in time following changes in the technological sphere to investigate how this addition changes the stability conditions of the first scenario.

2.4.1 The two-dimensional system

In the long run, the short-run equilibrium values of the variables will always be met with the economy moving over time through changes in these variables. We follow this over-time behavior of the system by looking into the dynamics between the short-run state variables wage share σ and ratio of capital stock to labor supply in productivity units k, while at first considering the degree of concentration c as constant. From the definition of these variables, we obtain the following differential equations:

$$\hat{\sigma} = \hat{W} - \hat{P} - \hat{a}\,, \tag{2.21}$$

$$\hat{k} = \hat{K} - \hat{N} - \hat{a}\,, \tag{2.22}$$

where the over-hats indicate time-rates of change. Substituting (2.9), (2.7), (2.12), (2.13), and (2.18) in the system (2.21) and (2.22) yields:

$$\hat{\sigma} = \beta(\lambda_0 + \lambda_1 u^* k - \sigma) - \tau(\sigma - \theta_0 + \theta_1 u^* + \theta_2 c) - [\gamma_0 + \gamma_1 c + \gamma_2(\delta_0 + \delta_1 g^*)]\,, \tag{2.23}$$

$$\hat{k} = g^* - n - (\gamma_0 + \gamma_1 c + \gamma_2(\delta_0 + \delta_1 g^*)\,, \tag{2.24}$$

where u^* and g^* are given by equations (2.15) and (2.18), respectively, and n is the exogenous growth rate of labor supply.

Equations (2.23) and (2.24) form an autonomous two-dimensional non-linear system of differential equations in which the rates of change of σ and k depend on the levels of these variables and the parameters of the system. Solving for the long-run equilibrium with $\hat{\sigma} = \hat{k} = 0$ yields a non-linear isocline for the former, and a vertical line for the latter in the relevant (σ, k) space. Still, there is at least one non-trivial equilibrium solution (σ^*, k^*) obtained from the system resolution. The local stability of this equilibrium can be examined through its Jacobian matrix of partial derivatives, given by:

$$J(\sigma, k) = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix}, \tag{2.25}$$

$$J_{11} = \frac{\partial \hat{\sigma}}{\sigma} = \beta(\lambda_1 u^*_\sigma k - 1) - \tau(1 + \theta_1 u^*_\sigma) - (\gamma_2 \delta_1 g^*_\sigma)\,, \tag{2.26}$$

$$J_{12} = \frac{\partial \hat{\sigma}}{\partial k} = \beta \lambda_1 u^* > 0\,, \tag{2.27}$$

$$J_{21} = \frac{\partial \hat{k}}{\partial \sigma} = (1 - \gamma_2 \delta_1) g^*_\sigma\,, \tag{2.28}$$

$$J_{22} = \frac{\partial \hat{k}}{\partial k} = 0\,. \tag{2.29}$$

From $J(\sigma, k)$, we see that not all partial derivatives have an ambiguous sign. On the one hand, equation (2.27) indicates that an increase in the ratio of capital to labor supply in productivity units will raise the rate of increase of the wage share by raising the employment rate and consequently the wage share desired by workers. Equation (2.29) in turn, shows that since an increase in k does not affect concentration, the wage share or capacity utilization, it thereby does not affect the rates of accumulation and productivity growth, consequently not affecting its rate of growth.

On the other hand, equation (2.26) shows how an increase in the wage share could either decrease or increase its rate of change. This direction depends mainly on the impact of the wage share on the rate of capacity utilization, as the wage shares desired by workers and firms, as well as productivity growth, depend directly or indirectly on capacity utilization. The wage shares claimed by workers and firms respectively rise and decline with an increase in capacity utilization due to a higher wage share. This increase also raises productivity growth through its indirect positive effect on diffusion. Yet, the term J_{11} would only be positive in case the weight of the workers' claims for higher wages is relatively strong, or if diffusion is weak, implying a small diffusion coefficient $\gamma_2\delta_1$. Lastly, equation (2.28) indicates that the effect of an increase in the wage share on the rate of change of k depends on its relative effects on the rates of growth and technological change. If a higher wage share has a relatively high enough effect on productivity growth by increasing the diffusion of technology, the growth rate of the capital-effective labor supply ratio would decrease.

To ensure stability of the two-dimensional system (2.24) and (2.23), two conditions need to be fulfilled. First, the partial derivative J_{11} should be negative, thus yielding a negative trace. This sign depends on the relative bargaining power of capitalists and workers and the degree of technological diffusion. Facing an increase in the wage share, workers bargaining power could be high enough to outweigh the opposing effects of higher capacity utilization on the firms' demands and on productivity through higher diffusion. In this case, J_{11} would be positive, which would cause an unstable spiral of wage share growth. The second condition also demands a higher relative degree of diffusion, expressed in the coefficient $\gamma_2\delta_1$. It entails a negative sign to J_{21}, that is, $1-\gamma_2\delta_1 < 0$, which yields a negative determinant of the Jacobian matrix $J(\sigma, k)$. This conditions requires that $\gamma_2 \geq 1$ and $\delta_1 > 1$, or the other way around.[5] In this case, an increase in the wage share conveys a decrease in the growth rate of the capital-effective labor supply ratio, as it sufficiently increases productivity through a higher technological diffusion. Otherwise, the equilibrium solution would be saddle-point unstable.

In this scenario, we can analyze how an exogenous shock in the degree of concentration c would affect the equilibrium points and the stability of the system. In fact, the second stability condition also determines how an exogenous increase in the level of concentration would affect the equilibrium wage share. As shown in the Appendix A, $1-\gamma_2\delta_1 < 0$ is a necessary condition to an exogenous increase in c to decrease the equilibrium value of the wage share. Therefore, in the stable case, an exogenous increase in concentration would bring the equilibrium point to a configuration with a smaller wage share. The partial derivative in relation to c for k^* is a concave-down function of c so that

[5] This seemingly restrictive condition could be relaxed by making the growth rate of the labor supply n endogenous in relation to g or if we include a Verdoorn effect of growth g on productivity $\hat{a}$. However, these paths were not pursued in this version to keep the model as simple as possible.

an increase in concentration could either increase or decrease the capital-effective labor output ratio depending on the actual parametric change.

Regarding the effect of a concentration shock on the stability conditions, a higher concentration can make this system more prone to instability. An increase in c affects the system by decreasing the values of u^*, u^*_σ, and g^*_σ. A closer look at the derivatives of the Jacobian matrix $J(\sigma, k)$ indicates that this effect can violate the first stability condition, the negative trace, even if it was ensured before the shock. By decreasing the absolute value of J_{11}, the absolute values of the trace decreases, which could make it eventually positive. Therefore, a shock in concentration can take the system off equilibrium and make it unstable from that point on, so that the system does not reach a new stable equilibrium point.

However, we proceed to check how the stability conditions and the effects of a concentration shock would change when considering the degree of concentration evolving through time alongside distribution and capital accumulation, which is a likely scenario of interaction. In the next section then we relax the hypothesis of a constant c and evaluate the resulting three-dimensional system.

2.4.2 The three-dimensional system

We now consider how the degree of concentration evolves with time and its dynamic behavior toward the time-rates of change of the wage share and capital accumulation. We define the dynamics of concentration in the following linear way:

$$\hat{c} = \rho_0 + \rho_1 \hat{a} - \rho_2 d - \rho_3 c \,, \tag{2.30}$$

where ρ_h are all positive parameters. The rate of change in concentration is assumed to be positively related to changes in productivity, while negatively related to the degree of diffusion. Successful technological change that accelerates productivity grants firms competitive advantages that allow them to concentrate the market. However, the persistence of these advantages depends on the diffusion of technology in the industry. The higher the diffusion, the faster innovation can be copied and the faster the competitive advantages will be lost and the market will become more competitive (DOSI, 1988; NELSON; WINTER, 1978; NELSON; WINTER, 1982). This is also consistent with the literature that appoints "superstar" firms, which have the highest productivity rates, as being the ones that concentrated the markets with themselves in the last decades. (AUTOR et al., 2017; AUTOR et al., 2020). We also assume that a higher level of concentration decreases its rate of change, as firms with larger competitive advantages will have fewer incentives to speed up the expansion of this advantage.

