The Dynamics of International Exploitation*

Jonathan F. Cogliano†, Roberto Veneziani‡, and Naoki Yoshihara§

August 10, 2022

Abstract

This paper develops a framework to analyse imperialistic international relations and the dynamics of international exploitation. A new measure of unequal exchange across borders is proposed which captures the territorial structure of imperialistic international relations: wealthy nations are net lenders and exploiters, whereas endowment-poor countries are net borrowers and exploited. Capital flows transfer surplus from countries in the periphery of the global economy to those in the core. However, while international credit markets and wealth inequalities are central in generating international exploitation, other factors, including labour-saving technical change, are shown to be essential in explaining its persistence.

JEL: F54 (Colonialism, Imperialism, Postcolonialism); B51 (Socialist, Marxian, Sraffian); D63 (Equity, Justice, Inequality, and Other Normative Criteria and Measurement); .

Keywords: International exploitation; Imperialism; Unequal exchange; Uneven development; Capital movements.

*We would like to thank Carolina Alves, Firat Demir, Giorgos Galanis, Makoto Itoh, Kazuhiro Kurose, Ingrid Kvangraven, John Willoughby and participants in the 2021 AHE conference, the 2021 IIPPE conference, the 2021 WAPE Forum, the 2022 ICAPE conference, and the PSA2022 conference for thoughtful comments and suggestions on an earlier version of this paper. The usual disclaimer applies.

†(Corresponding author) Economics Department, University of Massachusetts Boston, Wheatley Hall, 5th floor, 100 William T. Morrissey Blvd., Boston, MA 02125, U.S. (jonathan.cogliano@umb.edu)

‡School of Economics and Finance, Queen Mary University of London, Mile End Road, London E1 4NS, UK. (r.veneziani@qmul.ac.uk)

§Department of Economics, University of Massachusetts Amherst, Crotty Hall, 412 North Pleasant Street, Amherst, MA 01002, U.S.; The Institute of Economic Research, Hitotsubashi University, Naka 2-1, Kunitachi, Tokyo 186-8603, Japan; and School of Management, Kochi University of Technology, 2-22, Eikokuji-Chou, Kochi, Kochi, 780-8515, Japan. (nyoshihara@econs.umass.edu)

1 Introduction

The last four decades have witnessed the increasing integration of different national economies and the widespread adoption of neoliberal policies. This phenomenon, often labelled 'globalisation', has far-reaching implications, and it has stimulated a vast debate (Coe and Yeung 2001; Harvey 2003, 2005; Sheppard 2016; Yeung 2002). Globalisation has significant effects *within* each country, but special attention has been paid to its repercussions on the relations *between* countries. This is due to the economic stagnation of vast parts of the world and the large inequalities in income and standard of living among countries (Milanovic 2015; Sheppard 2016), and the asymmetries in bargaining power in the international arena. But also to the qualitatively different role that international institutions and nation-states and the use of force play in the global economy, according to various scholars, as compared to previous historical periods.

Different, if not opposite, analyses have been proposed, even outside of the neoclassical camp. Some authors argue that 'globalisation' is just a new name for old imperialistic practices by wealthy countries, including the use of force (Amin 1999; Petras and Veltmeyer 2001). According to others, a new world is taking shape, in which traditional imperialistic practices play no role, and the classical concept of imperialism is not useful to understand the global economy (Hardt and Negri 2000).

While admitting that classical approaches may be outdated, "economic globalization is certainly not just about the latest phase of uneven geographic development, deterritorialization/reterritorialization, or crisis-induced capitalist restructuring", it has "deeper historical roots in the founding of the modern nation-state" (Yeung 2002, p.288). Thus, this paper defends the theoretical and empirical relevance of the concept of imperialism to analyse current international relations and features of geographic stratification of the global economy.

Based on Roemer's (1982) theory of exploitation, a theoretical (albeit not historical) distinction can be drawn between a notion of *feudal* imperialism, in which the use of force and non-competitive distortions play a definitional role – as in 'classical' (Lenin 1970; Luxemburg 1951; Hobson 1954) and neoclassical (Schumpeter 1951) theories of imperialism; and neo-Marxist theories of dependency (Baran 1968; Franke 1978).[1] And a notion of *capitalist* imperialism, in which exploitation and mutual gains from trade may coexist. Capitalist imperialism is thus related to Hobson's (1954) "internationalism" and to the concept of "informal imperialism" (Griffin and Gurley 1985, pp.1092ff), in that power relations between states and exploitation are primarily the product of economic activities, rather than extra-economic coercion. It also captures some key aspects of Harvey's (2003; 2005) own seminal notion of capitalist imperialism, and in particular its emphasis on "imperialism as a diffuse political and economic process in space and time in which command over and use of capital take primacy" (Harvey 2003, p.26).

More precisely, in this paper capitalist imperialism is conceived of as a system "based on the export of capital from advanced countries to less developed regions ... accompanied by the utilization of political and military resources to protect and maintain the means of production over which control has been acquired" (Evans 1979, p.16), and by segmented labour

[1] For a discussion of the literature, see Griffin and Gurley (1985), Howard and King (1992), and Kvangraven (2020). The qualifier 'feudal' refers to the nature of the relations *between* countries and not to the presence of feudal elements *within* poorer countries sometimes stressed in the literature (Kvangraven 2020, p.84).

markets. Empirically, this allows us to incorporate two crucial features of the contemporary global economy, namely capital mobility and restrictions to labour movement (Harvey 1982, 2003, 2005; Sheppard 2016). Theoretically, this makes our approach conceptually close to theories of unequal exchange (Emmanuel 1972; Roemer 1983).[2]

This paper aims to show that, even granting that the feudal aspects of colonial relations may have become less significant, the concept of capitalist imperialism is relevant to analyse structural features of the global economy. First, we propose a new measure of unequal exchange across borders based on the theory of exploitation – an *exploitation intensity index*. Contrary to the received view, this measure is theoretically robust and logically consistent. Indeed, it can be used to precisely define the concept of capitalist imperialism and to provide a rigorous definition of the notions of *core* and *periphery* of the global economy that are central in dependency theory and in world systems theory (Arrighi 1994; Wallerstein 1974).

Far from being metaphysical, our exploitation index is empirically measurable based on widely available data. We calibrate our model to analyse the exploitation status of all countries in 2017, taking into account differences in the quantity *and* quality of the labour force, in addition to capital, and use the exploitation index to characterise the full structure of Imperialistic International Relations (henceforth, IIR). Indeed, unlike in post-modern approaches to globalisation, such as Hardt and Negri (2000), which depict IIR as immaterial and deterritorialised, the economic and geographic structure of imperialism can be identified, whereby wealthy nations gain, and endowment-poor countries lose from unequal exchange, as surplus is transferred *from* the latter *to* the former.

The second contribution of the paper is the analysis of the mechanism that allows such surplus transfer to occur. Unlike in classical approaches, where "characteristic of [imperialism] are: lending abroad, railroad constructions, revolutions, and wars" (Luxemburg 1951, p.419), the role of capital movements is emphasised. This is an important feature of recent accounts of imperialistic practices. As Harvey (2005, pp.134-135) notes, interconnected financial and government institutions and countries' positioning in highly connected financial markets are a primary channel through which imperialistic relations manifest.

This paper shows that competitive markets, profit-seeking, and international wealth inequalities are central in generating IIR. The exploitative nature of IIR can be understood focusing on credit relations and international capital flows: wealthy nations are net lenders and exploiters, and form the core of the global economy, whereas endowment-poor countries are net borrowers and suffer from exploitation, and are relegated to the periphery.

Crucially, however, IIR can be explained without any controversial assumptions on the existence of some inherent contradiction of capitalism that "spurs capital on to a continual extension of the market" (Luxemburg 1951, p.347). While realisation problems in accumulating economies feature prominently in classical accounts of late 19th century-early 20th century imperialism, such as Lenin (1970), Hobson (1954), and Luxemburg (1951), and overaccumulation plays a central role in Harvey's (2003; 2005) theory of new imperialism, we argue that accumulation is unnecessary to understand capitalist imperialism as an exploitative system of international relations. Indeed, we show that, under certain conditions, accumulation is *inconsistent* with the persistence of IIR. More generally, as argued by Howard

[2]See also Foot and Webber (1983), Sheppard (1984), Sheppard and Barnes (1990), and Webber and Foot (1984).

and King (1999), countries in the core have an incentive to exploit those in the periphery independently of accumulation needs: the incessant quest for profits.

As our analysis of the structure of imperialistic relations and the proposal of an index to measure international labour transfers involves the construction of a formal model and computational analyses, we shall briefly discuss some methodological aspects of our research.[3] This will also allow us to discuss some extensions of our main results.

1.1 Methodology

A detailed historical and institutional analysis is certainly crucial for a thorough understanding of imperialism and economic inequality across regions. In this paper, we use theoretical abstraction – and specifically, mathematical formalism – for various reasons.

One key contribution of the paper is the proposal of a measure of surplus transfers across countries, and all measurement is theory-specific. We set up a theoretical framework using mathematical formalism in order to define an exploitation index that can be used in the empirical analysis of international relations and uneven geographical patterns in development.

While mathematical-deductivist methods are inappropriate in the causal-explanatory analysis of open systems (Lawson 2003, 2009), our purpose here is different. Our aim is not to identify causal laws (or even tendencies) within a predictionist perspective (Lawson 2003, p.60). Rather, ours is an exercise in scientific ontology and, as Veneziani and Yoshihara (2017b) have argued, mathematical tools are appropriate when addressing the issue of measurement of certain social phenomena with a quantitative dimension. The use of formalism to derive a well-defined exploitation index is particularly important given the widespread scepticism surrounding exploitation theory in *both* mainstream *and* heterodox quarters.

The analytical methods we deploy are, as Barnes (1990, p.1004) argues, helpful "in clarifying and developing concepts", and our methodological choice contributes to the "engaged pluralism" in economic geography advocated by Barnes and Sheppard (2010), Plummer and Sheppard (2006), and Sheppard (2011), among others. Similar to Plummer, Sheppard, and Haining (2012, p.538), mathematics are adopted as "the language of theory" and their use in a Marxian framework here is intended to help clarify concepts of unequal exchange and exploitation. Thus, our approach is close to the "regional political economy" put forth by Sheppard (2011) and Plummer et al. (2012). Indeed, as Sheppard (2011) notes, Marxian mathematical models can highlight the class struggle and exploitative dynamics inherent to capitalism, and the introduction of a geographical (or spatial) dimension to these models renders the dynamics and inequalities of capitalism all the more apparent. More specifically, our analysis brings recent developments in the theory of exploitation and class to economic geography, and while Selwyn (2012, 2015) and Iliopoulos, Galanis, Kumar, and Popoyan (2021) have recently argued for greater attention to class and power, respectively, in analyses of global value chains and production networks, our emphasis on a well-defined notion of exploitation illuminates a key relationship between countries.[4]

[3]The model presented in this paper builds on Roemer (1982, 1983) and extends the framework developed by Cogliano, Veneziani, and Yoshihara (2016, 2019) to the international context.

[4]Recent research on global value chains and global production networks highlights the complexities of economic relationships between firms in different countries, as well as relationships in the nexus of firms, countries, labour, and institutions. See Gereffi and Korzeniewicz (1994) and Gereffi, Humphrey, and Sturgeon

We also aim to contribute to theoretical debates on the fundamental features of imperialistic relations, and use computational simulations to examine some simplified, counterfactual scenarios for three purposes. First, in order to investigate the nature and structure of IIR, we use theoretical abstraction in order to isolate some key characteristics of the global economy. It is remarkable, from this perspective, that an exploitation phenomenon and IIR can clearly emerge even in the absence of a number of features of real economies that play a central role in various strands of the literature, such as noncompetitive distortions, international wage and interest rate differentials, unequal access to technologies, differences in structures of production, price/value discrepancies, and spatial competition. Without denying the relevance of these factors, our analysis forcefully brings to the fore the role of credit markets, the constraints that limited wealth imposes on countries in the periphery, and their "financial dependence" (Kvangraven 2020) on core countries.

Second, the counterfactual analysis points to an explanatory gap by showing that competitive markets and inequalities in wealth and development are crucial in *generating* IIR; but they are not sufficient to make them *persistent*. Lacking any countervailing tendencies, accumulation eventually makes capital abundant, leading to the disappearance of international exploitation. This result is in stark contrast with the reality of the global economy – since capitalism is "conflictual and unstable" and produces "socio-spatial inequalities" (Sheppard 2011, p.320) – and it raises the issue of the possible mechanisms guaranteeing the persistence of exploitative relations. In this paper, we consider endogenous technical change and adaptive consumption norms, which introduce a degree of non-linearity and cyclicality in the interaction of accumulation, distribution, and technical change – arguably, two important features of the dynamics of capitalist economies (Bergmann, Sheppard, and Plummer 2009; Galanis and Kumar 2021; Galanis, Koutny, and Weber 2022; Plummer et al. 2012; Plummer and Sheppard 2006). We see this as a first, preliminary step in the analysis of the persistence of a spatially differentiated, unequal international economy.

Third, although we do not address normative issues explicitly in this paper, our analysis may be interpreted as showing that IIR can be condemned independently of the noncompetitive and violent forms they may – and usually do – take. The model provides the foundations for a condemnation of imperialism by specifying the theoretical counterfactual against which IIR should be evaluated – a desirable property of a theory of imperialism, as forcefully argued by Brewer (1999). The counterfactual is given by the economy in which international disparities in wealth are annihilated. Indeed, in the global economy wealth inequalities do seem to be morally arbitrary, as often primitive accumulation in the core has taken place – at least partly – at the expense of the periphery, as argued in chapter 31 of *Capital* I, where Marx (1976, p.926) famously refers to colonialism as robbery, looting, and plunder, such that "capital comes dripping ... from every pore, with blood and dirt."

The paper is organised as follows. The conceptual framework is laid out in section

(2005) for more on global value chains, and see Coe, Dicken, and Hess (2008), Coe (2011), Coe and Yeung (2019), and Yeung (2021) for more on global production networks. Value chain and production network analyses provide detailed accounts of the configurations of various relationships between different actors in the global economy, including possibly exploitative relationships (Selwyn 2019). Our focus on countries as the unit of analysis abstracts from much of the granular detail of value chain and production network analyses, yet it can be seen as capturing the overall sum of potentially unequal or exploitative relationships between various actors across the global economy.

2. Section 3 discusses the notions of exploitation and class and section 4 introduces the exploitation intensity index. Section 5 presents the results of the calibration of the basic model, and the simulations of its dynamics. Section 6 extends the model, and the simulations, to include endogenous technical change and consumption norms. Section 7 briefly discusses the robustness checks. The details of the formal analysis can be found in Appendix A.

2 The framework

Consider a dynamic extension of Roemer's (1982) accumulating economy with a credit market and only one good produced and consumed.[5] There are N countries that compete in the world economy for T periods, where T could be either finite or infinite. A country is generically denoted as ν.[6] At the beginning of each production period t, $t = 0, 1, \ldots, T$, there is a production technique (A_t, L_t) that specifies the amount of the produced good, A_t, and labour, L_t, necessary to produce one unit of output, where $0 < A_t < 1$ and $L_t > 0$.[7] The technique (A_t, L_t) is not necessarily fixed: it may vary over time due to technological innovations. As argued in section 1.1, we are interested in analysing unequal exchange and IIR abstracting from noncompetitive distortions and differences in the structure of production, and therefore assume that all countries have access to the same techniques.