Upon substitution of (2.12) and (2.13) in (2.30), we obtain

$$\hat{c} = \rho_0 + \rho_1[\gamma_0 + \gamma_1 c + \gamma_2(\delta_0 + \delta_1 g)] - \rho_2(\delta_0 + \delta_1 g) - \rho_3 c \,, \tag{2.31}$$

which alongside equations (2.24) and (2.23) form a three-dimensional non-linear system in which the rates of change of σ, k, and c depend on the levels of these variables and the parameters of the system. The local stability of the equilibrium solution (σ^*, k^*, c^*) can be verified with the following Jacobian matrix:

$$J(\sigma, k, c) = \begin{bmatrix} J_{11} & J_{12} & J_{13} \\ J_{21} & J_{22} & J_{23} \\ J_{31} & J_{32} & J_{33} \end{bmatrix}, \tag{2.32}$$

$$J_{11} = \frac{\partial \hat{\sigma}}{\partial \sigma} = \beta(\lambda_1 u^*_\sigma k - 1) - \tau(1 + \theta_1 u^*_\sigma) - (\gamma_2 \delta_1 g^*_\sigma)\,, \tag{2.33}$$

$$J_{12} = \frac{\partial \hat{\sigma}}{\partial k} = \beta \lambda_1 u^* > 0\,, \tag{2.34}$$

$$J_{13} = \frac{\partial \hat{\sigma}}{\partial c} = \beta \lambda_1 u^*_c k - \tau(\theta_1 u^*_c + \theta_2) - (\gamma_1 + \gamma_2 \delta_1 g^*_c)\,, \tag{2.35}$$

$$J_{21} = \frac{\partial \hat{k}}{\partial \sigma} = (1 - \gamma_2 \delta_1) g^*_\sigma\,, \tag{2.36}$$

$$J_{22} = \frac{\partial \hat{k}}{\partial k} = 0\,, \tag{2.37}$$

$$J_{23} = \frac{\partial \hat{k}}{\partial c} = (1 - \gamma_2 \delta_1) g^*_c - \gamma_1\,, \tag{2.38}$$

$$J_{31} = \frac{\partial \hat{c}}{\partial \sigma} = (\rho_1 \gamma_2 - \rho_2) \delta_1 g^*_\sigma\,, \tag{2.39}$$

$$J_{32} = \frac{\partial \hat{c}}{\partial k} = 0\,, \tag{2.40}$$

$$J_{33} = \frac{\partial \hat{c}}{\partial c} = (\rho_1 \gamma_2 - \rho_2) \delta_1 g^*_c + \rho_1 \gamma_1 - \rho_3\,. \tag{2.41}$$

Considering that we have already discussed the signs of the derivatives that appeared in the two-dimensional matrix $J(\sigma, k)$, we now look into the signs of the additional partial derivatives of the three-dimensional Jacobian matrix $J(\sigma, k, c)$. Equation (2.35) shows that an increase in concentration could either increase or decrease the rate of change of the wage share and that this effect is mostly mediated through the negative impact on capacity utilization. A smaller capacity utilization decreases employment, by decreasing the rates of growth and technological innovation, which decreases workers' bargaining power and their claims to a higher wage share. However, a higher concentration affects both firms' desired markup and productivity growth positively on its own and negatively through capacity utilization, thus having an ambiguous effect on price inflation and productivity growth and thereby on the growth rate of distribution. Equation (2.38)'s sign is given by the relative impact of changes in concentration on the rates of growth and technological change, the latter being determined by the relative strength of diffusion and concentration effects on productivity growth.

Regarding how changes in $\sigma, k,$ and c affect the growth rate of concentration, equation (2.39) shows that the effect of an increase in the wage share depends on its relative impact in increasing productivity through diffusion and diffusion itself, with more chances of being negative the stronger the direct influence of diffusion on the rate of change in concentration. Equation (2.40) shows that increases in the capital-effective labor supply ratio do not affect the growth rate of concentration since they do not affect any variable, like concentration, the wage share, or capacity utilization, that could affect the rates of accumulation or productivity growth. Finally, from equation (2.41) we see that an increase in the degree of concentration decreases its growth rate unless the higher concentration increases productivity while decreasing diffusion enough to counteract the negative direct effect of the level of concentration on its rate of growth.

The necessary and sufficient Routh-Hurwitz conditions for local stability, evaluated at the equilibrium, are the following:

$$1.\, Tr(J) = J_{11} + J_{33} < 0\,, \tag{2.42}$$

$$2.\, Det(J_1) + Det(J_2) + Det(J_3) = J_{11}J_{33} - J_{13}J_{31} - J_{12}J_{21} > 0\,, \tag{2.43}$$

$$3.\, Det(J) = J_{12}J_{23}J_{31} - J_{12}J_{21}J_{33} < 0\,, \tag{2.44}$$

$$4.\, -Tr(J)[Det(J_1) + Det(J_2) + Det(J_3)] + Det(J) > 0\,. \tag{2.45}$$

All four conditions can be simultaneously satisfied depending mainly on the relationship between the forces of concentration and the ones of diffusion. In the two-dimensional system, given an increase in σ, diffusion needs to be high enough just to allow productivity to grow and contain a possible increase in accumulation that would raise the rate of growth of k. This sequence implies a negative sign to $1 - \gamma_2\delta_1$ and consequently to J_{21}, necessary for stability. However, when we consider the growth rate of concentration endogenously, this condition is not enough to make the system stable. In this case, diffusion would need to be high enough to suppress the destabilizing effects of the changes on the level and the growth rate of concentration.

From equation (2.12), an increase in concentration can either increase productivity growth directly, mediated through the magnitude of the parameter γ_1, or decrease it indirectly, through the reducing diffusion effect of a smaller accumulation rate, which depends on the magnitude of the parameters $\gamma_2\delta_1$. If the effect of γ_1 is high enough in comparison with $\gamma_2\delta_1 g_c^*$, whenever there is a change in concentration, the positive direct effect over productivity growth would prevail. However, this is a destabilizing effect in this system. For instance, if this direct concentration effect on productivity is relatively higher to the indirect one over diffusion, it makes it more likely that an increase in concentration would increase its rate of growth. This positive effect, in turn, implies a positive partial derivative J_{33} in (2.41). Yet, this derivative being negative is a necessary, although not sufficient, condition for the system to be stable. A negative J_{33} ensures a negative trace to Jacobian matrix $J(\sigma, k, c)$, ensuring that the first Routh-Hurwitz criterion, in equation (2.42), is attended.

Moreover, a high enough diffusion is also important for the remaining conditions to be attended. If diffusion, expressed by $\gamma_2\delta_1 g_c^*$, is bigger than concentration tendencies, expressed by γ_1, an increase in concentration would cause a decrease in productivity growth. This fall in productivity would, in turn, increase the growth rates of the wage share and the ratio of capital stock to labor supply in productivity units. This effect makes it more likely that the partial derivatives J_{13} and J_{23} are positive. If we also assume that an increase in the wage share, by increasing the accumulation rate and consequently diffusion, would lower the rate of change in concentration, we assure that the partial derivative J_{31} is negative. Altogether this configuration of the Jacobian matrix $J(\sigma, k, c)$ attends the second and third stability criteria, in equations (2.43) and (2.44), respectively.

The fourth criterion, described in equation (2.45), although still ambiguous from a purely analytical analysis, depends highly on the attendance of the other stability criteria. Furthermore, a higher parameter ρ_3, which influences the effect of the level of concentration on its growth rate, makes this condition more easily satisfied. Given that $J_{33} < 0$, a higher ρ_3 would increase $|J_{33}|$, increasing $|Tr(J)|$, the sum $Det(J_1) + Det(J_2) + Det(J_3)$ and $|Det(J)|$, which are the first three stability conditions. This increase, therefore, will be higher on $-Tr(J)[Det(J_1) + Det(J_2) + Det(J_3)]$ than on $|Det(J)|$, making the fourth condition more likely to be fulfilled.

In sum, even if diffusion is high enough to stabilize the system when concentration is constant, when the degree of concentration is growing over time with the wage share and the capital-effective labor supply ratio, the system can become unstable despite the previously stabilizing diffusion level. This instability refers to a situation in which an increase in concentration decreases the growth rates of both the wage share and the capital-effective labor supply ratio while increasing the growth rate of concentration. This suggests a scenario in which concentration can asymptotically converge to its highest value, generating a monopoly, and an ever-decreasing and stagnating wage share and capital accumulation rate.

Supposing that the system is stable, we can also explore how this stability would be affected by an exogenous increase in concentration. In this case, this would be a shock in the autonomous component of the dynamic equation for concentration, which is ρ_0. As analyzed in the previous case, the absolute value of the derivative J_{11} can become positive. This change of sign could also make the trace of the Jacobian matrix $J(\sigma, k, c)$ positive, violating the first Routh-Hurwitz stability condition. However, in the three-dimensional case, most likely at least another condition would also fail to hold after the concentration shock. The second criterion can also fail to be fulfilled, as the first two terms in the sum displayed in equation (2.43), which are positive at stability, can become negative after a concentration shock, thus leaving this criterion more susceptible to be violated. If the first two no longer hold, but the third one does, it is simple to see that the fourth equation does not remain positive.

This simple comparative static analysis shows that the three-dimensional system, in comparison with the simpler two-dimensional one, is more prone to instability. When faced with a concentration shock, in the first scenario one of two conditions becomes susceptible not to hold, whereas in the second three of four conditions are likely to no longer be met. This result implies that, when the time-evolution of concentration is considered, it is more probable that an exogenous increase in concentration brings the previously stable system to an unstable situation. In other words, the inclusion of the concentration dynamics in the three-dimensional system unequivocally narrows down the stability corridor within which c is allowed to increase without turning an oligopoly into a stable monopoly.

This scenario of higher instability risk has many similarities with the current case of many advanced economies and raises concerns over its consequences for income distribution and capital accumulation. At the same time, higher concentration and smaller investment rates and wage shares have been noticed, and it is worrisome that this configuration could keep being exacerbated. Hence, according to this model, institutions, regulations, and firm strategies need to be focused on how to promote and improve imitation capacities and competition to try to counteract these negative effects and steer the system to the more desirable equilibrium. For instance, antitrust policies could complement policies that deal with inequality by addressing practices that compromise competition and thus endanger economic and wage growth. Moreover, since diffusion is also related to demand, it is important to consider the role of demand stimuli in increasing the diffusion rate to control the increase in concentration.

2.5 Concluding remarks

This paper contributes to the post-Keynesian literature by developing a macro model that encompasses some of the recent trends on the effects of market concentration on the wage share and capital accumulation and how the three are related. We also consider labor productivity induced by technological innovation as endogenous, positively related to concentration and the rate of technological diffusion. Concentration influences desired investment negatively, while the accumulation rate influences diffusion positively. Firms operate with planned excess capacity so that in the short run the equality between investment and savings will happen through adjustments in the rate of capacity utilization, which also responds negatively to an increase in the degree of concentration.

This model allows us to set the conditions in which the processes of income distribution, capital accumulation, and concentration can be simultaneously stable in the long-run. We observe that this stability depends mainly on how the diffusion of technology occurs and how it interacts with the influences of concentration. The two-dimensional system that sets the dynamics between the wage share and capital-effective labor supply ratio constitutes a baseline scenario in which concentration does not evolve endogenously. In this case, we observe that the local stability of the system is attained when firms bargaining power facing an increase in the wage share surpasses the strength of workers' claims and when diffusion is high enough to make productivity growth more responsive than capital accumulation to variations in the wage share. However, this situation could be not very representative, given that there is evidence that the degree of concentration evolves with income distribution and capital accumulation.

Therefore, we extend the model to a three-dimensional system that incorporates the state transition function of concentration. This function relates the growth of concentration to technological change positively through productivity growth, while negatively with diffusion and the level of concentration. The analysis of the local stability of the equilibrium solution with the Routh-Hurwitz Criteria shows that considering changes in concentration creates a new source of instability for the model. This configuration of the model exposes the interrelatedness of the effects of diffusion of technology and concentration, being, in general, stabilizing and destabilizing, respectively. If diffusion is not high enough to counteract the effects of concentration, an unstable situation can emerge in which both the wage share and the capital-effective labor supply ratio decrease continually, while concentration grows continually.

We also conduct simple comparative static analyses of the effects of an exogenous concentration shock on the equilibrium values of the variables and the stability of the two scenarios. First, this exercise shows that when the equilibrium solution is stable, an exogenous increase in the level of concentration would decrease the equilibrium value of the wage share in the scenario that concentration does not evolve endogenously. Second and most importantly, the three-dimensional system is shown to be more prone to remain in an instability trap following the concentration shock than the two-dimensional one. The instability scenario and the high instability risk raise concerns about the path that advanced economies are following, and the consequences that a rising concentration could entail for their income distribution and capital accumulation. In light of these consequences, if counteracting an increasing degree of concentration is the goal, given that diffusion depends on regulations and firm strategies but also demand, both supply and demand factors would need to be considered.

3 Market power and technological progress: a two-way relationship?

3.1 Introduction

Markups are important measures of market power and, thus, have important distributional effects. In fact, the reported increases in market power in the last three-two decades for advanced economies are consequently accompanied by trends of decreasing wage shares of output (AKCIGIT; ATES, 2019; AUTOR et al., 2020; DE LOECKER; EECKHOUT; UNGER, 2020). Besides, further increases in market power could have other significant macroeconomic implications, like weakening investment (GUTIÉRREZ; PHILIPPON, 2017a), altering the stabilizing effects of monetary policy, and deterring innovation (IMF, 2019). The determinants of the markups involve the pricing and profitability strategies of the firms and the level of concentration of their market. However, in explaining long-term trends of rising markups, the empirical literature also considers the role of antitrust regulations and technological progress (GRULLON; LARKIN; MICHAELY, 2019).

The relationship between technological progress and markups is somewhat similar to how the former relates to market concentration. A two-sided relationship is theorized, with technological innovation as a cause and a consequence of rising markups. The theoretical propositions found in the literature state that, on the one hand, successful technological innovation would confer competitive advantages that increase market power. On the other one, *ex-ante* market power would ensure barriers to entry and internal resources which could also be conducive to innovation. Using markups, either as only a measure of market power or a measure of market concentration, some empirical works have found a non-monotonical relationship between markups and innovation - innovation being positively related to markups at lower levels of markup and inversely related to markups at higher levels of markup (AGHION et al., 2005; DIEZ; LEIGH; TAMBUNLERTCHAI, 2018; IMF, 2019). At the same time, innovation increases productivity and creates new products, both of which grant transient market power to firms, or market power high enough to create barriers to entry and concentrate the market, as empirically supported by Autor et al. (2020).