In every period t, countries have (possibly different) endowments of labour, l^ν_{t-1}, and capital, $\omega^\nu_{t-1} \geq 0$, inherited from previous periods. The labour endowment consists of country ν's population, represented by $\ell^\nu_{t-1} > 0$, *and* of its (average) skill level, or human capital, represented by $s^\nu_{t-1} > 0$. Thus, country ν's labour endowment is defined by $l^\nu_{t-1} = \ell^\nu_{t-1} s^\nu_{t-1}$ which may also be called ν's endowment of *effective* labour.

As in Roemer (1982), production takes time and current choices are constrained by past events: every country must be able to lay out in advance the operating costs for the production activities it operates. A country ν endowed with $\left(l^\nu_{t-1}, \omega^\nu_{t-1}\right)$ can either use its own capital to operate the technique (A_t, L_t) at the production activity level $x^\nu_t \geq 0$, or it can borrow capital on international credit markets in order to operate (A_t, L_t) at the level $y^\nu_t \geq 0$. Alternatively, it can lend its capital abroad, $z^\nu_t \geq 0$. Countries can borrow or lend at a market rate r_t.

Letting p_{t-1} denote the price of the produced commodity at the end of $t-1$ and beginning of t, the market value of country ν's endowment – its wealth – is $W^\nu_{t-1} = p_{t-1}\omega^\nu_{t-1}$. The wealth that is not used for production activities, and is not lent abroad, can be saved and sold on international markets at the end of the period, $\delta^\nu_t \geq 0$.

As is standard Marxist theory, we conceive of capitalist economies as driven by the need to accumulate (formally, maximise wealth) subject to workers consuming $b_t > 0$ per unit of

[5] Focusing on one-good economies allows us to abstract from price/value disparities that are central in much of the literature on unequal exchange (see, for example, Sheppard (1984) and Sheppard and Barnes (1990); for a discussion of the literature, see Ricci (2021)). More generally, given our interest in the dynamics of exploitation, the one-good assumption yields no loss of generality. The model can be extended to include n commodities, albeit at the cost of a significant increase in technicalities and computational intensity.

[6] Following Roemer (1982, 1983), in order to focus on *international* exploitation, we consider countries as black boxes and do not explicitly analyse heterogeneity *within* each country.

[7] More precisely, production techniques (A_t, L_t) at any t are *Leontief production techniques*, requiring fixed proportions of both inputs to produce the final good.

labour performed. Country ν's labour performed is denoted by Λ_t^ν.[8] Within every period t, we consider b_t as a constant parameter, but we do allow for the possibility that b_t changes endogenously over time (more on this in section 6 below). This assumption is motivated by our focus on the dynamics of exploitation in a global economy characterised by a drive to accumulate, rather than on consumer choices. Theoretically, it is consistent with the classical-Marxian tradition where consumption is largely the product of social norms, rather than utility-maximising behaviour, and it allows us to analyse the international structure of exploitation and class abstracting from heterogeneous consumption behaviour.

Following Roemer (1982, 1983), we analyse the global economy focusing on *Reproducible Solutions* (henceforth, RS): at a RS, in every period (a) all countries maximise their wealth; (b) aggregate capital is sufficient for production (and speculative saving) plans; (c) the credit market clears; (d) aggregate supply is sufficient for consumption and accumulation plans.[9]

Let (p_{t-1}, p_t, r_t) be a profile of prices observed at period t in a RS. This price information allows us to define an implicit wage rate w_t that each country faces during t.[10] In contrast with some of the classic contributions in dependency theory, as all countries have access to the same technology, and international commodity and credit markets are competitive, the wage rate is identical across countries even in the absence of an international labour market.

3 Exploitation and Class

Two structural aspects of the global economy arguably characterise *imperialistic* international relations. First, the presence of some form of unequal exchange in which certain countries benefit disproportionately from interaction in the global economy compared to others. And, second, a stratification of countries into a core and a periphery – based on their position in international markets – which highlights the mechanisms that allow the former to gain at the expense of the latter. We capture the former aspect of IIR focusing on the concept of *exploitation*; and the latter by identifying *classes* of countries based on their position in the global credit market.

Consider first the concept of exploitation. The key point to note is that focusing on *actual* consumption would be highly misleading: poor and rich countries may have similar consumption levels and yet it would be counterintuitive to consider them as having a similar exploitation status.[11] Conceptually, exploitation status should not depend on idiosyncratic choices, and preferences, and depend instead on *potential* consumption. We define exploitation status focusing on the maximum level of consumption that a country can achieve subject to being able to reproduce itself over time.

Formally, for all countries ν and market prices (p_t, r_t), let $R_t^\nu\left(W_{t-1}^\nu, \Lambda_t^\nu; (p_t, r_t)\right)$ denote country ν's gross revenue, which depends on ν's endowments and on equilibrium prices.[12]

[8] Formally, the labour performed in country ν is defined by: $\Lambda_t^\nu \equiv L_t x_t^\nu + L_t y_t^\nu$. A detailed description of countries' behaviour can be found in Appendix A.1.

[9] For a comprehensive discussion of the Marxian roots of the concept of RS, see Roemer (1982, 1983). A rigorous definition of the RS in the context of the global economy can be found in Appendix A.1.

[10] Formally, $w_t \equiv \frac{p_t - (1+r_t)p_{t-1}A_t}{L_t}$.

[11] In our model, both poor and rich countries consume b_t per unit of labour expended, but their potential consumption is very different.

[12] An explicit expression for $R_t^\nu\left(W_{t-1}^\nu, \Lambda_t^\nu; (p_t, r_t)\right)$ is in Appendix A.1.

A country ν's potential consumption, c_t^ν, is determined by gross national revenue minus the cost of reproducing the country's initial capital, $p_t\omega_{t-1}^\nu$. Formally,

$$p_t c_t^\nu = R_t^\nu \left(W_{t-1}^\nu, \Lambda_t^\nu; (p_t, r_t)\right) - p_t\omega_{t-1}^\nu. \tag{1}$$

Let $v_t = L_t(1-A_t)^{-1}$ denote the embodied labour value. Definition 1 identifies exploitation status in terms of a country's potential consumption.[13]

Definition 1 [Roemer (1982)]: Country ν is *exploited* at t if and only if $\Lambda_t^\nu > v_t c_t^\nu$; it is an *exploiter* if and only if $\Lambda_t^\nu < v_t c_t^\nu$.

Let $\widehat{w}_t \equiv \frac{w_t}{p_t}$ be the real wage rate at t. By using similar arguments as in Cogliano et al. (2019), it is not difficult to show that at any RS, in every period t, if $r_t > 0$ then the exploitation status of each country is determined by its wealth per unit of labour performed:[14]

$$\text{country } \nu \text{ is an exploiter if and only if } \frac{W_{t-1}^\nu}{\Lambda_t^\nu} > \frac{1}{r_t}\frac{[1-\widehat{w}_t v_t]}{v_t};$$
$$\text{country } \nu \text{ is exploited if and only if } \frac{W_{t-1}^\nu}{\Lambda_t^\nu} < \frac{1}{r_t}\frac{[1-\widehat{w}_t v_t]}{v_t},$$

This generalises analogous results by Roemer (1982), as it characterises the exploitation status of all countries even in the presence of unemployed labour. More precisely, if full employment obtains at t then $\Lambda_t^\nu = l_t^\nu$, all ν, and so exploitation status is determined by the ratio of capital and labour *endowments* as in Roemer (1982). However, if labour is not fully employed world-wide, then $\Lambda_t^\nu < l_t^\nu$ for at least some ν, and exploitation status is determined by the ratio of the capital endowment *and labour performed*.

Observe that the previous conclusions hold if and only if $r_t > 0$. If $r_t = 0$, then $\widehat{w}_t = (1/v_t) > b_t$ and $\Lambda_t^\nu = v_t c_t^\nu$ for all ν, and no exploitation exists in the economy. This correspondence between profits and exploitation is a standard result in Marxian theory (Veneziani and Yoshihara 2015).

Definition 1 provides the foundations for the analysis of the unequal exchange involved in IIR, whereby some countries gain at the expenses of others: some countries exploit, while others are exploited. However, while it permits us to identify the winners and losers of globalisation, it does not tell us much about the structural features of IIR that allow exploitation to emerge. For that purpose, we shall introduce a concept that identifies a clear stratification of countries based on their position in international markets.

To be specific, following Roemer (1982), in every period t *classes* can be defined based on the countries' position in the credit market. Let (a_1, a_2, a_3) be a vector where $a_i \in \{+, 0\}$, $i = 1, 2, 3$, where '+' means a positive entry. Country ν is said to be a member of class (a_1, a_2, a_3), if there is an optimal vector $(x_t^\nu, y_t^\nu, z_t^\nu, \delta_t^\nu)$ such that $(x_t^\nu, y_t^\nu, z_t^\nu)$ has the form (a_1, a_2, a_3). The notation $(+, +, 0)$ implies, for instance, that a country activates production

[13] In what follows, exploitation and class status are defined in every period t: this is natural if the model describes a series of one-period economies, otherwise it reflects a focus on *within period* relations. For a discussion of *within period* and *whole life* exploitation and class, see Veneziani (2007, 2013).

[14] The proofs of all formal results discussed in this section are simple modifications of the demonstrations in Cogliano et al. (2019) and are shown in the Addendum.

using both its own capital and borrowed capital; $(+, 0, +)$ implies that the country uses part of its capital to activate production and lends the rest; and so on.

Although there are eight conceivable classes, only the following four can be shown to be *theoretically* relevant: C_t^1 is the set of countries which are members of class $(+, 0, +)$ but not of class $(+, 0, 0)$; C_t^2 is the set of countries which are members of class $(+, 0, 0)$; C_t^3 is the set of countries which are members of class $(+, +, 0)$ but not of class $(+, 0, 0)$; C_t^4 is the set of countries which are members of class $(0, +, 0)$.[15]

By using similar arguments as in Cogliano et al. (2019), it is possible to show that at any RS, in every period t, if the interest rate is positive, the set of countries can be exactly partitioned into the four classes above: all countries belong to one, and exactly one, of C_t^1-C_t^4 and a country's class depends on its position in the credit market. C_t^1 corresponds to the set of net lenders; C_t^2 comprises all countries that are neither net lenders nor net borrowers; C_t^3 corresponds to the set of net borrowers; C_t^4 comprises all countries with zero wealth at t.[16]

In other words, a precise stratification emerges in the world economy whereby countries can be sorted into classes based on their status in the international credit market, which is in turn related to their productive endowments: countries with higher (lower) wealth per capita belong to the higher (lower) echelons of the class hierarchy.

As both class and exploitation status depend on per capita wealth, it is legitimate to wonder whether a country's position in the exploitation hierarchy and its position in the credit market are linked, as predicted in theories of unequal exchange, and also in some of the classical approaches to imperialism discussed in the Introduction.

The hypothesis that a tight relation exists between class positions and exploitation status is known as the *Class-Exploitation Correspondence Principle* (CECP, Roemer (1982)), and it is possible to prove that indeed the CECP holds in the world economy: countries that enjoy a privileged position in the credit market are exploiters, while net borrowers are exploited. Formally, at any RS, at any period t, if the interest rate is strictly positive then: if $\nu \in C_t^1$ then ν is an exploiter and if $\nu \in C_t^3 \cup C_t^4$ then ν is exploited.[17]

In other words, based on the concepts of exploitation and class that we have proposed here, building on Roemer (1982, 1983), it is possible to show that IIR are clearly characterised by a hierarchical structure that emerges endogenously, and that, contrary to postmodern claims, has a clear economic and territorial dimension: wealthy countries are exploiters and poor countries are exploited. Further, contrary to classical theories, IIR emerge from the functioning of competitive markets: wealthy countries are net creditors, poor countries are net debtors, and it is the credit market that allows surplus to be transferred from the latter to the former. Thus, the previous analysis provides rigorous foundations to the concepts of *core* countries – which enjoy a privileged position in the credit market and exploit – and the *periphery* of the global economy – poor countries that need to borrow in order to activate production and reach subsistence, and are exploited.

[15] Of course, *empirically*, only $C_t^1 - C_t^3$ matter, as shown by our simulations: C_t^4 is empty because there is no country with zero wealth and producing *only* using borrowed capital.

[16] Formally, let MP_t^ν be country ν's optimisation programme at t described in Appendix A.1. Then C_t^1 is the set of countries such that $A_t y_t^\nu < z_t^\nu$ at all solutions to MP_t^ν; C_t^2 is the set of countries such that $A_t y_t^\nu = z_t^\nu$ at a solution to MP_t^ν; C_t^3 is the set of countries such that $A_t y_t^\nu > z_t^\nu$ at all solutions to MP_t^ν; C_t^4 is the set of countries such that $W_{t-1}^\nu = 0$.

[17] The converse is also true if $\widehat{w}_t > b_t$.

4 An index of exploitation

The core/periphery structure that characterises IIR derived in the previous section provides some important insights on the structural injustices characterising the world economy, as Roemer (1982) has forcefully argued. Yet, simply identifying the countries in the core and in the periphery of the global economy yields a rather partial, coarse picture of the structure of IIR: international economies with similar numbers of countries belonging to each class and each exploitation category may be very different. Based on Definition 1, the normative reach of the concept of exploitation can be extended to provide a finer and more comprehensive picture of IIR, moving beyond a purely aggregate analysis to explore the *intensity of exploitation*. For, it is certainly desirable to have a notion of exploitation that allows us to make statements such as "country A is more exploited than country B", or "IIR are becoming increasingly exploitative over time".

Definition 1 states that exploitation status is determined according to whether $\Lambda_t^\nu \gtrless v_t c_t^\nu$. Therefore a natural index of the intensity of exploitation of any country ν in period t is:

$$e_t^\nu = \frac{\Lambda_t^\nu}{v_t c_t^\nu}.$$

Thus, country ν is an exploiter (exploited) if and only if $0 \leq e_t^\nu < 1$ ($e_t^\nu > 1$). Assuming e_t^ν to be a meaningful cardinal and internationally comparable measure, however, the index allows for a much richer analysis of IIR. For example, one can say that the greater e_t^ν the more exploited ν is and, for any two countries ν, μ in the periphery, if $e_t^\nu > e_t^\mu > 1$ then ν is more exploited than μ. And similarly for countries in the core. We can also analyse the dynamics of the distribution of e_t^ν, and ask a number of questions about the structure of IIR. A more polarised distribution of e_t^ν, for instance, suggests a worsening of IIR. More generally, the measurement of some aggregate degree of exploitation raises similar issues as in the debate on the measurement of income or wealth inequalities.

Three important features of the exploitation index e_t^ν should be emphasised. First, it has robust theoretical foundations. It is conceptually related to the so-called 'New Interpretation' of Marx by Duménil (1980) and Foley (1982). It can be shown that a country is exploited if the share of labour it contributes to the global economy is higher than the share of income it receives, and vice versa if it is an exploiter (Veneziani and Yoshihara 2018). It can also be proved that Definition 1, upon which the index is based, is the only definition of exploitation that satisfies the core insights of exploitation theory (Veneziani and Yoshihara 2017b, 2018).