Despite some important and robust results that have already been reported in the empirical literature, there are several measurement and methodological issues that can still be addressed. Most existent papers approach one side at a time of the markup-technological progress relationship with instrumental variable estimators (BLUNDELL; GRIFFITH; REENEN, 1999; DIEZ; LEIGH; TAMBUNLERTCHAI, 2018; IMF, 2019). However, especially because the interest in the trends of market power and concentration in advanced economies is so recent and reliable data so hard to obtain, most analyses focus just on capturing the trends, presenting only simple data analyses and correlation exercises, while others propose theoretical modeling on the topic (AKCIGIT; ATES, 2019; BAJGAR et al., 2019; BOAR; MIDRIGAN, 2019). Moreover, the data restriction is relevant to the point that the majority of papers deal only with the US case (AGHION et al., 2005; AUTOR et al., 2020; DE LOECKER; EECKHOUT; UNGER, 2020; DIEZ; LEIGH; TAMBUNLERTCHAI, 2018; GRULLON; LARKIN; MICHAELY, 2019).

This paper aims to investigate empirically how market power and technological progress are related. An important contribution to the literature is the focus on the possibility of a simultaneous determination between these variables, addressed with the use of the Vector Autoregressive (VAR) methodology applied to panel data. This method deals with the reverse causality, that is, it encompasses both sides of this relationship by dealing with the simultaneity and endogeneity present. We carry this investigation on a sample of 131 countries over the period 1990-2017, a period that has been identified with rising market power. Thus, we perform a cross-country empirical analysis with overall-country markups and technological capabilities being proxied respectively by the inverse of the observed share of wages in national income, following Neiss (2001), and by the productivity gap between individual countries' labor productivity and the technological frontier. These overall-country measures have the disadvantage of being less precise than firm or industry level markups and productivity, also concealing heterogeneities and composition effects. Yet, they allow the extension of the argument to the more comprehensive country level, providing important evidence on how the variables are related at a broader level.

The paper is structured as follows. Section 3.2 reviews theoretical links concerning markups, income distribution, and technological progress, also highlighting empirical works that have investigated the markup-technological capabilities relationship. Section 3.3 describes the empirical strategy adopted in the paper, which includes the data and the estimation method. Section 3.4 presents and discusses the results. Finally, section 3.5 concludes.

3.2 Market power, income distribution, and technological progress

Markups are costing margins imposed by firms over some measure of prices. In an oligopolistic setting, businesses and firms mark up the costs to determine a price. This is the general view of price determination of the post-Keynesian theory, which shares this pricing theory of cost-plus pricing. In a standard Kalecki-Steindl single-good growth model, since the market is oligopolistic firms set prices by applying a markup on unit labor costs (KALECKI, 1971):

$$P = z\frac{W}{a}\,, \tag{3.1}$$

where z is the markup factor (one plus the markup rate), P is the price level, W stands for the nominal wage and a for labor productivity.

The markup, however, will directly impact the share of labor in income, so-called the labor or wage share. The wage share σ can be defined as

$$\sigma = \frac{W}{Pa}\,. \tag{3.2}$$

Substituting (3.2) in (3.1), the markup becomes directly related to the wage share, as follows:

$$z = \frac{1}{\sigma}\,, \tag{3.3}$$

where the markup is simply the reciprocal of the wage share.

This relationship between the markup and wage share shows how the former has direct and important distributional consequences - which is quite intuitive. This direct relation also has consequences for the macro setting in this demand-led approach. For example, the paradox of costs is derived from this setting. Proposed first by Kalecki (1969) in a static version and later by Rowthorn (1981) in a dynamic one, this paradox refers to the result that higher real wages could generate higher profit rates, contrary to the microeconomic prediction that higher wages would mean higher costs, lower profit margins, and lower profit rates.[1] In particular, since in the Kalecki-Steindl general model the rate of capacity utilization adjusts to lead the system to equilibrium, an increase in the markup reduces the rate of capacity utilization and thus the rate of growth. If firms reduce the real wages of workers, increasing the profit share and the markup, the consequence is a general decrease in the rate of profit, not the other way around.

However, the results of this approach could be challenged by the investment-profit puzzle, which appears with the detachment of profit and investment rates. This detachment refers to the fact that higher profits have been observed without the counterpart of investment, which has declined. Concerning the explanations for the puzzle, Rabinovich (2020) highlights that firms' considerations about maximizing shareholder's value in the context of financialization do not explain by themselves the "supply-side" of the puzzle. The supply-side refers to how firms remain profitable and capable of distributing funds to shareholders despite not investing, as investment is acknowledged as the basis of the supply of products and competition. One of the explanations put forward to address this issue is firms' higher market power. Thus the need to investigate market power and its causes.

Market power, in turn, is usually measured by markups. This interpretation agrees with Kalecki (1971) in taking markups as a good measure of the degree of monopoly, that

[1] Interestingly, Lavoie (2014, p. 18-19) discusses how this is an important topic during periods of crises, in which firms would be tempted to reduce labor costs to increase their individual profitability. "While this will be profitable to the firms that achieve the greatest real wage reductions, the overall effect will be detrimental to the overall economy, and most certainly to the overall world economy(. . .)" (p. 19).

is, of firms' market power. Firms with higher market power are the ones that can increase their markups without losing revenue, leading to higher profits while reducing their output and demand for capital, reducing their investment rates. The level of markups, in turn, is also related to firms' pricing and profitability strategies and the level and dynamics of market concentration.

Investigations have been conducted on the subject motivated by the observation of rising markups in the last decades. Diez, Leigh and Tambunlertchai (2018) investigate this increase in 74 countries from 1980-2016. Using data from the Thomson Reuters Worldscope, an international database of publicly traded firms, the authors find that in advanced economies, the average increase in markups has been 39% since 1980. For emerging markets the evidence is less clear, that is, these countries have not experienced such a pronounced and general increase as the advanced countries did. Furthermore, the paper reports evidence of a positive correlation of markups with profitability measures and market concentration measured by the Herfindahl-Hirschman index.[2] These correlations are highlighted since they suggest that the increasing trend of markups translates into higher market power, which would not be the case if markups were only serving to recover lost profits. The same trend was reported by IMF (2019)'s report using a sample of private firms of 27 countries (16 advanced and 11 emerging market economies) in the period 2000-2015. This report finds that markups increased 8% on average in advanced economies, while in emerging markets they show stability.[3] For advanced economies, this increase has also been accompanied by increases in profits and market concentration.

Yet, both Diez, Leigh and Tambunlertchai (2018) and IMF (2019) find that the largest markup increases are found in the US. Dealing specifically with the US case, Hall (2018) reports that in a sample of 60 industries the incidence of high market power is heterogeneous across them. Particularly, using data from the US Economic Census from 1998 to 2015 and an instrumental variable approach, the author finds no relation between the market concentration measured by the fraction of megafirms (firms with 10,000 or more employees) in the industry and higher markups. However, he finds a positive relation between markups and industries with growing mega-firm fractions, that is, the ones that gained more market power in the period considered.[4] This result implies that the growth rates of the markup and concentration are related.

However, the underlying cause of this increase in the markups is less explored,

[2] The Herfindahl-Hirschman index is a common measure of concentration calculated as the sum $\sum m_i^2$, where m is the market share of ith firm.

[3] The authors highlight that this stability could reflect limited country coverage in the firm-level data or even the effect that market concentration was already a trend at advanced economies at the beginning of the period considered. Therefore, this result should be considered with caution.

[4] However, Hall (2018) does not mention if those firms are the ones with higher productivity in the sector, as has been done elsewhere. Autor et al. (2020) use the terminology of "superstar" firms to designate the most productive ones, which have concentrated the market. Their tested and confirmed hypothesis is that the concentration of the market with those firms is an important cause of the reported fall on the wage share.

although the literature appoints technological change, increases in market concentration, investment in intangibles (as patents), and changes in antitrust regulations as probable ones. The role of technological change is an important one, as there are theoretical propositions that *ex-ante* market power, by conferring internal resources to innovate and making it easier to prevent imitation, could be conducive to innovation, as claimed by Schumpeter (1942).

Thus, the relationship between markups and technological progress is an important one to be evaluated. Some empirical works have found correlations between the two variables. According to IMF (2019)'s study of the rise in market power through markups, this increase has been concentrated in a small fraction of more innovative and productive firms. The top 10% of firms in the markup distribution are shown to be 50% more profitable and 30% more productive and intensive in their use of intangible assets than the remaining 90% of the distribution. This indicates the role of structural changes in markets, since certain firms obtain very large amounts of market power from being productive and innovative, probably from having specific intangible assets and economies of scale. Moreover, as the report mentions, this process could have been magnified by a policy-driven weakening of competition.

Some studies have also tried to estimate the impact of markups on technological innovation. Diez, Leigh and Tambunlertchai (2018) perform a regression analysis using innovation measured by US R&D expenditure as the dependent variable and markups as explanatory, controlling for time and fixed effects. The authors also include interactions of the markups with themselves and with the Herfindahl-Hirschman index of sector-level market concentration on the regressions. The model is estimated using instrumental variables, obtaining similar results of the baseline ordinary least squares procedure. The results show a non-monotonic relation between markups and R&D expenditure. Higher markups are initially associated with increases in innovation expenditure. When they reach higher levels, however, the relation becomes negative as firms that obtain higher market power have fewer incentives to innovate.

IMF (2019)'s report, in turn, uses patent counts as a proxy for technological innovation in their cross-country firm and industry level analysis. They conduct a Poisson regression with instrumental variables, specified with the number of patents depending on the lagged markup and its square value. The results also point to a non-monotonic inverted-U shaped relationship, although with not so large effects. This implies that while the markup impact on the pace of technological innovation has been marginally positive, in case the markups keep rising they could affect innovation negatively.

3.3 Empirical investigation

3.3.1 Data description

To conduct the empirical assessment proposed here, data from the Penn World Table 9.1 were used to measure both technological capabilities and markups using proxies.[5] The sample used comprises data for 131 countries, as listed in Table 6 in the Appendix B, over the period 1990-2017. The period was chosen according to data availability but it also coincides with the period identified with rising markups and market power in advanced economies.

Technological capabilities are proxied by labor productivity, as countries with higher levels of labor productivity are the ones with higher technological stocks and capacity. We use a comparative measure of labor productivity that looks at the position of each country in relation to the labor productivity of the world's technological frontier. This relative position is given by a "productivity gap". The productivity gap is measured by the ratio of each country's labor productivity to each year's highest labor productivity level, which indicates where the frontier is at each year. Therefore, the higher the productivity gap, the closer the country is of the technological frontier.

Country overall markups are measured by the inverse of the country's wage share, as presented in the last section with equation (3.3). This measurement strategy is also conducted by Neiss (2001) when investigating the relationship between the overall markup and inflation in OECD countries. An economy-wide markup conveys the country's degree of market power of firms within this economy. The higher the markup, the higher the market power. Yet, it also conveys the country's degree of market concentration and its aggregate pricing and profitability strategies.

Both the technological capabilities and the markup variables are used in log and a further description of their calculations and sources is detailed in Table 7 in the Appendix B. Table 1 shows descriptive statistics for the two constructed variables. All values are within the expected range.

Table 1: Descriptive statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
Ln of Technological capabilities	917	-1.721	1.073	-4.776	0
Ln of Markup	917	-0.0578	0.548	-1.908	1.855

Source: Author's elaboration.

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5 See Feenstra, Inklaar and Timmer (2015) for more information on the Penn World Table database and the specificities of the particular 9.1 version.

3.3.2 Estimation strategy

The motivation to apply a panel VAR estimation is the theoretical indeterminacy of the causal relations between the variables markup and technological capabilities. Therefore, we extend the usual single equation investigation of panel data moving to a Vector Autoregressive (VAR) estimation. The VAR deals with the issues of simultaneity and endogeneity due to ambiguous causality direction, which affects the relationship between these variables.

The VAR methodology was first proposed by Sims (1980) to model the long-run dynamic relationship between two variables. The application of this methodology to panel data was introduced by Holtz-Eakin, Newey and Rosen (1988). In our case, this regression model conveys that the evolution of technological capabilities is explained by its lagged values and the lagged values of the markup, the same being true for the evolution of the markup. Taking Y_{it} as the (1×2) vector of endogenous variables technological capabilities and markup, the specification of an autoregressive model of order $p = 1$, that is, with one lag of the variables, is the following:

$$Y_{it} = a_1 Y_{it-1} + f_i + \varepsilon_{it} \, , \tag{3.4}$$

where a_1 is the (2×2) matrix of parameters to be estimated, while f_i are country-specific fixed-effects and ε_{it} are idiosyncratic errors, both (1×2) matrices.

Regarding the econometric issues involved in estimating the parameters of the system (3.4), to deal with unobserved fixed country-specific characteristics the estimation could be carried out with fixed effects or ordinary least squares, after removing the fixed effects by taking the first difference version of the equations. However, the lagged dependent variables acting as explanatory and the reverse causality caused by the other explanatory variable create endogeneity, which with these methods leads to biased estimates. Thus, the estimation is usually carried out with difference GMM (HOLTZ-EAKIN; NEWEY; ROSEN, 1988; ARELLANO; BOND, 1991), which provides consistent estimates in fixed T large N settings. The difference GMM approach estimates the model in first difference using as instruments lagged observations in levels of the explanatory variables (ANDERSON; HSIAO, 1982).

In using a GMM estimator, the validity of the instruments needs to be verified. The validity of the instruments depends on instruments being correlated with the endogenous explanatory variables, while exogenous to the error term. This is assessed here with Hansen's J Test of the joint validity of instruments in overidentified regressions. Furthermore, the GMM estimator also requires a panel with a relatively small time dimension to provide consistent estimates. A larger time dimension leads to more moment conditions to be fulfilled and thus demands more instruments. However, too many instruments can, in turn, lead to instrument proliferation, which can overfit of the endogenous variables and bias the estimates (ROODMAN, 2009). These issues are avoided with the reduction of the

Table 2: Panel unit root test

	P-value					
	No trend			Trend		
	Level	1st diff	2nd diff	Level	1st diff	2nd diff
Ln of Technological capabilities	0.0143	0.0000	0.0000	0.0167	0.6852	0.0000
Ln of Markup	0.9425	0.0000	0.0000	0.3132	0.9267	0.0000

Notes: The null hypothesis is that all countries' series contain a unit root.
Source: Author's elaboration.

time dimension of the panel by taking four-year averages, so that the final dimension of the panel consists of five time periods and 131 units, and restricting the lag range of the instruments. The results of Hansen's J test and the number of lags used as instruments are reported along with the results.

The model specification is defined following a three-step procedure. First, as in the VAR methodology the variables need to be stationary, we proceed with the Harris-Tzavalis unit root test for panel data on the aforementioned variables, which is adequate for fixed/small T large N panels (HARRIS; TZAVALIS, 1999). As Table 2 shows, we can consider in this specification that the technological capabilities variable is stationary in log-levels, while the markup is stationary in the second difference of log-levels. Therefore, we estimate the model with the level of the ln of the technological capability and the second difference of the ln of the markup.