Second, the exploitation index embodies some intuitive normative views. For e_t^ν can be interpreted as the rate of (effective) labour supplied relative to the labour necessary to produce ν's maximum potential consumption and exploitative relations are equivalent to inequalities in labour hours supplied to earn one unit of income (measured in the labour numéraire). From this perspective, exploited countries need to work more than exploiters in order to secure an analogous standard of living, and the additional labour they contribute to the global economy is transferred to the latter. In IIR, exploitation represents an unreciprocated transfer of labour from the periphery to the core, and the higher the amount of labour transferred from a country in the periphery, the higher e_t^ν.

Unlike most empirical measures of unequal exchange,[18] the exploitation index does not

[18]See Foot and Webber (1983) and Sheppard and Barnes (1990) for discussions of measures of unequal

capture price-value deviations, whose normative content is unclear (Schweickart 1991). Nor does it crucially rely on the existence of market imperfections and international wage differentials: although differences in the remuneration of labour across countries are of great relevance (Ricci 2021, 2022), the unfairness of international relations is not reducible to them, and a global economy with complete wage equalisation might still be highly unjust.

Finally, and perhaps more importantly for our purposes, contrary to a widespread view, the exploitation index is all but metaphysical, as it is entirely based on empirically measurable magnitudes.

5 Exploitation and class in space and time

This section develops a computational analysis of the basic economy, in which technology, population, and consumption norms are all constant over time (see Appendix A.1). Using 2017 data from the Penn World Table (PWT) (Feenstra, Inklaar, and Timmer 2015) to calibrate the model, the aim is to illustrate the relevance of the theoretical results derived in the previous section; and to rigorously describe the dynamics of IIR, both in their exploitation and in their class dimensions, in the benchmark case. (A thorough description of the calibration of the model, and simulation procedure can be found in Appendix A.2.)[19]

5.1 Exploitation in the world economy: a new map

The exploitation intensity index is designed to map the hierarchical structure of the global economy giving rise to spatially-driven injustices in the form of unequal exchange, and a transfer of surplus across borders. In this section we derive its distribution across countries in 2017. To be sure, our results should not be taken as providing a comprehensive picture of IIR: they are primarily meant to illustrate the power of our measure of exploitation, while bearing in mind that ours is an imperfect calibration exercise in the context of a simplified one-good model.[20] With this caveat in mind, the results are rather striking indeed.

Figure 1 provides a map of exploitation intensity, where the shading of each country corresponds to its value of e_1^ν: a darker (brighter) colour indicates lower (higher) values of e_1^ν. The pattern of exploitation in figure 1 chimes with intuition and with the literature discussed in the Introduction, with a concentration of darker colours around the North Atlantic, Western Europe, Australia, and Japan, while lighter colours dominate in Africa, Latin America, and South Asia.

More generally, the exploitation index can be used to identify the core and the periphery of the global economy, consistent with theories of unequal exchange and uneven development. Using $e_1^\nu = 1$ as the relevant threshold, in figure 2 we cluster countries into two clearly defined groups based on their exploitation status and graph e_1^ν against ω_0^ν per capita.[21] Both panels

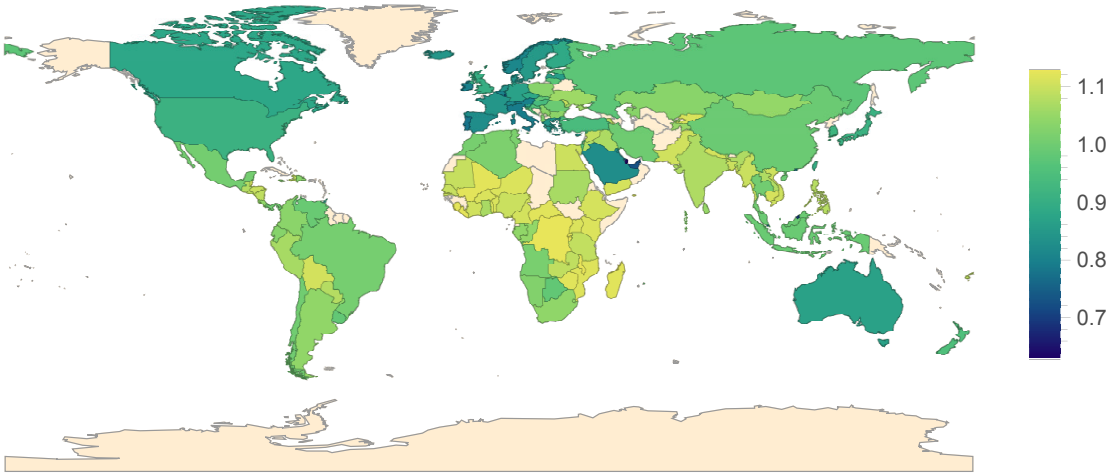
exchange, and Webber and Foot (1984) for an empirical analysis of the case of Canada and the Philippines.

[19] All simulations are done using *Mathematica* version 13. The simulation code is available from the authors upon request and will be made fully accessible together with the dataset for replication purposes.

[20] This is particularly relevant for the measurement of the denominator of e_t^ν, while the numerator more or less accurately captures actual (effective) labour contributed to the world economy.

[21] While e_1^ν is based on effective labour performed, Figure 2 uses initial wealth *per capita* on the horizontal axis. We make this choice here, and in figures 11-13 in Appendix B, for merely presentational reasons.

Figure 1: Worldwide Exploitation Intensity - Basic economy

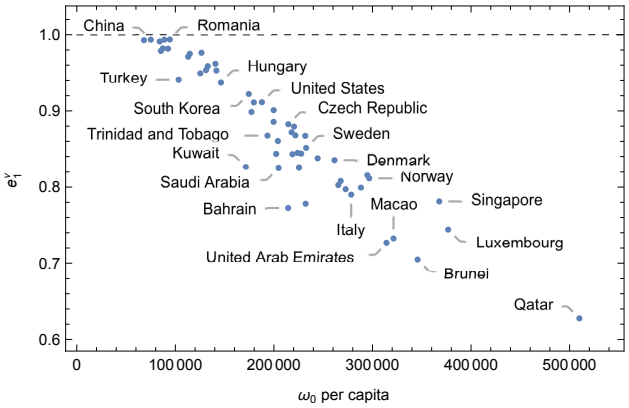


Note: Countries not shaded according to the color scale above are not included in the data set for this simulation. The shading of Alaska separately from the rest of the United States is an artefact of *Mathematica*'s mapping procedure.

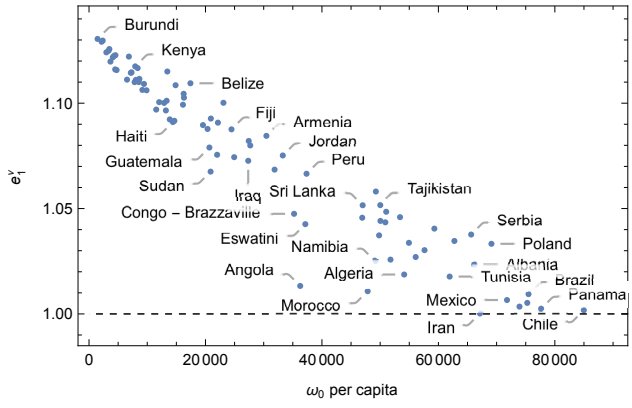
of figure 2 show a strong, clear inverse relation between exploitation intensity and per capita wealth, with higher wealth associated with lower levels of exploitation. The core consists of exploiter countries (figure 2(a)), whereas exploited countries are in the periphery of the global economy (figure 2(b)). Thus, figure 2 clearly shows the economic and geographic structure of IIR, and in particular the crucial relevance of wealth, and productive endowments in general, in determining a country's position within IIR.

Figure 2: Exploiter & Exploited Countries - Basic economy

(a) Exploiter Countries



(b) Exploited Countries



Tables 1 and 2 below show the complete listing of e_1^ν for all countries sorted by ω_0^ν per capita, with exploiter countries shown in table 1 and exploited countries in table 2. Apart from the Latin American members of the club, *all* of the OECD countries are in the core, with an exploitation intensity index well below 1;[22] while nearly *all* of the African countries

[22]Poland is the only exception, but its exploitation intensity index is only marginally above 1, which may be due to measurement error and/or the simplifying assumptions adopted in the calibration of our model.

are exploited, including the twenty most exploited.[23] Further, among the main exploiters are oil-producing countries as well as countries at the core of the international financial system. Although its exploitation index is too close to one to draw any definite conclusions, the classification of China as one of the exploiting countries is likely to reflect its increasing role in the world economy, which is moving it from the periphery to the core of IIR; and a similar point may be made about Indonesia (for an interesting discussion, see Kvangraven (2020)).

Table 1: Exploitation Intensity for Exploiter Countries at $t = 1$ - Basic economy

	e_1^ν		e_1^ν		e_1^ν
Indonesia	0.9928	South Korea	0.9223	Germany	0.8672
China	0.9935	Taiwan	0.8985	Portugal	0.7781
Venezuela	0.9912	Japan	0.9112	Sweden	0.8514
Mauritius	0.9788	United States	0.9114	Netherlands	0.8377
Uruguay	0.9820	Trinidad and Tobago	0.8675	Denmark	0.8352
Malaysia	0.9935	Finland	0.8857	Belgium	0.8027
Botswana	0.9816	United Kingdom	0.9010	Hong Kong	0.8081
Romania	0.9938	Cyprus	0.8435	Ireland	0.7972
Turkey	0.9409	Latvia	0.8605	Italy	0.7901
Lithuania	0.9711	Saudi Arabia	0.8252	Austria	0.7993
Russia	0.9750	Bahrain	0.7725	Switzerland	0.8159
Malta	0.9493	Czech Republic	0.8825	Norway	0.8116
Slovakia	0.9764	Slovenia	0.8720	United Arab Emirates	0.7268
New Zealand	0.9535	Greece	0.8431	Macao	0.7324
Croatia	0.9587	Canada	0.8794	Brunei	0.7048
Israel	0.9618	Australia	0.8679	Singapore	0.7811
Estonia	0.9529	France	0.8448	Luxembourg	0.7441
Hungary	0.9373	Spain	0.8256	Qatar	0.6277
Kuwait	0.8261	Iceland	0.8439		

5.2 Credit markets and the dynamics of exploitation

The previous subsection provides a snapshot of exploitative relations in the international context and it forcefully illustrates the importance of wealth inequalities for the *emergence* of IIR. In this section, we extend the analysis to analyse the mechanisms allowing for the transfer of surplus between countries, and derive the entire class structure of the global economy, based on the definition in section 3. Then, we tackle the issue of the dynamics of IIR by performing a counterfactual exercise. We ask: what would happen if the world economy behaved as in our model? Would exploitation *persist* in a competitive economy with significant wealth inequalities, and a drive to accumulate?

The results of the simulation can be found in figures 3-5. Figure 3 reports aggregate activity levels (y_t, z_t, δ_t) and wealth W_{t-1}, the growth rate of capital g_t, $\widehat{w}_t$ and b, and r_t.[24] In all panels, the dashed vertical line denotes the period in which the economy becomes labour constrained.

[23] Two notable outliers are Trinidad and Tobago and, partly, Botswana. Although they have a small capital stock compared to OECD countries, they are categorised as exploiters largely due to their very small population and thus low effective labour capacity.

[24] Aggregate x_t is not reported since $x_t = 0$, all t, without loss of generality as explained in Appendix A.2.

Table 2: Exploitation Intensity for Exploited Countries at $t = 1$ - Basic economy

	e_1^ν		e_1^ν		e_1^ν
Burundi	1.1305	Kyrgyzstan	1.1150	Sri Lanka	1.0516
Congo - Kinshasa	1.1292	Tanzania	1.0923	Morocco	1.0108
Malawi	1.1297	Haiti	1.0910	Namibia	1.0253
Mali	1.1241	Lesotho	1.0916	Ukraine	1.0581
Sierra Leone	1.1249	Bolivia	1.1085	Colombia	1.0373
Liberia	1.1257	Honduras	1.0993	Tajikistan	1.0516
Mozambique	1.1197	Vietnam	1.1045	Gabon	1.0441
Central African Republic	1.1218	Egypt	1.1026	South Africa	1.0435
Madagascar	1.1224	Belize	1.1095	Mongolia	1.0485
Niger	1.1160	Nicaragua	1.0896	Maldives	1.0258
Rwanda	1.1228	El Salvador	1.0878	Argentina	1.0459
Burkina Faso	1.1157	Guatemala	1.0790	Algeria	1.0187
Ethiopia	1.1112	Sudan	1.0675	Dominican Republic	1.0337
Zimbabwe	1.1221	Syria	1.0927	Jamaica	1.0270
Togo	1.1144	Laos	1.0755	Ecuador	1.0303
Benin	1.1146	Zambia	1.0908	Bulgaria	1.0405
Gambia	1.1100	Moldova	1.1002	Tunisia	1.0177
Kenya	1.1175	Fiji	1.0876	Kazakhstan	1.0346
Yemen	1.1110	India	1.0744	Serbia	1.0377
Uganda	1.1167	Iraq	1.0727	Albania	1.0234
Nepal	1.1100	Philippines	1.0821	Iran	1.0002
Cambodia	1.1115	Paraguay	1.0799	Poland	1.0333
Ivory Coast	1.1063	Armenia	1.0845	Mexico	1.0066
Cameroon	1.1091	Ghana	1.0685	Thailand	1.0035
Pakistan	1.1061	Jordan	1.0752	Barbados	1.0052
Senegal	1.0970	Congo - Brazzaville	1.0475	Brazil	1.0094
Myanmar	1.1005	Angola	1.0133	Panama	1.0025
Nigeria	1.1001	Eswatini	1.0426	Chile	1.0018
Mauritania	1.0966	Peru	1.0665		
Bangladesh	1.1012	Costa Rica	1.0456		

Figure 3: Summary results - Basic economy

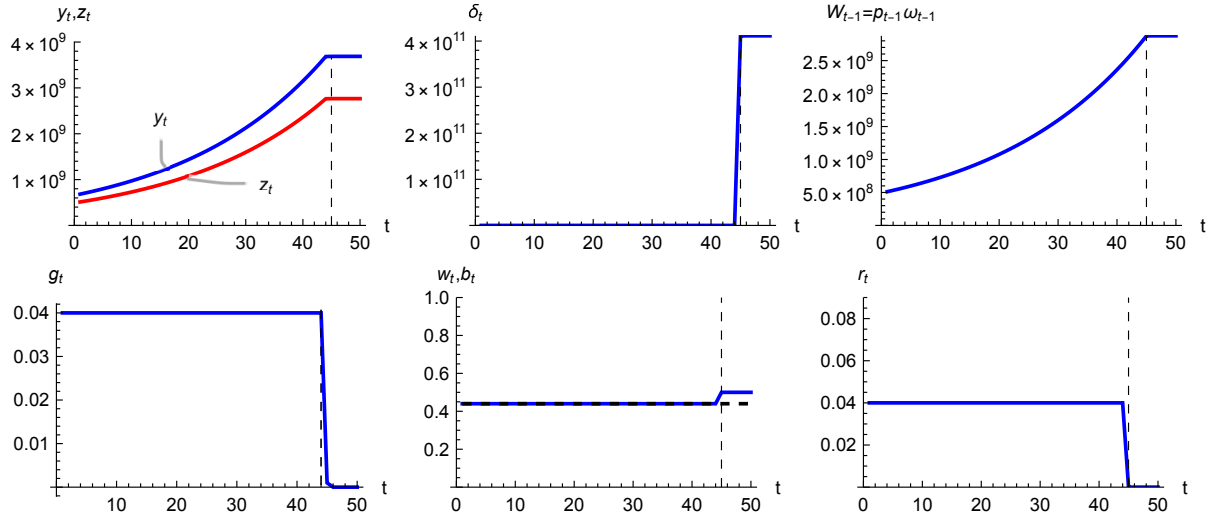


Figure 4(a) reports the dynamics of exploitation by providing a headcount of exploiting and exploited countries. Exploitation status is constant while the economy is capital constrained and exploitation ceases to exist once it becomes labour constrained.

Figure 4: Class and exploitation status - Basic economy

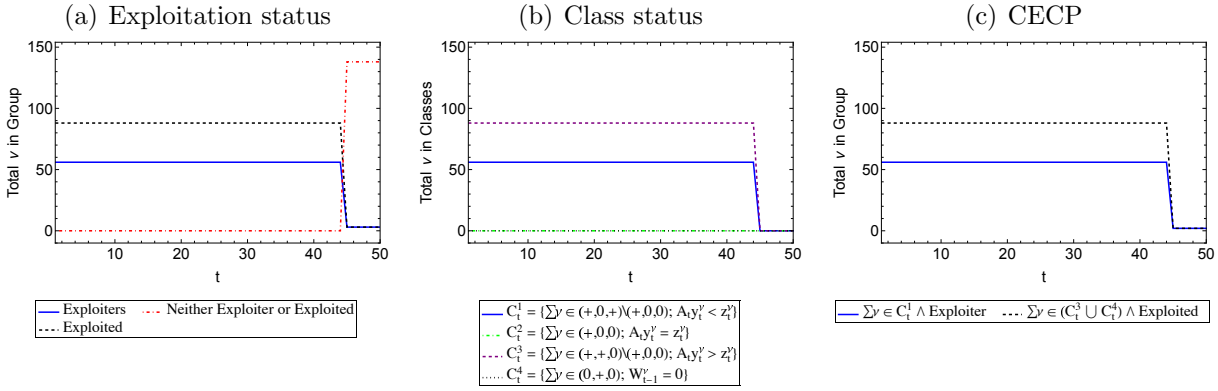


Figure 4(b) derives the entire class structure of the global economy based on each country's position in the international credit market, while figure 4(c) compares exploitation and class status. Together, they complete our depiction of IIR, and confirm common intuitions in dependency theory. For, wealthy countries are net creditors ($Ay_t^\nu < z_t^\nu$), belong to C_t^1, and are exploiters, while poor countries are net debtors ($Ay_t^\nu > z_t^\nu$), belong to C_t^3, and are exploited.[25] Surplus is transferred from poor to rich countries via global capital markets.

Figure 5 describes the dynamics of the distribution of the exploitation intensity index, e_t^ν, with countries sorted on the vertical axis by their initial per capita wealth (countries with the highest per capita wealth are at the top). When the economy is capital constrained, the distribution of e_t^ν is constant over time with a Gini coefficient of 0.0644787: there is no tendency for exploitation to diminish, and endowment-poor (rich) countries are exploited (exploiters). When the economy becomes labour constrained, profits and exploitation disappear, and $e_t^\nu = 1$, for all countries ν.

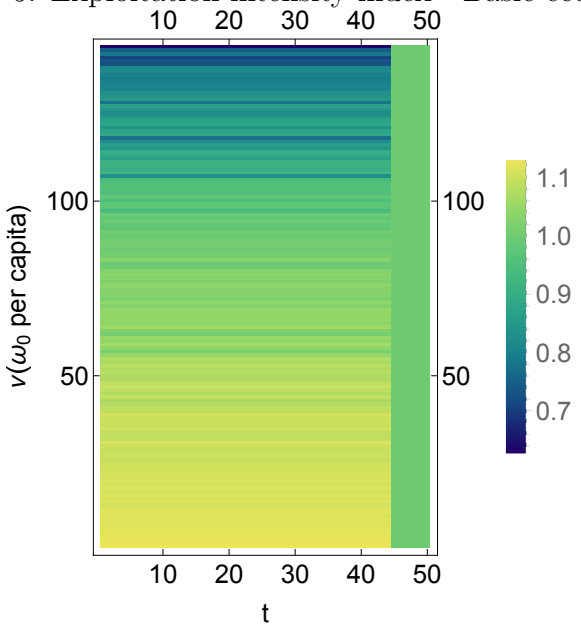
These results confirm and generalise an argument originally suggested by Devine and Dymski (1991) and later proved by Veneziani and Yoshihara (2017a): wealth inequalities and competitive markets are sufficient for exploitation, and IIR, to emerge, but not for them to persist. Given the strong empirical evidence of persistent, if not widening, inequalities across borders, our simulation exercise suggests that something else is necessary to explain the dynamics of IIR. In the next section, we extend our analysis to incorporate some possible mechanisms to explain persistence of IIR, without having to assume the open use of force by core countries to stem the growth of those in the periphery.

6 Endogenising consumption and technical change

In this section we exploit the power of computational methods in dealing with complex, non-linear dynamics in economies with heterogeneous agents (Bergmann et al. 2009; Plummer

[25] In figure 4(b), and in all similar figures below, the class composition of the economy is shown only for the periods t with $r_t > 0$. For if the profit rate vanishes the definition of classes needs to be revised (see Cogliano et al. (2019)). C_t^2 is empty in all simulations because no country satisfies the knife-edge condition $Ay_t^\nu = z_t^\nu$ exactly. This is a peculiarity of the one-good model and it can be shown that in more general economies some countries will indeed belong to C_t^2.

Figure 5: Exploitation intensity index - Basic economy



et al. 2012) to allow both consumption and technology to change endogenously over time, and analyse their effect on IIR. This choice reflects both empirical and theoretical concerns. Empirically, the long-run evolution of capitalist economies has been characterised by an increase in (average) consumption opportunities and by an expansion of technical knowledge, leading to a progressive increase in labour productivity (Flaschel, Franke, and Veneziani 2013; Cogliano, Flaschel, Franke, Fröhlich, and Veneziani 2018). Theoretically, a fundamental feature of capitalism as a dynamic system is its constant tendency to revolutionise production with a strong propensity, according to Marx, for labour-saving innovations.

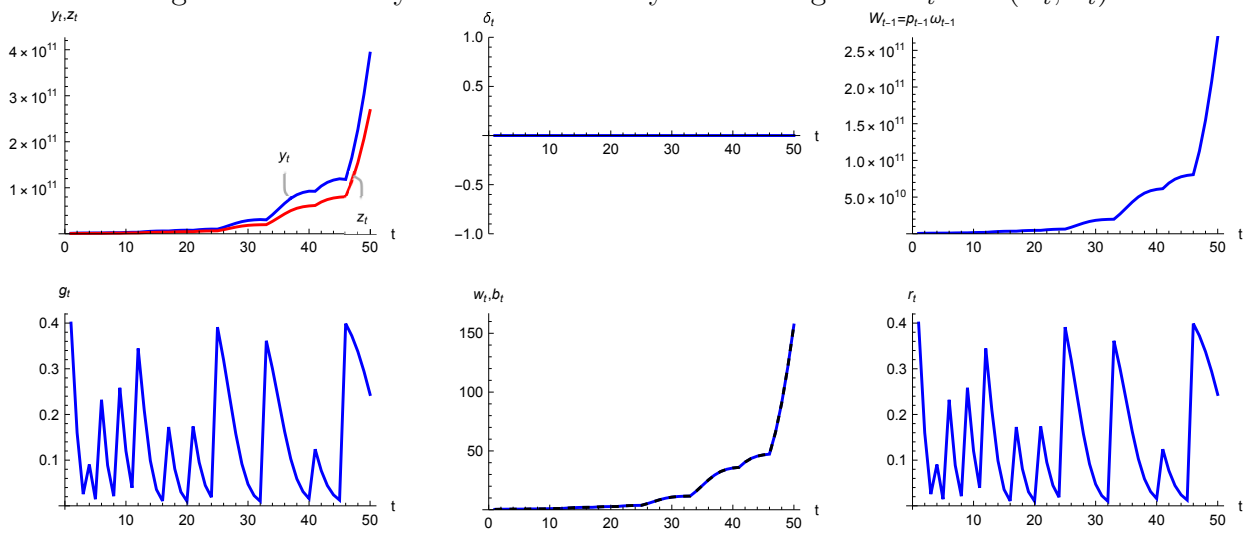
To be specific, concerning consumption, we incorporate some Marxian insights on the social nature of consumption and assume that b_t is the product of social norms, by making it an increasing function of the general level of development of the economy, as proxied by aggregate capital, and of the history of consumption itself. To be specific, we assume:

$$b_t = b_{t-1} \cdot \left(1 + \phi \frac{\omega_{t-1} - \omega_{t-2}}{\omega_{t-2}}\right), \tag{2}$$

where the parameter ϕ captures the degree to which the development of the economy influences consumption norms.

Concerning technology, we follow Marx and assume that when the rate of return on capital falls beneath a certain threshold, capitalists increase their efforts to innovate and introduce new techniques, thus leading (A_t, L_t) to change over time. In our model, given perfect competition, profitability is measured by the interest rate fetched on the international credit market. Therefore, in the computational analysis, we assume that there is a threshold value r^*, which represents the capitalists' minimum profitability benchmark, and depends on economic, institutional and even cultural factors, such that if at $t-1$ capitalists obtained sufficient profits ($r_{t-1} \geqq r^*$) then no innovations appear. If, however, profitability falls below the threshold ($r_{t-1} < r^*$) then R&D efforts lead to the discovery and adoption of a new

Figure 6: Summary results - Economy with endogenous b_t and (A_t, L_t)



technique, denoted as (A', L'), such that technical change is capital-using ($A' \geqq A_{t-1}$) and labour-saving ($L' < L_{t-1}$) à la Marx and it restores profitability.[26] This formulation of innovations is grounded theoretically in the Marxian and evolutionary tradition, as argued by Cogliano et al. (2016), and it has robust empirical support (Tavani and Zamparelli 2017).

6.1 Persistent exploitation cycles

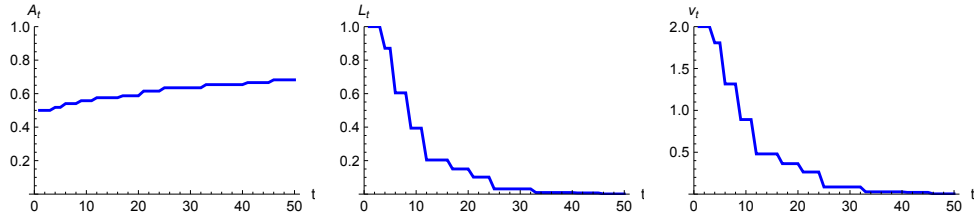
Figure 6 reports the same information as figure 3 for the basic model. Some differences clearly emerge: aggregate production, lending, and wealth, all increase over time but their growth path is no longer smooth, and g_t exhibits a cyclical downward trend, without the economy reaching a stationary state. This is caused by the joint dynamics of distribution, consumption norms, and technical change. Initially, the economy is capital constrained, and $\widehat{w}_t = b_t$. As accumulation proceeds, the subsistence norm, b_t, increases, leading to a decrease in r_t, and thus in the growth rate of aggregate output, lending, and capital, even before the economy becomes labour constrained. As the rate of return hits the critical threshold, however, capitalists manage to introduce an innovation that restores global profitability, lowers employment, and speeds up growth again, starting a new accumulation cycle. Throughout the cycles of accumulation and technical change the economy remains capital constrained, as recurrent Marx-biased technical change (cyclically) lowers labour demand and the labour embodied in the production good (figure 7). Therefore there is a secular increase in $\widehat{w}_t = b_t$, while r_t oscillates between $r_0 = 0.4$ and r^*.

In light of the cyclical behaviour of g_t and r_t, the core/periphery structure of the global economy is remarkably stable. Throughout the simulation, fifty-six countries are exploiters and belong to C_t^1, and eighty-eight are exploited and belong to C_t^3, and the CECP holds at all t.[27] However, this draws only a partial picture of IIR, and beneath a seemingly unchanging surface, figures 8(a)-8(b) uncover an interesting phenomenon of "exploitation

[26] For a detailed description of the simulation procedure, see Appendix A.2.

[27] These results are not shown for reasons of space and are available in the Addendum.

Figure 7: Technology and labour values - Economy with endogenous b_t and (A_t, L_t)



Note: $A_{\max} = 0.682261$, $L_{\min} = 0.000964239$, $v_{\min} = 0.00303469$

cycles" that trace the cycles in r_t. As accumulation progresses with a given technique (A_t, L_t), exploitation tends to decrease as e_t^ν tends to 1 for all ν. However, when a new technique is introduced, profitability and inequality in exploitation intensity are restored, and the pattern of accumulation and exploitation resumes until another innovation is introduced.

Figure 8: Exploitation intensity index - Economy with endogenous b_t and (A_t, L_t)

(a) Exploitation intensity across agents (b) Gini coefficient of e_t^ν

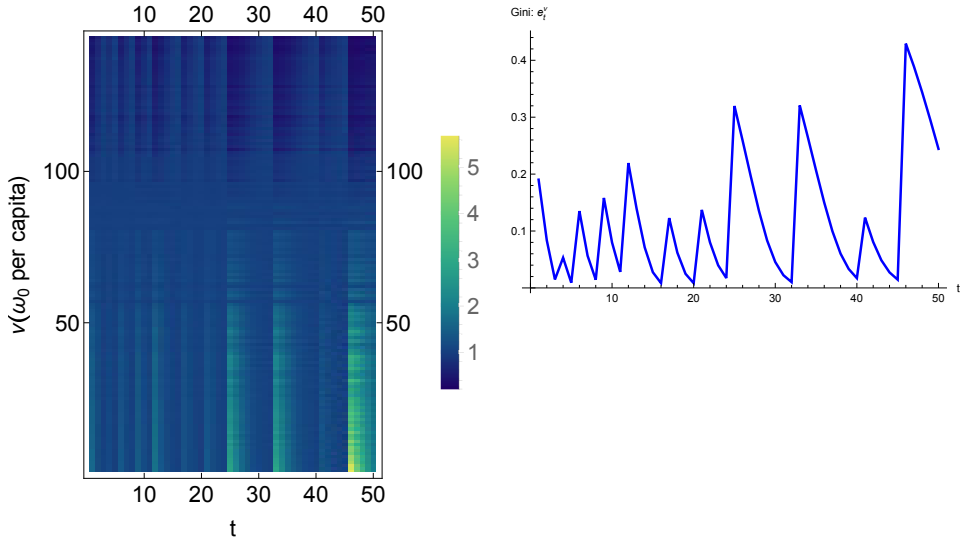


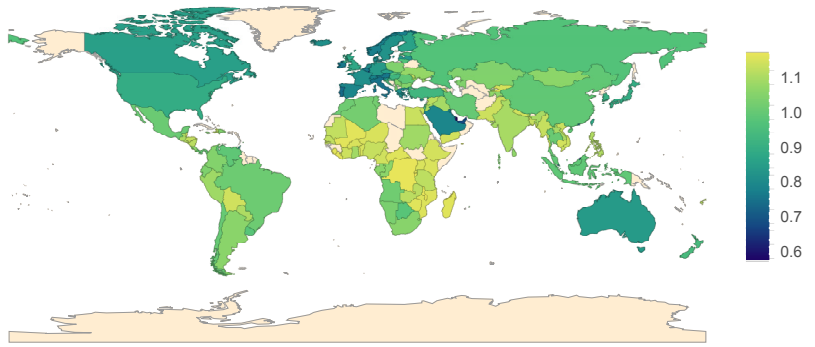
Figure 9 maps e_t^ν for all countries across select t. Unlike at $t = 1$, the distributions shown in figure 9 are counterfactuals: they show what the global distribution of e_t^ν would look like at different points in the cycles shown in figure 6.[28] In periods with high r_t $(t = 25, 50)$, international relations are more exploitative and e_t^ν is more disperse than in periods with low r_t $(t = 10, 40)$.