The second step is to choose the optimal number of lags to be included in the VAR model specification. From Andrews and Lu (2001)'s moment model selection criteria (MMSC), both the MMSC-Bayesian and MMSC-Akaike information criteria suggest that the number of lags that minimizes the statistic is one. Therefore, the model is specified as an autoregressive model of order one, so that one lag of the endogenous variables are included in the estimation. The third and final step is to assure that the specification satisfies the stability condition, which implies the invertibility of the panel VAR so that it can be represented as an infinite-order vector moving-average, necessary to correctly interpret estimated impulse-response functions. We conclude that our panel VAR specification is stable, as will be detailed alongside the presentation of the results, allowing us to present and interpret the impulse-response functions.

We also explore whether any of the variables would precede the other, or even if there is a case of bi-directional causality between them, with the Granger causality test developed by Granger (1969). Nonetheless, we must reinforce that this investigated causality is different from identifying an endogenous causality. The Granger-causality running from x_{it} to z_{it} conveys that relevant information to predict the variable z_{it} is given by x_{it} so that the prediction of the former variable, after controlling for its past values, is improved when considering lags of the latter.

The empirical investigation is concluded with the estimation of impulse-response functions. The impulse-response functions describe the evolution of our variables along a determined time frame after a shock. To find this response, we start with the infinite vector moving average representation of the panel VAR, which is

$$Y_{it} = (I - a)^{-1}\bar{Y_i} + \sum_{j=0}^{\infty} a^j \varepsilon_{it-j}\,, \tag{3.5}$$

where I is a (2×2) identity matrix and $\bar{Y_i}$ is the stacked average of Y_{it}. The impulses are shocks on the sth component of ε_{it-j} and we look for the reaction of the dependent variable to the shock. Thus, from equation (3.5) we calculate the following derivative:

$$\frac{\partial Y_{it+j}}{\partial(\varepsilon_{it})_s} = a^j e_s\,, \tag{3.6}$$

where e_s is a (2×1) vector with the number one in the sth column and zero otherwise. Equation (3.6) provides the response of the variable Y_i in the period $t + j$ to a shock in period t. The impulse response function plots equation (3.6) for all $j = 0, \ldots, h$, with h being the previously defined time frame.

3.4 Results

Table 3 reports the results of the panel VAR estimation following the specification described in the last section. These results show that, on the one hand, the level of technological capabilities is not impacted by either its past values or the markup. This result supports the view that *ex-ante* market power would not influence increases in technological innovation, which gives evidence against the hypothesis that only large and profitable firms with high market shares would innovate. The process of investing and succeeding in innovation seems to depend on other factors, which could be, for instance, the national infrastructure and institutional setting that compose the country's National System of Innovations (NELSON, 1993). However, the expectation of future increases in the markup could affect national firms' innovative behavior, which would corroborate that firms look for profit increases coming from successful innovations (SCHUMPETER, 1934).

Meanwhile, lagged observations of both technology gap and markup have significant effects on current markup, with the former effect being positive and the latter negative. This result indicates that increases in the level of technological capabilities lead to future increases in markups. Thus, the view that successful technological innovation confers market power is corroborated. This also gives justification for countries to pursue a strategy of increasing their technological capabilities to obtain innovation rents and market power. Furthermore, higher markups would, in turn, decrease future markups. Firms would face increasing difficulties to continue to increase their markup rate, especially if

Table 3: Panel VAR of Technological capabilities and Markup

	Ln of Technological capabilities	Ln of Markup
Ln of Technological capabilities, lagged	-0.0967	0.5409***
	(0.1388)	(0.2039)
Ln of Markup, lagged	-0.0514	-0.3569***
	(0.0454)	(0.0731)
Observations	393	
Lags of instruments	1-3	
Hansen's J test	0.132	

Note: Standard errors between parenthesis. The Hansen's J test has the null that the instruments are valid, the value reported is the p-value. Significance: ***=1%; **=5%; *=10%.
Source: Author's elaboration.

Table 4: Eigenvalue stability condition

Eigenvalue		
Real	Imaginary	Modulus
-0.2268	-0.1044	0.2497
-0.2268	0.1044	0.2497

Source: Author's elaboration.

the rising markup encourages the entry of potential competitors in the market. Moreover, conflicting claims on income by workers and firms could arise after the increase in the markup, engendering a reaction from workers in the next period's wage settlement process.

The results presented in Table 3 are corroborated by the verification of the adequacy of the model's specification. First, the result of Hansen's J test suggests that the instruments are valid, which gives evidence in favor of the GMM estimation strategy. Second, the stability of the model is assessed with the system's matrix of eigenvalues reported in Table 4. The moduli are all within the unit circle, that is, smaller than one, indicating that the panel VAR model is stable.

This empirical investigation using the VAR methodology is complemented with the assessment of precedence or simultaneity relationships between the markup and the level of technological capabilities, which is done using the Granger causality test. Table 5 reports the Granger causality test results. According to these results, the test mostly corroborates the estimation with the panel VAR model. The test rejects the null hypothesis that the level of technological capabilities does not Granger-causes the markup. However, it does not reject the null that the markup does not Granger-causes technological capabilities. The causality, therefore, does not seem to run both ways. This once more indicates that drivers of the process of technological progress and subsequent increases in productivity need to be further assessed.

Finally, since we ensured that the panel VAR model is stable, we can calculate

Table 5: Granger causality test

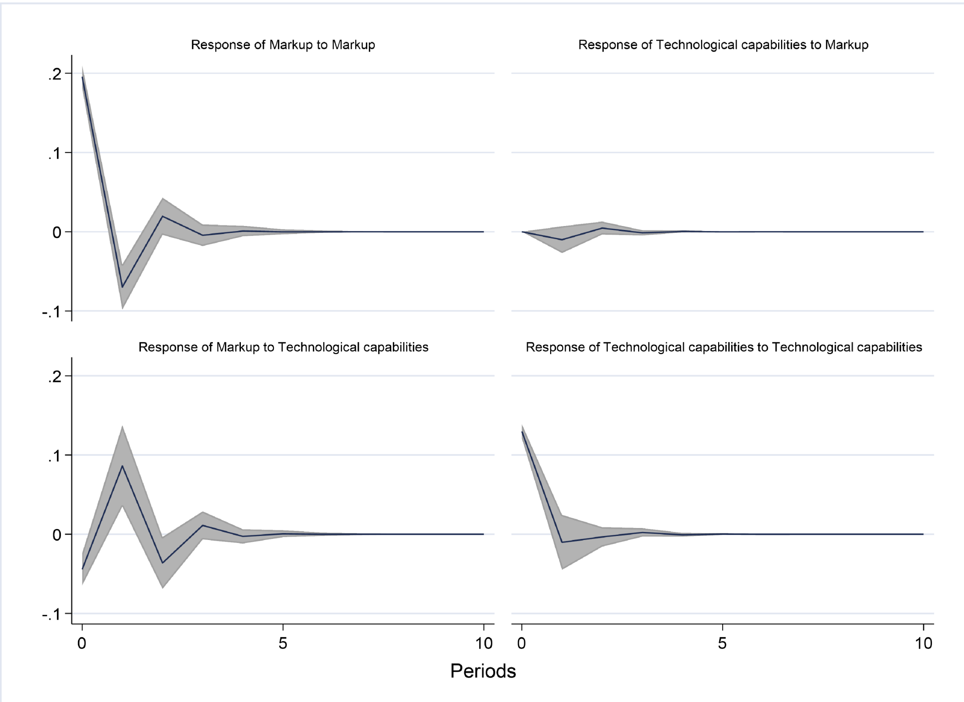
Null hypothesis	χ^2	d.f.	p-value
Markup does not Granger-cause Technological capabilities	1.287	1	0.257
Technological capabilities do not Granger-cause Markup	7.036	1	0.008

Note: d.f. denotes degrees of freedom.