The results support the claim that capital-using labour-saving technical change can help to explain the persistence of IIR (Skillman 1995). In the global economy, international trade and development raise (norms, expectations and therefore) living standards, including for countries in the periphery, which increases their reservation wage and tends to reduce the rate of return on capital. What can countries in the core do in order to counter this tendency,

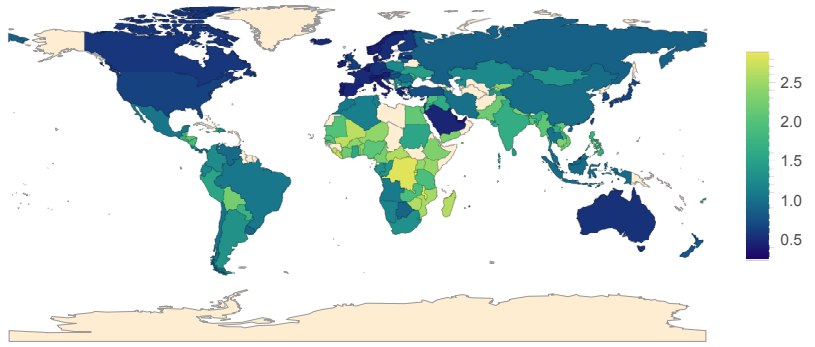
[28]The full list of values of e_t^ν at select t can be found in table 4 in Appendix B, where diagrams showing e_t^ν versus wealth per capita can also be found.

Figure 9: Worldwide Exploitation Intensity - Economy with endogenous b_t and (A_t, L_t)

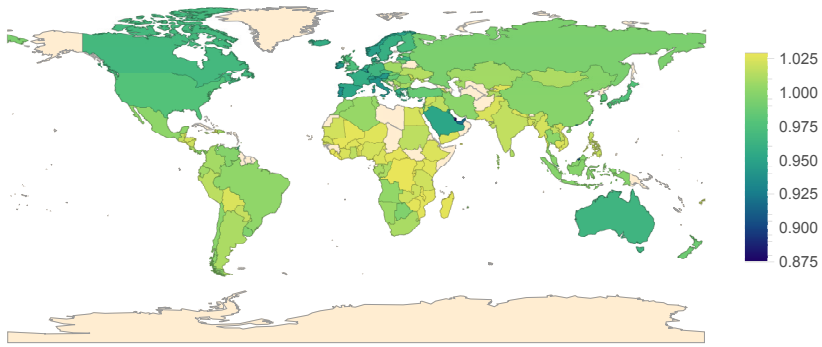
(a) $t = 10$



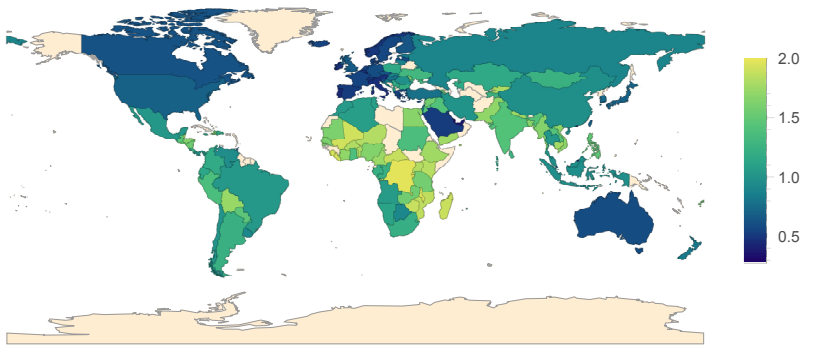
(b) $t = 25$



(c) $t = 40$



(d) $t = 50$



and maintain exploitation, without recourse to war and coercion? The previous analysis suggests that Marx-biased technical change may do the job as it makes capital persistently scarce relative to labour, thus maintaining the advantage of capital-rich core countries over labour-abundant countries in the periphery. In a competitive setting, countries in the core cannot coordinate their innovation efforts and therefore technical change tends to occur occasionally, which leads to cycles that capture the varying degree to which core countries are able to exploit the periphery over time.

In closing this section, we note that while the Gini of e_t^ν fluctuates widely around a mildly increasing trend, the Gini of the distribution of wealth remains constant at 0.8156 – as all countries accumulate at the rate r_t – and the Gini of the distribution of income stays within a rather narrow range, [0.780087, 0.812067].[29] This is an important point that was not evident in the basic economy: an analysis of international relations focusing on the concepts of exploitation and class is *not* reducible to a focus on income and wealth inequality (even though a strong relation exists between wealth inequalities and exploitation and class status, as shown above). The notions of exploitation and class identify the key economic and geographic structure of IIR, and the emergence in the global economy of a core and a periphery, in a way that international inequalities of income and wealth do not.

7 Robustness

We have analysed many variations of the two economies in order to assess the robustness of our results. In this section, we briefly summarise the main points.[30]

First, the empirical estimates of the global distribution of exploitation intensity in tables 1-2, and the partition of countries into exploiters and exploited, are robust to a number of perturbations. To be sure, alternative estimates of national wealth and consumption levels, or of the technological parameters A, L (and thus of embodied labour value v) may make a difference for countries that are very close to the threshold $e^\nu = 1$. But on the whole the picture of the international economy in 2017 derived in section 5.1 is quite robust.

We have also considered alternative determinations of each country's labour endowment, including (i) assigning a proxy value of one to those countries in the Penn World Table that do not report human capital attainment; and (ii) using the PWT data on persons engaged rather than population. In some respects, using persons engaged may yield better estimates of effective labour capacity, since it could ostensibly capture cultural and other differences across countries that determine different labour forces, even when populations are very similar. Option (i) expands N to 180 to include almost all countries in the world; while (ii) yields $N = 171$. Either way, our main conclusions remain unchanged.

Second, the key qualitative features of both economies are robust to a large number of perturbations of the initial conditions, production set, and, to a large extent, behavioural assumptions. The results in section 6.1 remain unchanged for a range of values of the threshold rate r^* and of the parameter ϕ linking the growth of consumption norms to accumulation, and they continue to hold with more general formulations of technical change.

[29] Figures for the distributions of wealth and income are omitted for space and shown in the Addendum.

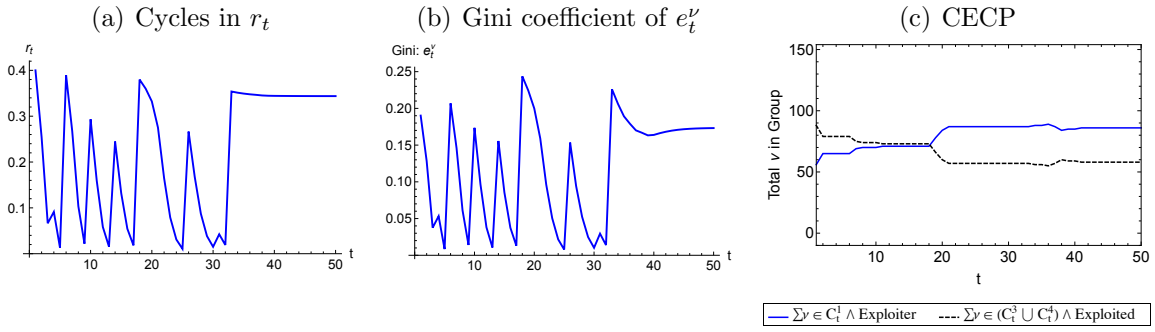
[30] A complete description of all robustness checks is available in the Addendum.

Third, we have considered a variant of the economy with endogenous consumption norms but *exogenous* labour-saving technical change that occurs at a pace sufficient to maintain a stable r_t for all t. In this economy, the class and exploitation structure and the distribution of e_t^ν remain stable and consistent with that of the basic economy, but the economy does not reach a non-exploitative stationary state consistent with the results in section 6.1.

Fourth, it may be argued that our conclusions in section 6 depend on the rather specific dynamics of consumption norms, which are assumed to grow at the same rate as the capital stock. Although we believe this assumption to be empirically plausible, we have also tested a host of alternative specifications of consumption behaviour that largely confirm our results, except when consumption of core countries is so high that they stop accumulating straight away and there is a mild tendency for exploitation inequality to decrease.

Specifically, we examined a series of economies with highly heterogeneous consumption which we assume to be an increasing function of consumption norms, as determined in section 6, and of a country's interest revenue – the intuition being that wealthy countries tend to consume more from interest revenue and accumulate less.[31]

Figure 10: Sample results - Example economy with standard of living consumption



These economies display similar cycles to those in section 6 (see figure 10). As countries accumulate, they gradually shift toward consuming more interest income and their rate of accumulation slows. Yet, there seems to be no clear tendency for the Gini of e_t^ν to decrease. Overall, the general pattern is for a slight decrease in the intensity of exploitation over time, as most countries' exploitation status remains constant over time. However, as time goes on, some exploited countries switch to become exploiters, while some exploiting countries show notable increases in the intensity with which they exploit. This pattern of exploitation intensity is particularly interesting since it occurs even as r_t and the Gini of e_t^ν show no clear tendency to decline. Further, the structure of the CECP shown in figure 10 is robust even as standard of living-based consumption is introduced, b_t grows with aggregate accumulation, various technical changes take place, and the global economy eventually reaches a stationary state around $t = 40$, after which e_t^ν is almost constant for all ν. Stated differently, the CECP persists even as the world economy switches from a capital accumulation regime to a stationary one, thus the structure of exploitation and class is robust to shifts in the stage of world development – further confirming the analysis in section 5.

[31] These economies are closer to the non-linear models developed by Bergmann et al. (2009), Galanis and Kumar (2021), and Plummer et al. (2012).

8 Conclusions

In this paper, we have developed a rigorous conceptual framework to analyse the new guise that IIR have taken in the global economy, and have derived a new measure of unequal exchange across borders – an exploitation intensity index. Contrary to the received view, this measure is theoretically robust, logically consistent, and empirically grounded. We have used it to derive the complete structure of IIR.

Unlike in post-modern approaches to globalisation, which depict IIR as immaterial and deterritorialised, the spatial-economic structure of the new imperialism can be identified, whereby wealthy nations are net lenders and exploiters, whereas endowment-poor countries are net borrowers and exploited. In line with a long tradition in radical geography, our model precisely identifies a set of countries in the core of the global economy, and those in the periphery based on their position in the class and exploitation structure.

We have also shown that unlike in classical theories, which emphasise monopolistic distortions, and the contradictions in the process of capital accumulation in core economies, competitive markets, profit-seeking, and international inequalities in development and wealth are central in generating IIR. The exploitative nature of IIR can be understood focusing on credit relations, which transfer surplus from the periphery to the core of the global economy.

While international credit markets and wealth inequalities are sufficient to generate an exploitation phenomenon, we show that they are not sufficient for it to persist. We have therefore explored some mechanisms to guarantee the persistence of IIR – without assuming the sheer use of force from core countries. Consistent with a classic Marxian intuition, we show that capital-using labour-saving technical change may play this role.

Indeed, if one adopts an evolutionary model of the creation and adoption of technical innovations, it is possible to show that the world economy displays endogenous fluctuations in the growth rate of output, as well as profitability and exploitation. Although ours is an exercise in scientific ontology – trying to identify the nature of IIR and an appropriate index to measure exploitative relations – these results suggest a possible explanation of the turbulent dynamics of the global economy. We leave this issue for further research.

References

Amin, S. (1999). Capitalism, Imperialism, Globalization. In R. M. Chilcote (Ed.), *The Poltiical Economy of Imperialism*. Boston, MA: Kluwer.

Arrighi, G. (1994). *The Long Twentieth Century*. London: Verso.

Baran, P. (1968). *The political economy of growth*. New York, NY: Monthly Review Press.

Barnes, T. J. (1990). Analytical Political Economy: A Geographical Introduction. *Environment and Planning A: Economy and Space 22*(8), pp. 993–1006.

Barnes, T. J. and E. Sheppard (2010). 'Nothing includes everything': towards engaged pluralism in economic geography. *Progress in Human Geography 34*(2), pp. 193–214.

Barro, R. J. and J. Lee (2013). A new data set of educational attainment in the world, 1950-2010. *Journal of Development Economics 104*, pp. 184–198.

Bergmann, L., E. Sheppard, and P. S. Plummer (2009). Capitalism beyond harmonious equilibrium: mathematics as if hunan agency mattered. *Environment and Planning A: Economy and Space 41*, pp. 265–283.

Brewer, A. (1999). Imperialism in retrospect. In R. M. Chilcote (Ed.), *The Poltiical Economy of Imperialism*. Boston, MA: Kluwer.

Coe, N. M. (2011). Geographies of production II: A global production network A-Z. *Progress in Human Geography 36*(3), pp. 389–402.

Coe, N. M., P. Dicken, and M. Hess (2008). Global production networks: realizing the potential. *Journal of Economic Geography 8*, pp. 271–295.

Coe, N. M. and H. W. Yeung (2001). Geographical perspectives on mapping globalisation. *Journal of Economic Geography 1*(4), pp. 367–380.

Coe, N. M. and H. W. Yeung (2019). Global production networks: mapping recent conceptual developments. *Journal of Economic Geography 19*, pp. 775–801.

Cogliano, J. F., P. Flaschel, R. Franke, N. Fröhlich, and R. Veneziani (2018). *Value, Competition, and Exploitation: Marx's Legacy Revisited*. Cheltenham: Edward Elgar.

Cogliano, J. F., R. Veneziani, and N. Yoshihara (2016). The Dynamics of Exploitation and Class in Accumulation Economies. *Metroeconomica 67*(2), pp. 242–290.

Cogliano, J. F., R. Veneziani, and N. Yoshihara (2019). Exploitation, skills, and inequality. *Review of Social Economy 77*(2), pp. 208–249.

Devine, J. and G. Dymski (1991). Roemer's 'General' Theory of Exploitation is a Special Case. *Economics and Philosophy 7*, pp. 235–275.

Duménil, G. (1980). *De la valuer aux prix de production*. Paris: Economica.

Emmanuel, A. (1972). *Unequal Exchange: A Study of the Imperialism of Trade*. New York, NY: Monthly Review Press.

Evans, P. (1979). *Dependent Development: The Alliance of Multinational, State and Local Capital in Brazil*. Princeton, NJ: Princeton University Press.

Feenstra, R., R. Inklaar, and M. Timmer (2015). The Next Generation of the Penn World Table. *American Economic Review 105*, pp. 3150–3182. Available for download at www.ggdc.net/pwt.

Flaschel, P., R. Franke, and R. Veneziani (2013). Labor productivity and the Law of Decreasing Labor Content. *Cambridge Journal of Economics 37*(2), pp. 379–402.

Foley, D. K. (1982). The Value of Money, the Value of Labor Power and the Marxian Transformation Problem. *Review of Radical Political Economics 14*(2), pp. 37–47.

Foot, S. P. H. and M. J. Webber (1983). Unequal exchange and uneven development. *Environment and Planning D: Society and Space 1*, pp. 281–304.

Franke, A. G. (1978). *Dependent accumulation and underdevelopment*. New York, NY: Monthly Review Press.

Galanis, G., C. Koutny, and I. Weber (2022). System Cycles of Accumulation and Chaos in the World Capitalist System: A Missing Link. University of Massachusetts Amherst, Economics Department Working Paper Series, WP.321.

Galanis, G. and A. Kumar (2021). A dynamic model of global value network governance. *Environment and Planning A: Economy and Space 53*(1), pp. 53–72.

Gereffi, G., J. Humphrey, and T. Sturgeon (2005). The governance of global value chains. *Review of International Political Economy 12*(p), pp. 78–104.

Gereffi, G. and M. Korzeniewicz (Eds.) (1994). *Commodity Chains and Global Capitalism*. Westport, CT: Praeger.

Griffin, K. and J. Gurley (1985). Radical Analyses of Imperialism, the Third World, and the Transition to Socialism: A Survey Article. *Journal of Economic Surveys 23*, pp. 1089–1143.

Hardt, M. and A. Negri (2000). *Empire*. Cambridge, MA: Harvard University Press.

Harvey, D. (1982). *The Limits to Capital*. Oxford: Basil Blackwell.

Harvey, D. (2003). *The New Imperialism*. Oxford: Oxford University Press.

Harvey, D. (2005). *A Brief History of Neoliberalism*. Oxford: Oxford University Press.

Hobson, J. A. (1954). *Imperialism: a Study*. London: Allen & Unwin.

Howard, M. C. and J. E. King (1992). *A history of Marxian economics*. Princeton, NJ: Princeton University Press.

Howard, M. C. and J. E. King (1999). Whatever happened to imperialism? In R. M. Chilcote (Ed.), *The Political Economy of Imperialism*. Boston, MA: Kluwer.

Iliopoulos, P., G. Galanis, A. Kumar, and L. Popoyan (2021). The Power of Sectoral Geographical Centrality in Global Production. Scuola Superior Sant'Anna, Laboratory of Economics and Management Working Paper Series, WP.2020/12.

Kvangraven, I. (2020). Beyond the Stereotype: Restating the Relevance of the Dependency Research Programme. *Development and Change 52*, pp. 76–112.

Lawson, T. (2003). *Reorienting Economics*. London: Routledge.

Lawson, T. (2009). The current economic crisis: its nature and the course of academic economics. *Cambridge Journal of Economics 33*, pp. 759–777.

Lenin, V. I. (1970). *Imperialism: The Highest Stage of Capitalism*. Moscow: Progress Publishers.

Luxemburg, R. (1951). *The Accumulation of Capital*. London: Routledge. First published in 1913 as *Die Akkumulation des Kapitals*, first English edition published in 1951.

Marx, K. (1976). *Capital: Volume I*. New York, NY: Penguin Group.

Milanovic, B. (2015). Global Inequality of Opporunity: How Much of Our Income is Determined by Where We Live? *Review of Economics and Statistics 97*, pp. 452–460.

Petras, J. and H. Veltmeyer (2001). *Globalization Unmasked: Imperialism in the 21st Century*. New York, NY: Zed Books.

Plummer, P. and E. Sheppard (2006). Georaphy matters: agency, structures and dynamics at the intersection of economics and geography. *Journal of Economic Geography 6*, pp. 619–637.

Plummer, P., E. Sheppard, and R. Haining (2012). Rationality, stability, and endogenous price formation in spatially interdependent markets. *Environment and Planning A: Economy and Space 44*, pp. 538–559.

Psacharopoulos, G. (1994). Returns to investment in education: A global update. *World Development 22*, pp. 1325–1343.

Ricci, A. (2021). *Value and Unequal Exchange in International Trade*. London: Routledge.

Ricci, A. (2022). Global locational inequality: Assessing unequal exchange. *Environment and Planning A: Economy and Space*, forthcoming.

Roemer, J. E. (1982). *A General Theory of Exploitation and Class*. Cambridge, MA: Harvard University Press.

Roemer, J. E. (1983). Unequal Exchange, Labor Migration, and International Capital Flows: a Theoretical Synthesis. In P. Desai (Ed.), *Marxism, Central Planning and the Soviet Economy*. Cambridge, MA: MIT Press.

Schumpeter, J. A. (1951). *Imperialism and Social Classes*. New York, NY: A. Kelley.

Schweickart, D. (1991). The politics and morality of unequal exchange. *Economics and Philosophy 7*, pp. 13–36.

Selwyn, B. (2012). Beyond firm-centrism: re-integrating labour and capitalism into global commodity chain analysis. *Journal of Economic Geography 12*(1), pp. 205–226.

Selwyn, B. (2015). Commodity chains, creative destruction and global inequality: a class analysis. *Journal of Economic Geography 15*, pp. 253–274.

Selwyn, B. (2019). Poverty chains and global capitalism. *Competition & Change 23*(1), pp. 71–97.

Sheppard, E. (1984). Value and Exploitation in a Capitalist Space Economy. *International Regional Science Review 9*(2), pp. 97–107.

Sheppard, E. (2011). Geographical political economy. *Journal of Economic Geography 11*, pp. 319–331.

Sheppard, E. (2016). *Limits to Globalization: Disruptive Geographies of Capitalist Development*. Oxford: Oxford University Press.

Sheppard, E. and T. J. Barnes (1990). *The Capitalist Space Economy: Geographical Analysis after Ricardo, Marx and Sraffa*. Abingdon, Oxon: Routledge.

Skillman, G. L. (1995). *Ne Hic Saltaveris*: The Marxian Theory of Exploitation After Roemer. *Economics and Philosophy 11*(2), pp. 309–331.

Tavani, D. and L. Zamparelli (2017). Endogenous Technical Change in Alternative Theories of Growth and Distribution. *Journal of Economic Surveys 31*(5), pp. 1272–1303.

Veneziani, R. (2007). Exploitation and time. *Journal of Economic Theory 132*(1), pp. 189–207.

Veneziani, R. (2013). Exploitation, Inequality, and Power. *Journal of Theoretical Politics 25*(4), pp. 526–545.

Veneziani, R. and N. Yoshihara (2015). Exploitation in economies with heterogeneous preferences, skills and assets: An axiomatic approach. *Journal of Theoretical Politics 27*(1), pp. 8–33.

Veneziani, R. and N. Yoshihara (2017a). Globalisation and Inequality in a Dynamic Economy: An Axiomatic Analysis of Unequal Exchange. *Social Choice and Welfare 49*, pp. 445–468.

Veneziani, R. and N. Yoshihara (2017b). One million miles to go: taking the axiomatic road to defining exploitation. *Cambridge Journal of Economics 41*(6), pp. 517–524.

Veneziani, R. and N. Yoshihara (2018). The theory of exploitation as the unequal exchange of labour. *Economics and Philosophy 34*, pp. 381–409.

Wallerstein, I. (1974). *The Modern World-System I*. New York, NY: Academic Press, Inc.

Webber, M. J. and S. P. H. Foot (1984). The measurement of unequal exchange. *Environment and Planning A: Economy and Space 16*, pp. 927–947.

Yeung, H. W. (2002). The Limits to Globalization Theory: A Geographic Perspective on Global Economic Change. *Economic Geography 78*(3), pp. 285–305.

Yeung, H. W. (2021). The trouble with global production networks. *Environment and Planning A: Economy and Space 53*(2), pp. 428–438.

A Mathematical appendix

A.1 The basic economy

In this subsection, we analyse the *basic economy*, which is characterised by constant population, technology, consumption norms, and human capital. Formally, let $\mathcal{N}_t$, $\mathcal{P}_t$ denote, respectively, the set of agents and the set of available technologies at t. In the basic economy, $\mathcal{N}_t = \mathcal{N}$, $\mathcal{P}_t = \mathcal{P} = \{(A, L)\}$, $b_t = b$, and $l^\nu_{t-1} = l^\nu$ for all t and all ν. The basic economy provides a theoretical benchmark and a natural starting point for our analysis, but the framework, concepts, and definitions presented in this section, and in the next one, can be easily extended and the results derived continue to hold in more general economies (as confirmed also by the simulations).

We assume throughout that technology is sufficiently advanced to allow for the production of a surplus: $1 - vb > 0$, at all t. This condition is equivalent to $(1 - bL) > A$: it implies that if Ax units of capital are invested in the production process, gross output x is sufficient for necessary consumption bL and to replace capital used up in production, or $x > bLx + Ax$.

In every t, given (p_t, r_t), every country ν chooses $(x^\nu_t, y^\nu_t, z^\nu_t, \delta^\nu_t)$ to maximise its wealth subject to consuming b per unit of labour performed (3) and to the constraints set by its capital (4) and labour (5) endowments. Formally, every ν solves the following programme:[32]

$$(MP^\nu_t) \max_{(x^\nu_t, y^\nu_t, z^\nu_t, \delta^\nu_t)} p_t \omega^\nu_t$$

subject to

$$\begin{aligned} p_t x^\nu_t + [p_t - (1 + r_t) p_{t-1} A]\, y^\nu_t + (1 + r_t) z^\nu_t + p_t \delta^\nu_t &= p_t b \Lambda^\nu_t + p_t \omega^\nu_t \quad (3) \\ p_{t-1} A x^\nu_t + z^\nu_t + p_{t-1} \delta^\nu_t &= p_{t-1} \omega^\nu_{t-1}, \quad (4) \\ L x^\nu_t + L y^\nu_t &\leqq l^\nu. \quad (5) \end{aligned}$$

The *basic economy* is defined by the set of countries, $\mathcal{N}$, technology, (A, L), consumption bundle, b, labour endowments, $(l^\nu)_{\nu \in \mathcal{N}}$, and initial capital endowments, $(\omega^\nu_0)_{\nu \in \mathcal{N}}$; and is denoted as $E(\mathcal{N}, (A, L), b, (l^\nu)_{\nu \in \mathcal{N}}, (\omega^\nu_0)_{\nu \in \mathcal{N}})$. Let $x_t \equiv \sum_{\nu \in \mathcal{N}} x^\nu_t$, and likewise for y_t, z_t, δ_t, ω_t, Λ_t, and l. Based on Roemer (1982), the concept of a reproducible solution can be defined.

Definition A.1: A *reproducible solution* (RS) for $E(\mathcal{N}, (A, L), b, (l^\nu)_{\nu \in \mathcal{N}}, (\omega^\nu_0)_{\nu \in \mathcal{N}})$ is a sequence of vectors (p_t, r_t) and associated actions $(x^\nu_t, y^\nu_t, z^\nu_t, \delta^\nu_t)_{\nu \in \mathcal{N}}$, such that at all t:

(a) $(x^\nu_t, y^\nu_t, z^\nu_t, \delta^\nu_t)$ solves MP^ν_t for all $\nu \in \mathcal{N}$ (optimality);

(b) $A(x_t + y_t) + \delta_t \leqq \omega_{t-1}$ (feasibility of production);

(c) $p_{t-1} A y_t = z_t$ (credit market);

(d) $(x_t + y_t) + \delta_t \geqq b\Lambda_t + \omega_t$ (goods market).

[32] Although we are focusing on an one-good economy, we provide a general formulation of programme MP^ν_t, and of the rest of the economy, in order to point the reader to the n-good extension of our analysis. Observe that if $\mathcal{P}$ is not a singleton, as in the model of section 6, then countries also choose A, L optimally.

At a RS, in every period (a) all countries maximise their wealth; (b) aggregate capital is sufficient for production (and speculative saving) plans; (c) the credit market clears; (d) aggregate supply is sufficient for consumption and accumulation plans.[33]

Given the structure of the one-good economy, we shall focus on RS's with strictly positive prices without loss of generality,[34] and we can take the produced commodity as the numéraire, setting $p_t = 1$, all t.[35] This implicitly defines a real wage rate $\widehat{w}_t$ at any t. It is immediate to prove that at any nontrivial RS, the real wage is at least enough to cover subsistence and the interest rate is nonnegative. Formally, if $\omega_{t-1} > 0$, then $\widehat{w}_t \geqq b$ and $r_t \geqq 0$, all t.

Given the previous observations, by constraints (3)-(4), it follows that at any RS, for all countries ν, the following equation must hold in every period t

$$\omega_t^\nu = \omega_{t-1}^\nu + r_t \left(A x_t^\nu + z_t^\nu\right) + \left(\widehat{w}_t - b\right) L \left(x_t^\nu + y_t^\nu\right). \tag{6}$$

Equation (6) implies that for all countries at the solution to MP_t^ν, if the interest rate is strictly positive, no wealth is used for speculative savings ($\delta_t^\nu = 0$ all ν), and if the wage rate is above subsistence, then the labour constraint (5) binds.

It is not difficult to show that this has some implications for the set of RS's: the interest rate can be strictly positive *and* the real wage rate can be greater than the subsistence norm only if the aggregate (effective) labour and capital endowments satisfy the knife-edge condition $l = LA^{-1}\omega_{t-1}$. If capital (labour) is abundant, the interest rate (the real wage rate) drops to zero (the subsistence level). This observation provides the foundations for the analysis of the dynamics of the global economy in the simulations.[36]

For every country ν, its gross revenue minus the subsistence cost is given by:

$$V_t^\nu \left(W_{t-1}^\nu, \Lambda_t^\nu; (p_t, r_t)\right) \equiv (1 + r_t) W_{t-1}^\nu + (w_t - p_t b) \Lambda_t^\nu.$$

Therefore, $R_t^\nu \left(W_{t-1}^\nu, \Lambda_t^\nu; (p_t, r_t)\right) \equiv V_t^\nu \left(W_{t-1}^\nu, \Lambda_t^\nu; (p_t, r_t)\right) + p_t b \Lambda_t^\nu$. Moreover, taking the produced commodity as the numéraire for each t, it follows that $V_t^\nu \left(W_{t-1}^\nu, \Lambda_t^\nu; (p_t, r_t)\right)$ can be reduced to $V_t^\nu \left(W_{t-1}^\nu, \Lambda_t^\nu; (1, r_t)\right)$ as defined below, and from equation (6) the growth rate of capital, g_t^ν, is also defined in period t:[37]

$$V_t^\nu \left(W_{t-1}^\nu, \Lambda_t^\nu; (1, r_t)\right) = (1 + r_t) \omega_{t-1}^\nu + \left(\widehat{w}_t - b\right) \Lambda_t^\nu, \tag{7}$$

$$g_t^\nu = r_t + \left(\widehat{w}_t - b\right) \frac{\Lambda_t^\nu}{\omega_{t-1}^\nu}. \tag{8}$$

From equation (8) it follows that, at all t, the aggregate growth rate of the economy is $g_t = r_t + \left(\widehat{w}_t - b\right) \frac{l}{\omega_{t-1}}$.