Source: Author's elaboration.

impulse-response functions. These functions illustrate the response of the variables to shocks in themselves and the other variables. Following the Granger-causality test results, we establish the Cholesky decomposition order arguing that shocks in technological capabilities have a direct effect on contemporaneous markup, while the markup would impact technological capabilities only in the future.

Figure 4: Impulse response functions



Note: The 95% confidence interval was estimated with 1000 Monte Carlo simulation draws.
Source: Author's elaboration.

The impulse-response functions are presented in Figure 4. The top right graph shows that a positive shock on the markup does not affect the level of technological capabilities, as expected. However, from the bottom left graph, a positive technological shock reduces the markup at first, but the sharp increase in the subsequent period overcompensates the initial loss. This advantage begins to disappear already in the second period, and the level of technological capabilities gradually returns to its initial level.

In sum, this set of results indicates that, on the one hand, increases in the markup, coming from increases in concentration, pricing strategies, or profitability plans, do not impact technological progress. On the other hand, increases in productivity coming from technological innovations have a positive impact on markups. As shown in Figure 4, at first this impact is negative, possibly due to the financial burden of initial costs of implementing the new methods, machines, or products. However, the markup soon increases, showing how the increase in technological capabilities confers more market power to the countries' domestic firms. As soon as the other countries imitate and catch up with the new technology through spillovers and technological diffusion, this advantage fades away.

3.5 Concluding remarks

This paper contributes to the empirical literature concerned with the relationship between market power and technological progress given the recent increase in markups across many countries. Our empirical strategy encompasses the possibility of a simultaneous determination between these variables through a panel VAR estimation. This estimation is carried out with country-level data for 131 countries over the period 1990-2017. The results indicate that technological capabilities measured by a productivity gap are not influenced by markups. However, we find that technological progress does lead to higher markups, while increases in previous market power would reduce current markups.

These results suggest, first, that the prospect of gaining market power and escape competition with successful technological innovation is reinforced by the evidence indicating that technological capabilities lead to higher markups. Second, the reported results do not support the view that higher market power is responsible for promoting technological change that would lead to productivity gains and consequent income growth. Thus, the discussion around market power would be better framed in terms of the distributive consequences of high markups. As higher market power is obtained at the cost of lower wage shares of income, without the exculpatory proposal that market power is a necessary path to higher productivity, it becomes purely an obstacle to a more even distribution of income. Considerations about technological developments should then focus on other factors, like an institutional setting conducive to national scientific and technological innovation to take place.

Implications for future investigations relate especially to measurement imperfections in this paper's analysis. These measurement caveats are mostly related to how the average country-level measures cover heterogeneities between sectors and firms that could be taken into account. For instance, although some previous analyses have focused on specific sectors, a useful division would be a technologically sensitive one. Differentiating levels of technological development could provide information about whether market power gains manifest themselves differently according to the sector and technological level. Another option is to extend the study to other datasets to include a larger number of countries or go into national estimates that could be analyzed with time-series econometrics. Hence, there are many ways to extend the investigation of the relevant issues addressed by this paper, which already provides important results to guide future studies.

Conclusion

This dissertation was inspired by the recent protagonism of the fall of competition in composing the current economic scenario of advanced capitalist countries. Higher market concentration brought along weaker investment, growth, and productivity and lower wage shares of income. Most of the existing works on the subject rely on mainstream endogenous growth theory, which disregard many aspects of this process. Our argument is that market concentration has an intricate relationship with technological change, and thus, can be better understood by this angle. Moreover, this relationship is affected and affects demand factors, which also need to be taken into account.

This argument was the basis for this research, which aimed to provide theoretical and empirical grounds of the process of market concentration and its relationship with technological change. Combining the neo-Schumpeterian and post-Keynesian approaches, we were able to conduct a comprehensive account of the relationship in question. The consequences of this relationship were also shown, with a focus on income distribution and capital accumulation. The need to further grasp these processes motivated the research to take a step back and first understand and complement the microeconomics of competition and technological change. With this foundation, the investigation was brought to the macro level, with a theoretical and an empirical part.

We organized the research through two theoretical chapters and an empirical one. In the first two chapters, we developed dynamic models that contribute to the post-Keynesian modeling tradition, but both also rely on theoretical propositions coming from the neo-Schumpeterian approach. The micro model encompasses a two-way long-run relationship between market concentration and technological change. To make the competition process explicit, the model includes two heterogeneous firms that compete on technological factors. The growth of firms is constrained by demand so that a leader-follower relationship emerges, leaving the follower capturing only the residual demand of the market.

The investigation of the long-run dynamics of the system formed by market share and technological change shows that a higher market share is not conducive to technological change, while a higher relative technological advantage speeds up the concentration of the industry with the leading firm. The stability properties of the system depend on the interactions between innovation, imitation, and market concentration. Different configurations of these interactions yield different scenarios of changes in market domain and technological advantage driven by an exogenous innovation shock. In sum, the system is more stable the higher the imitative and catching up capacities of the follower firm, which can also partially counteract the concentrating effects of technological change.

The macro model, in turn, incorporates some of the recent evidence on market concentration and its effects on capital accumulation and income distribution. In this model, technological factors are endogenous to concentration and technological diffusion, both of which affect positively labor productivity induced by technological innovation. The long-run dynamics of the system is analyzed in two steps. The first involves a two-dimensional system that sets the dynamics between the wage share and the capital-effective labor supply ratio, while concentration is kept exogenous. In the second step, we extend the model to a three-dimensional system that adds an endogenous state transition function for concentration. We conclude that the stability of the model depends mainly on how the diffusion of technology occurs and how it interacts with the destabilizing influences of concentration. Comparative statics analyses of an exogenous shock on concentration show that, in the first scenario, an increase in concentration would decrease the equilibrium value of the wage share. Also, facing this shock, the three-dimensional system is shown to be more prone to become unstable in comparison with the two-dimensional one, expanding the possibilities that a concentration increase would turn an oligopoly into a stable monopoly.

This research is concluded with an empirical assessment of the simultaneous determination between market power and technological capabilities, which has been discussed in the previous chapters. Although market power and market concentration are different phenomena, market power is one of the possible effects of a more concentrated market. The investigation is done with a sample of 131 countries that extends over the period 1990-2017. The chosen estimation method is the panel Vector Autoregressive (VAR) methodology, which is suitable because of its robustness to reverse causality.

The results present evidence only that technological progress affects market power, but not the other way around. Increases in the markup, which reflect increases in the market power of firms, do not impact the technological content of the economy. However, increases in technological capabilities are shown to have a positive effect on markups. These results contradict the hypothesis of *ex-ante* market power being determinant to develop countries' technological capabilities but support the view that technological improvements confer market power gains.

From the set of results of this dissertation, we can highlight that the microeconomic study of market concentration needed to be pursued, as competition is a phenomenon essentially defined by firms' behavior. Looking first to the micro level to explain how firms behave and grow and how they are affected by outside events was crucial to understand their role in generating value and how their decisions rebound to the macro level.

Technological change is shown to be an important addition to the analysis of market concentration. When considering its feedback effects to concentration, as we did, a more complete and nuanced theory of how it can boost or counteract concentration tendencies can be specified. A common feature of both the micro and macro models is that the diffusion of technological advances to other firms is the way to reduce the amount of transient market power gained by firms that innovate. Besides, this gain of market power following successful innovation is a result empirically supported by this dissertation.