[33] The economy can thus be interpreted either as a sequence of generations living for one period or as a single generation in a sequence of temporary equilibria.

[34] Formally, $p_t, p_{t-1} > 0$ all t. Observe that from MP_t^ν it immediately follows that if there is some t' such that $p_{t'} = 0$, then at any RS it must be $p_t = 0$ for all $t > t'$.

[35] Given the commodity as the numéraire, r_t should be considered to represent the *real* interest rate at period t, which is defined by the *nominal* interest rate minus the inflation rate. Therefore one will invest or lend (rather than storing the good) provided $r_t \geqq 0$.

[36] A characterisation of the set of RS's can be derived using similar arguments as in Cogliano et al. (2019).

[37] Recall that $W_{t-1}^\nu = p_{t-1}\omega_{t-1}^\nu$, that $\widehat{w}_t = \frac{w_t}{p_t}$ and that we are setting $p_t = p_{t-1} = 1$.

A.2 The simulation routine and model calibration

A.2.1 The basic economy

The simulation begins with data on the various parameters of the model. The set of countries, and the distribution of capital and labour endowments are calibrated using 2017 data from the Penn World Table (PWT) (Feenstra et al. 2015). The PWT estimates of nations' capital stock at current PPPs (millions of 2011 U.S. dollars) are taken as ω_0^ν for each country ν. The values of l^ν are set by multiplying each country's population by the Penn estimates of average human capital attainment and scaling this figure up by 100,000 to ensure $l > LA^{-1}\omega_0$.[38] Countries for which there are no estimates of the capital stock or average human capital attainment are removed from the simulations, leaving $N = 144$.[39]

As for technology and consumption, we set: $A = 0.75$, $L = 0.5$, and $b = 0.44$, thus $v = 2$.

The choices of initial parameter values, and the scaling up of labour endowments, allow the simulations to start far from the knife-edge condition $l = LA^{-1}\omega_{t-1}$ and ensure a reasonable initial value of r_t such that the dynamics of the simulation have room to play out before the simulation becomes labour constrained, but – as discussed in section 7 – our key insights are robust to different choices of parameters.

For all countries and time periods, we restrict the computational analysis to solutions of MP_t^ν of the form $(0, y_t^\nu, z_t^\nu, \delta_t^\nu)$. As shown in Cogliano et al. (2019), this is without any loss of generality and it allows us to focus more closely on the interaction of countries in international credit markets and the resulting exploitative dynamics.

To be specific, at any t, we set $(x_t^\nu, y_t^\nu, z_t^\nu, \delta_t^\nu) = \left(0, \frac{A^{-1}\omega_{t-1}}{l} l^\nu, \omega_{t-1}^\nu, 0\right)$, $(x_t^\nu, y_t^\nu, z_t^\nu, \delta_t^\nu) = \left(0, L^{-1}l^\nu, \frac{l}{LA^{-1}\omega_{t-1}}\omega_{t-1}^\nu, \omega_{t-1}^\nu - z_t^\nu\right)$, or $(x_t^\nu, y_t^\nu, z_t^\nu, \delta_t^\nu) = \left(0, L^{-1}l^\nu, \omega_{t-1}^\nu, 0\right)$, for all ν, depending on whether the economy is capital constrained, labour constrained, or on the knife-edge. This specification of agents' optimal choices guarantees that the conditions in Definition A.1 are always satisfied.

To see this, observe that the economy is capital constrained, labour constrained, or on the knife-edge depending on whether $l \gtreqless LA^{-1}\omega_{t-1}$. Suppose the economy is capital constrained with $l > LA^{-1}\omega_{t-1}$, some t. Then at any RS it must be $\widehat{w}_t = b$, so that $r_t > 0$ and labour performed does not produce any net income for accumulation. Thus, for all ν, any $(0; y_t^\nu; z_t^\nu; 0)$ with $z_t^\nu = \omega_{t-1}^\nu$ solves MP_t^ν. Therefore since $z_t = \omega_{t-1}$ and $l > LA^{-1}\omega_{t-1}$, we choose a suitable profile (y_t^ν) for all ν such that $Ay_t = z_t$ and all conditions of Definition A.1 are satisfied at t. A similar logic holds in the other cases.

The simulation runs for $T = 50$ periods. The simulation first checks whether the economy is capital constrained, labour constrained, or on the knife-edge and updates r_t accordingly. Given the choice of ω_0, the simulation begins with r_1 such that $\widehat{w}_1 = b$ and countries then choose activities $(0, y_t^\nu, z_t^\nu)$ to maximise their wealth subject to their existing wealth and

[38] In the PWT (Feenstra et al. 2015), capital stocks are estimated using a perpetual inventory method and include six assets: structures (residential and non-residential); transport equipment; computers; communication equipment; software; and other machinery and assets. The human capital index in the PWT is based on average years of schooling, provided by Barro and Lee (2013), and assumptions about the rate of return to education from Psacharopoulos (1994).

[39] Robustness checks are run using proxies for average human capital attainment, but the main results of the simulations are not altered by reintroducing these countries. See section 7.

labour endowments and their subsistence needs. Wealth endowments are then updated according to equation (6) and the simulation repeats as necessary.

A.2.2 The economy with endogenous technical change

In our simulations, we set $r^* = 0.01$. Let $r^{(\widehat{w}_t;A_{t-1},L_{t-1})}$ be the interest rate given the real wage $\widehat{w}_t$ at t and the production technique adopted at $t-1$. Formally,

$$r^{(\widehat{w}_t;A_{t-1},L_{t-1})} \equiv \frac{1 - A_{t-1} - \widehat{w}_t L_{t-1}}{A_{t-1}},$$

where either $\widehat{w}_t = b_t$ or $\widehat{w}_t = \frac{1-A_{t-1}}{L_{t-1}}$ depending on whether the economy is capital constrained or labour constrained in period t. If $r^{(\widehat{w}_t;A_{t-1},L_{t-1})} \geq r^*$ then $(A_t, L_t) = (A_{t-1}, L_{t-1})$. When $r^{(\widehat{w}_t;A_{t-1},L_{t-1})} < r^*$, the new technique prevailing at t is identified by first selecting an interest rate, r', from the set of all previous interest rates $\{r_\tau\}_{\tau<t}$, such that $r_\tau > r^*$ and then randomly choosing an increase in A_{t-1} in the range $[0.01, 0.03]$ and setting $L_t = \frac{1-A_t-A_t r'}{\widehat{w}_t}$. To ensure that $A_t < 1$ a limit is set such that $A_{\max} = 0.991$. If r' and A_t entail a negative L_t, r' is adjusted downward by 0.02 so that $L_t > 0$.[40] These parameter values are chosen to ensure that new techniques restore a higher interest rate while not being so large as to preclude additional new innovations over the course of the simulation, i.e. these values allow us to examine the impact of a series of new techniques on exploitation and the core-periphery structure of the global economy. New techniques also provide the highest possible interest rate during any t. Given the persistently rising b_t, a new technique provides a higher interest rate than older techniques, thus there is no desire for any kind of reswitching.

The simulation occurs in the following order: (1) initialisation, $t = 1$; (2) subsistence b_t is updated; (3) $\widehat{w}_t$ and $r^{(\widehat{w}_t;A_{t-1},L_{t-1})}$ are determined depending on whether the economy is capital constrained or labour constrained;[41] (4) given $r^{(\widehat{w}_t;A_{t-1},L_{t-1})}$, A_t and r_t are updated if appropriate, leading L_t to be subsequently updated to reflect the new technology; (5) countries' actions are determined as in section A.2.1 and wealth endowments are updated according to equation (6);[42] and (6) the sequence (2)-(5) is repeated for all T periods.

The simulation runs for $T = 50$, with $A_0 = 0.5$, $L_0 = 1$, $b_0 = 0.3$, and $\phi = 1$. Parameters are chosen to allow the dynamics of technical change and evolving consumption norms to play out over T, and similar to section 5, $v_1 = 2$ and declines thereafter as a result of technical change. The effective labour endowments and the initial distribution of wealth are determined as in the basic model.

[40] The downward adjustment of r' by 0.02 is only to ensure that the simulations run smoothly and does not actually take place in the simulation results shown below. Similarly, the upper limit on A_t is not actually reached and new techniques in the simulation results fit the Marx-biased pattern described above.

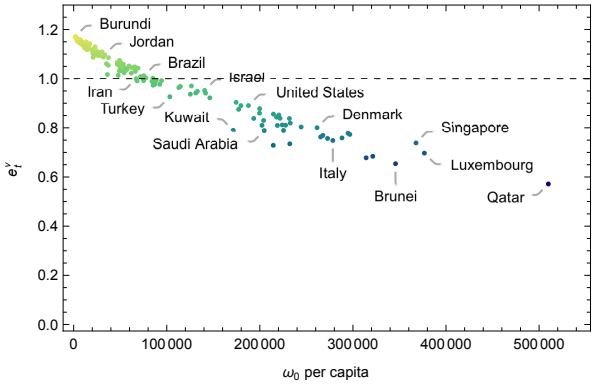
[41] In principle, the global economy could also be on the knife-edge, in which case we would need to specify a rule to determine the distributive variables. However, our simulations do not encounter this situation.

[42] Given the changes in consumption norms and technical changes that take place. Note that if prices are in a state of disequilibrium, the consumption norms determined by the equation (2) may violate feasibility, however, this does not occur in our simulations.

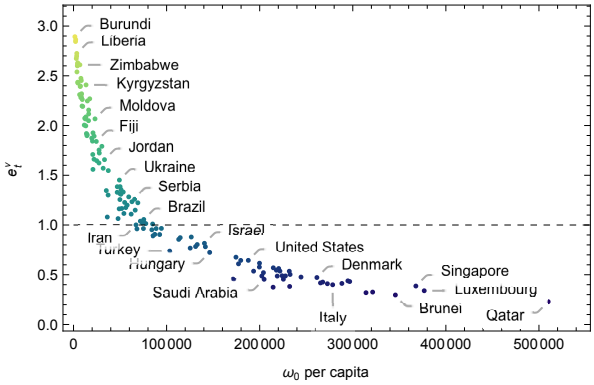
B Exploitation and class in the global economy with endogenous technical change

Figure 11: Worldwide Exploitation Intensity vs. Wealth per Capita - Economy with endogenous b_t and (A_t, L_t)

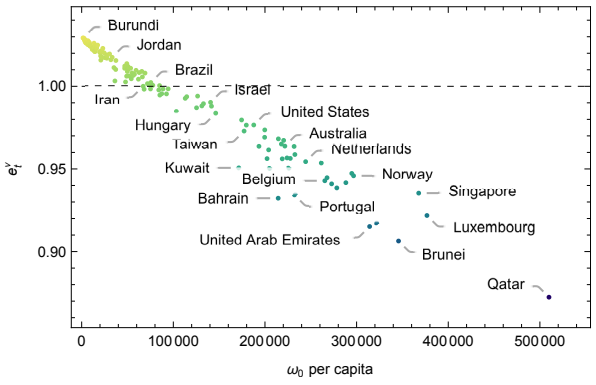
(a) $t = 10$



(b) $t = 25$



(c) $t = 40$



(d) $t = 50$

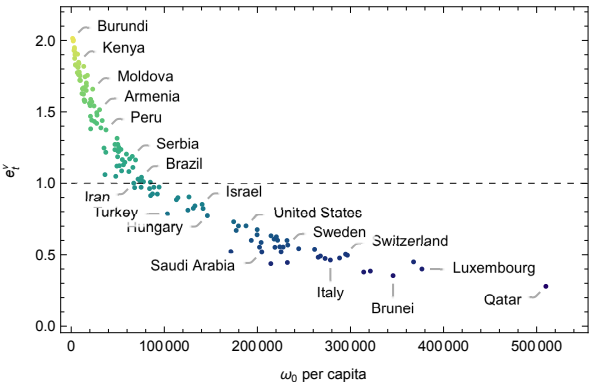
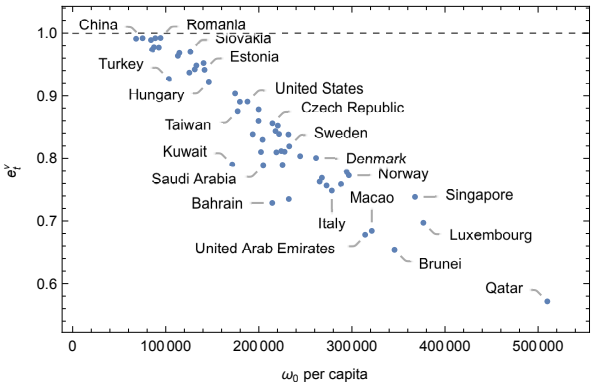
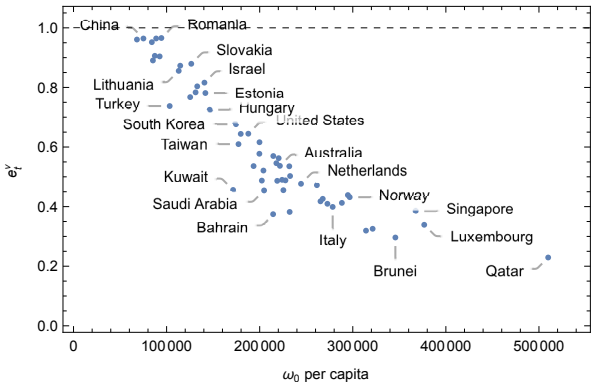


Figure 12: Exploiter Countries - Economy with endogenous b_t and (A_t, L_t)

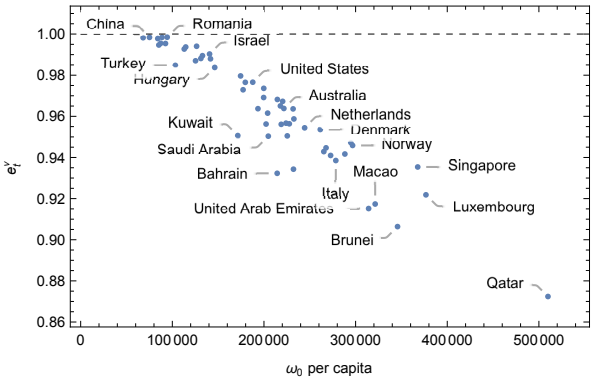
(a) $t = 10$



(b) $t = 25$



(c) $t = 40$



(d) $t = 50$

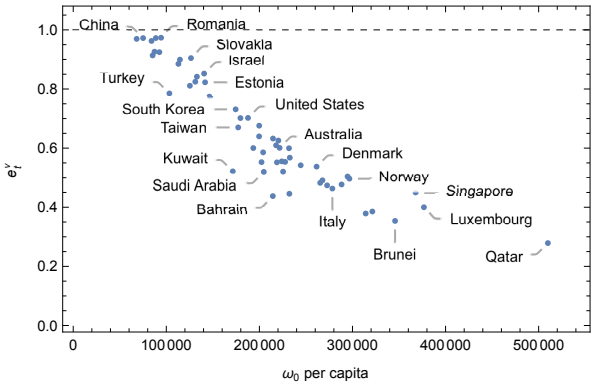
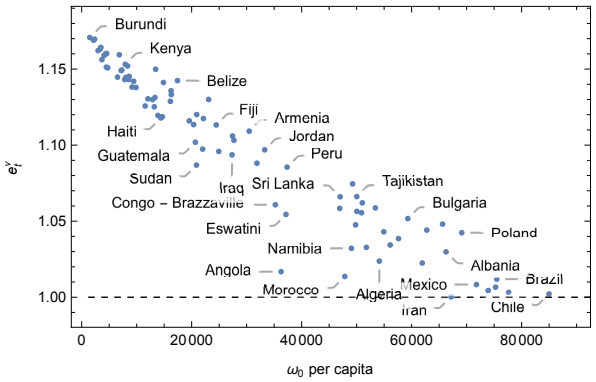
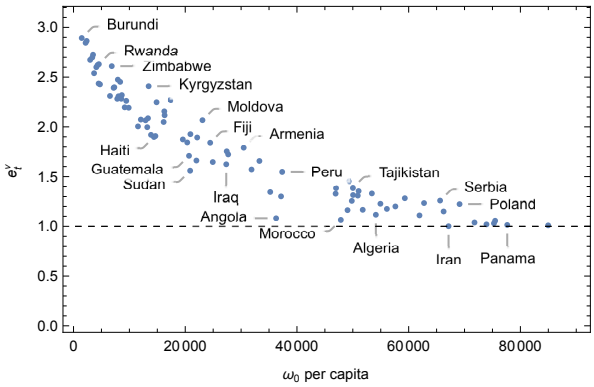


Figure 13: Exploited Countries - Economy with endogenous b_t and (A_t, L_t)

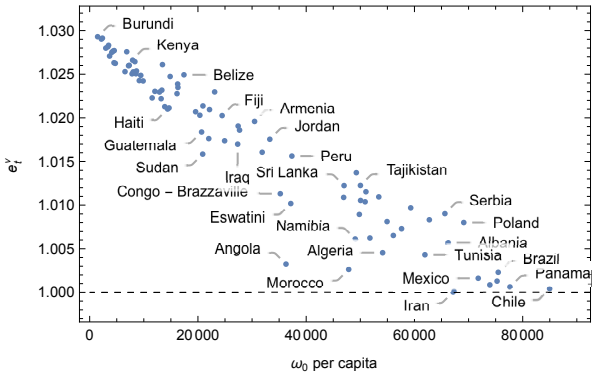
(a) $t = 10$



(b) $t = 25$



(c) $t = 40$



(d) $t = 50$

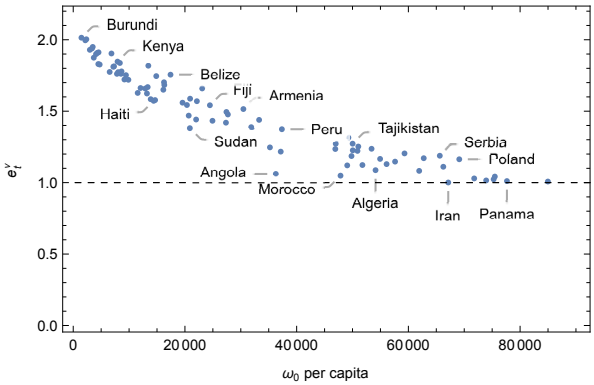


Table 3: Exploitation Intensity for Exploiter Countries at select t with countries sorted by initial per capita wealth - Economy with endogenous b_t and (A_t, L_t)

	e_1^ν	e_{10}^ν	e_{25}^ν	e_{40}^ν	e_{50}^ν
Indonesia	0.97654	0.99098	0.96075	0.99823	0.96952
China	0.97865	0.99180	0.96422	0.99839	0.97224
Venezuela	0.97116	0.98887	0.95192	0.99781	0.96259
Mauritius	0.93254	0.97331	0.89045	0.99468	0.91351
Uruguay	0.94257	0.97742	0.90610	0.99551	0.92614
Malaysia	0.97870	0.99182	0.96431	0.99839	0.97231
Botswana	0.94131	0.97691	0.90413	0.99541	0.92456
Romania	0.97962	0.99218	0.96583	0.99846	0.97350
Turkey	0.82697	0.92652	0.73754	0.98476	0.78503
Lithuania	0.90969	0.96373	0.85555	0.99271	0.88501
Russia	0.92117	0.96858	0.87295	0.99371	0.89928
Malta	0.84880	0.93675	0.76749	0.98699	0.81094
Slovakia	0.92534	0.97033	0.87934	0.99407	0.90449
New Zealand	0.86020	0.94197	0.78345	0.98812	0.82461
Croatia	0.87438	0.94836	0.80365	0.98948	0.84174
Israel	0.88300	0.95217	0.81609	0.99029	0.85221
Estonia	0.85859	0.94124	0.78118	0.98796	0.82266
Hungary	0.81771	0.92208	0.72510	0.98378	0.77414
Kuwait	0.58765	0.78990	0.45592	0.95065	0.52128
South Korea	0.78071	0.90377	0.67672	0.97964	0.73120
Taiwan	0.72654	0.87515	0.60972	0.97291	0.66998
Japan	0.75478	0.89035	0.64410	0.97653	0.70165
United States	0.75529	0.89062	0.64473	0.97659	0.70223
Trinidad and Tobago	0.66270	0.83828	0.53602	0.96372	0.60020
Finland	0.69912	0.85975	0.57740	0.96915	0.63970
United Kingdom	0.73185	0.87805	0.61609	0.97361	0.67589
Cyprus	0.61782	0.81006	0.48732	0.95624	0.55261
Latvia	0.64914	0.82996	0.52104	0.96155	0.58569
Saudi Arabia	0.58610	0.78884	0.45433	0.95035	0.51968
Bahrain	0.50463	0.72881	0.37460	0.93230	0.43769
Czech Republic	0.69253	0.85595	0.56978	0.96820	0.63248
Slovenia	0.67142	0.84352	0.54576	0.96506	0.60957
Greece	0.61708	0.80957	0.48653	0.95611	0.55183
Canada	0.68624	0.85229	0.56256	0.96728	0.62563
Australia	0.66340	0.83870	0.53679	0.96382	0.60094
France	0.62024	0.81163	0.48988	0.95667	0.55515
Spain	0.58686	0.78937	0.45512	0.95050	0.52047
Iceland	0.61854	0.81053	0.48808	0.95637	0.55336
Germany	0.66211	0.83791	0.53535	0.96362	0.59955
Portugal	0.51266	0.73512	0.38216	0.93430	0.44561
Sweden	0.63217	0.81930	0.50263	0.95873	0.56770
Netherlands	0.60760	0.80334	0.47656	0.95440	0.54194
Denmark	0.60321	0.80042	0.47198	0.95360	0.53737
Belgium	0.54963	0.76301	0.41779	0.94285	0.48253
Hong Kong	0.55816	0.76920	0.42621	0.94468	0.49116
Ireland	0.54117	0.75678	0.40951	0.94098	0.47401
Italy	0.53033	0.74867	0.39901	0.93851	0.46316
Austria	0.54431	0.75910	0.41257	0.94168	0.47717
Switzerland	0.57071	0.77814	0.43874	0.94729	0.50392
Norway	0.56370	0.77317	0.43172	0.94584	0.49678
United Arab Emirates	0.44385	0.67799	0.31939	0.91517	0.37881
Macao	0.45091	0.68419	0.32563	0.91736	0.38555
Brunei	0.41733	0.65392	0.29634	0.90638	0.35369
Singapore	0.51707	0.73854	0.38634	0.93537	0.44997
Luxembourg	0.46594	0.69712	0.33906	0.92184	0.39998
Qatar	0.33588	0.57160	0.22922	0.87240	0.27873

Table 4: Exploitation Intensity for Exploited Countries at select t with countries sorted by initial per capita wealth - Economy with endogenous b_t and (A_t, L_t)

	e^{ν}_{1}	e^{ν}_{10}	e^{ν}_{25}	e^{ν}_{40}	e^{ν}_{50}		e^{ν}_{1}	e^{ν}_{10}	e^{ν}_{25}	e^{ν}_{40}	e^{ν}_{50}
Burundi	1.6254	1.1707	2.8931	1.0293	2.0143	Laos	1.3056	1.0974	1.6613	1.0176	1.4416
Congo - Kinshasa	1.6163	1.1689	2.8446	1.0290	1.9961	Zambia	1.3838	1.1175	1.8929	1.0209	1.5699
Malawi	1.6199	1.1697	2.8638	1.0291	2.0033	Moldova	1.4359	1.1300	2.0672	1.0230	1.6591
Mali	1.5824	1.1621	2.6735	1.0280	1.9294	Fiji	1.3669	1.1133	1.8400	1.0203	1.5416
Sierra Leone	1.5874	1.1631	2.6975	1.0281	1.9390	India	1.3000	1.0959	1.6461	1.0174	1.4328
Liberia	1.5929	1.1643	2.7248	1.0283	1.9498	Iraq	1.2917	1.0936	1.6235	1.0170	1.4195
Mozambique	1.5538	1.1562	2.5392	1.0271	1.8744	Philippines	1.3384	1.1060	1.7544	1.0191	1.4946
Central African Republic	1.5670	1.1590	2.5999	1.0275	1.8995	Paraguay	1.3276	1.1032	1.7232	1.0186	1.4770
Madagascar	1.5714	1.1599	2.6206	1.0276	1.9080	Armenia	1.3508	1.1092	1.7911	1.0196	1.5149
Niger	1.5304	1.1512	2.4355	1.0263	1.8301	Ghana	1.2716	1.0881	1.5706	1.0161	1.3881
Rwanda	1.5734	1.1603	2.6302	1.0277	1.9119	Jordan	1.3040	1.0969	1.6569	1.0175	1.4390
Burkina Faso	1.5285	1.1508	2.4272	1.0262	1.8265	Congo - Brazzaville	1.1781	1.0608	1.3461	1.0113	1.2466
Ethiopia	1.5004	1.1447	2.3105	1.0253	1.7745	Angola	1.0457	1.0168	1.0802	1.0032	1.0606
Zimbabwe	1.5692	1.1594	2.6103	1.0276	1.9038	Eswatini	1.1577	1.0544	1.3014	1.0102	1.2169
Togo	1.5202	1.1490	2.3922	1.0260	1.8111	Peru	1.2624	1.0855	1.5469	1.0156	1.3737
Benin	1.5216	1.1493	2.3981	1.0260	1.8137	Costa Rica	1.1703	1.0584	1.3289	1.0109	1.2353
Gambia	1.4932	1.1431	2.2817	1.0250	1.7614	Sri Lanka	1.1954	1.0660	1.3850	1.0122	1.2721
Kenya	1.5394	1.1532	2.4746	1.0266	1.8470	Morocco	1.0369	1.0137	1.0644	1.0026	1.0488
Yemen	1.4996	1.1445	2.3074	1.0253	1.7732	Namibia	1.0896	1.0322	1.1625	1.0061	1.1205
Uganda	1.5342	1.1521	2.4522	1.0264	1.8373	Ukraine	1.2240	1.0745	1.4518	1.0137	1.3149
Nepal	1.4933	1.1431	2.2823	1.0251	1.7617	Colombia	1.1361	1.0476	1.2559	1.0089	1.1859
Cambodia	1.5026	1.1452	2.3193	1.0254	1.7786	Tajikistan	1.1957	1.0661	1.3857	1.0123	1.2726
Ivory Coast	1.4712	1.1382	2.1964	1.0243	1.7217	Gabon	1.1640	1.0564	1.3151	1.0105	1.2261
Cameroon	1.4881	1.1420	2.2615	1.0249	1.7521	South Africa	1.1612	1.0556	1.3092	1.0104	1.2221
Pakistan	1.4701	1.1379	2.1922	1.0242	1.7197	Mongolia	1.1822	1.0620	1.3552	1.0115	1.2526
Senegal	1.4178	1.1257	2.0046	1.0223	1.6277	Maldives	1.0914	1.0328	1.1660	1.0062	1.1231
Myanmar	1.4376	1.1304	2.0732	1.0230	1.6621	Argentina	1.1714	1.0587	1.3313	1.0109	1.2369
Nigeria	1.4355	1.1299	2.0660	1.0230	1.6585	Algeria	1.0652	1.0237	1.1161	1.0045	1.0870
Mauritania	1.4154	1.1252	1.9967	1.0222	1.6237	Dominican Republic	1.1221	1.0430	1.2270	1.0081	1.1660
Bangladesh	1.4413	1.1313	2.0866	1.0232	1.6687	Jamaica	1.0961	1.0344	1.1752	1.0065	1.1296
Kyrgyzstan	1.5241	1.1499	2.4086	1.0261	1.8183	Ecuador	1.1085	1.0385	1.1998	1.0073	1.1470
Tanzania	1.3921	1.1195	1.9196	1.0213	1.5839	Bulgaria	1.1490	1.0517	1.2829	1.0097	1.2044
Haiti	1.3854	1.1179	1.8978	1.0210	1.5725	Tunisia	1.0616	1.0225	1.1095	1.0043	1.0822
Lesotho	1.3885	1.1186	1.9079	1.0211	1.5778	Kazakhstan	1.1255	1.0441	1.2341	1.0083	1.1709
Bolivia	1.4844	1.1412	2.2472	1.0247	1.7455	Serbia	1.1377	1.0481	1.2591	1.0090	1.1882
Honduras	1.4306	1.1288	2.0488	1.0228	1.6500	Albania	1.0827	1.0298	1.1492	1.0057	1.1110
Vietnam	1.4604	1.1357	2.1559	1.0239	1.7024	Iran	1.0007	1.0003	1.0012	1.0001	1.0009
Egypt	1.4497	1.1333	2.1167	1.0235	1.6835	Poland	1.1202	1.0424	1.2233	1.0080	1.1634
Belize	1.4900	1.1424	2.2690	1.0249	1.7556	Mexico	1.0223	1.0083	1.0386	1.0016	1.0294
Nicaragua	1.3777	1.1160	1.8734	1.0207	1.5595	Thailand	1.0117	1.0044	1.0200	1.0009	1.0153
El Salvador	1.3679	1.1135	1.8430	1.0203	1.5432	Barbados	1.0177	1.0066	1.0305	1.0013	1.0233
Guatemala	1.3226	1.1019	1.7090	1.0184	1.4690	Brazil	1.0321	1.0119	1.0558	1.0023	1.0424
Sudan	1.2672	1.0869	1.5590	1.0158	1.3811	Panama	1.0083	1.0031	1.0142	1.0006	1.0109
Syria	1.3943	1.1201	1.9266	1.0214	1.5876	Chile	1.0059	1.0022	1.0101	1.0004	1.0077