Developing imitation and catching up capacities seems to be the best strategy for follower firms to adopt.

Yet, one of the main conclusions is that market concentration can be a worrisome trend. If investment, distribution, and innovation are all affected negatively by higher market concentration, a strategy for higher economic growth does not seem to be compatible with very concentrated markets. The main reason in favor of low competition is that only in this case firms would have the resources to risk investing in R&D to innovate. However, what we observed is that this amount of market power creates significant barriers to entry and imitation, while also draining the incentives to innovate from firms, so that it does not promote overall productivity gains.

Thus, the academic and political discussion about the control of market concentration should be framed to focus on the distributive implications of economies dominated by very concentrated industries with high market power. It seems that the incentives to mergers, barriers to entry, and fiscal stimuli are only serving the purpose of transferring more resources for the ones that are already at the top of the income distribution. These resources, in turn, are not returned to the productive sphere in the form of investment or employment. Hence, a comprehensive growth with distribution strategy needs to look closer at the damaging effects of market concentration and consider which role antitrust and innovation policies could play.

Finally, although we do not deny that this dissertation has many limitations, our findings can be seen as small steps into a fuller understanding of crucial features of the capitalist economy. By resuming topics relatively unexplored in some aspects, this work casts light on their relevance. Most importantly, we fill some gaps in the literature that offer many paths for future research. Regarding the theoretical framework used, the combination of the neo-Schumpeterian and post-Keynesian approaches has resulted in a more comprehensive analysis and there are still complementary possibilities to be explored.

A welcome extension of the formal models presented here is to make additions to turn them into larger-scale models. It is possible to add more firms, more interactions between firms, and more levels to the analysis, like the financial sector, governments, and the external sector. A large scale version of these models can be used to check if the studied relationship between market concentration and technological change would behave similarly and present outcomes close to the ones of the dynamic models developed here. Simulations and comparisons of the effects of different types of public policies, such as innovation incentives, subsidies, taxes, and antitrust, are also fruitful paths to be followed from these theoretical reflections. Besides, the empirical strategy can be replicated encompassing heterogeneities present in different industries and firms. Sectors, size of firms, and level of technological development can be differentiated to see if the same patterns presented for the country level are found. More detailed analyses about the effects on emerging economies of the changes happening in advanced countries are also needed to add more information on the worldwide ramifications of the changes in competition.

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APPENDIX A – Equilibrium solution of the two-dimensional system

Equations (2.23) and (2.24) form an autonomous two-dimensional non-linear system of differential equations in which the rates of change of σ and k depend on the levels of these variables and the parameters of the system. Solving for the long-run equilibrium with $\hat{\sigma} = \hat{k} = 0$, we obtain the following equilibrium solution (σ^*, k^*):

$$\sigma^* = 1 + \frac{\alpha_2(n + \gamma_0 + \gamma_1 c)}{s(\alpha_0 - \alpha_3 c)(1 - \gamma_2\delta_1) - (s - \alpha_1)(n + \gamma_0 + \gamma_1 c)}\,, \tag{A.1}$$

$$k^* = \frac{A + (\tau\theta_2 + \gamma_1)c + (\beta + \tau)\sigma^* + \gamma_2\delta_1 g^* + \tau\theta_1 u^*}{\beta\lambda_1 u^*}\,, \tag{A.2}$$

where $A = -\beta\lambda_0 - \tau\theta_0 + \gamma_0 + \gamma_2\delta_0$, σ^* is given by expression (A.1), g^* by (2.18), and u^* by (2.15). The partial derivatives in relation to c of the equilibrium expressions are:

$$\sigma^*_c = \frac{\partial\sigma^*}{\partial c} = \frac{\alpha_2\gamma_1 D + [s\alpha_3(1 - \gamma_2\delta_1) + (s - \alpha_1)\gamma_1]\alpha_2(n + \gamma_0 + \gamma_1 c)}{D^2}\,, \tag{A.3}$$

$$k^*_c = \frac{\partial k^*}{\partial c} = \frac{[\tau\theta_2 + \gamma_1 + (\beta + \tau)\sigma^*_c + \theta_2\delta_1 g^*_c + \tau\theta_1 u^*_c]\beta\lambda_1 u^* - \beta\lambda_1 u^*_c F}{(\beta\lambda_1 u^*)^2}\,, \tag{A.4}$$

where $D = s(\alpha_0 - \alpha_3 c)(1 - \gamma_2\delta_1) - (s - \alpha_1)(n + \gamma_0 + \gamma_1 c)$, the denominator of the fraction in σ^*, $F = A + (\tau\theta_2 + \gamma_1)c + (\beta + \tau)\sigma^* + \gamma_2\delta_1 g^* + \tau\theta_1 u^*$, the numerator of k^*, σ^*_c is given by expression (A.3), g^*_c by (2.20), and u^*_c by (2.17). We notice that $(1 - \gamma_2\delta_1) < 0$ is a necessary, although not sufficient, condition for σ^*_c to be negative, while k^*_c is a quadratic-down function of c.

APPENDIX B – Data details

Table 6: List of countries

Angola	Côte d'Ivoire	Kyrgyzstan	Romania
Argentina	Denmark	Lao People's DR	Russian Federation
Armenia	Djibouti	Latvia	Rwanda
Australia	Dominican Republic	Lebanon	Sao Tome and Principe
Austria	Ecuador	Lesotho	Saudi Arabia
Azerbaijan	Egypt	Lithuania	Senegal
Bahamas	Estonia	Luxembourg	Serbia
Bahrain	Eswatini	Malaysia	Sierra Leone
Barbados	Fiji	Malta	Singapore
Belarus	Finland	Mauritania	Slovakia
Belgium	France	Mauritius	South Africa
Benin	Gabon	Mexico	Spain
Bolivia	Georgia	Mongolia	Sri Lanka
Bosnia and Herzegovina	Germany	Morocco	Sudan
Botswana	Greece	Mozambique	Suriname
Brazil	Guatemala	Namibia	Sweden
Bulgaria	Guinea	Netherlands	Switzerland
Burkina Faso	Honduras	New Zealand	Taiwan
Burundi	Hungary	Nicaragua	Tajikistan
Cabo Verde	Iceland	Niger	Thailand
Cameroon	India	Nigeria	Togo
Canada	Indonesia	North Macedonia	Trinidad and Tobago
Central African Republic	Iran	Norway	Tunisia
Chad	Iraq	Oman	Turkey
Chile	Ireland	Panama	U.R. of Tanzania
China	Israel	Paraguay	Ukraine
China, Hong Kong SAR	Italy	Peru	United Kingdom
China, Macao SAR	Jamaica	Philippines	United States
Colombia	Japan	Poland	Uruguay
Costa Rica	Jordan	Portugal	Venezuela
Croatia	Kazakhstan	Qatar	Zimbabwe
Cyprus	Kenya	Republic of Korea	
Czech Republic	Kuwait	Republic of Moldova	

Source: Author's elaboration.

Table 7: Definitions and sources of variables

Variable	Definition	Source
Wage share (σ)	Share of labor compensation in GDP at current national prices (labsh)	PWT
Markup	$(1/\sigma) - 1$	Author's calculations
Output	Expenditure-side real GDP at chained PPPs (in mil. 2011US$) (rgdpe)	PWT
Labor supply	Number of persons engaged (in millions) (emp)	PWT
Labor productivity (Lprod)	Output/labor supply	Author's calculations
Technological capabilities	$Lprod_{it}/max(Lprod_t)$	Author's calculations

Source: Author's elaboration.