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The technology Gradient in the Market Economy

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Abstract

Technological creation and mass production are usually associated with large-scale production, while technological absorption is found more often in small-scale competitive firms. Thus, the link between the innovative and absorptive sectors defines a technological and market power gradient that is a key endogeneous feature of the economy. We construct a stylized two sector *mass market economy* model, one with monopolistic and the other with perfect competition, that innovate and absorb technologies. Innovation profits are concentrated among a few owners of large-scale innovation, and economy-wide wage levels reflect the lagging average technological level. The model shows there are innovative-distributive policies that can increase efficiency in production, innovation and absorption, by increasing wages and reducing profits. Cointegration and weak-exogeneity results based on our study corroborate the assertion that the large-scale sector drives aggregate employment, wages and inequality.

Keywords: Innovation and absorption, large and small scale technological change, technological gradient, long term inequality, long term market inefficiency, innovative-distributive policies.

Resumen

La innovación tecnológica y la producción en masa se asocian usualmente con la producción a gran escala; mientras que la absorción tecnológica se encuentra con mayor frecuencia en firmas competitivas de pequeña escala. La relación entre innovación y absorción tecnológica define un gradiente tecnológico y de poder de mercado que es una característica endógena clave de la economía. Construimos un modelo estilizado de dos sectores en una *economía de mercado de masas*: un sector con competencia monopolística y el otro con competencia casi perfecta, que innovan y aboserben tecnologíaas. Las ganancias de la innovación se concentan dentro de pocos dueños de la innovación a gran escala, y los niveles salariales de toda la economía reflejan el rezago del nivel tecnológico promedio. El modelo muestra que existen políticas que aumentan la eficiencia en la producción, innovación y absorción, aumentando salarios y reduciendo las ganancias. Los resultados de cointegración y exogeneidad débil basados en nuestro estudio panel de Estados Unidos entre 1997 y 2011 corroboran la aserción de que los sectores de gran escala llevan a empleo, salario y desigualdad agregada.

Keywords: Innovación y absorción tecnológicas, cambio tecnológico a gran y pequeña escala, gradiente tecnológico, desigualdad de largo plazo, ineficiencia de mercado de largo plazo, políticas innovadoras-distributivas.

Introduction

Technological creation and mass production are usually associated with large-scale production, while technological absorption is found more often in small-scale, competitive firms, which absorb technologies from leading sectors. Thus, the link between the innovative and absorptive sectors defines a technological and market power gradient that is a key endogeneous feature of the economy. Technological difference have been found to be central to income differences between countries. We show that they also play a key role *within* countries. A competitive framework with properties expressed by the welfare theorems does not adequately describe economies with a significant innovating sector with market power, in addition creating a technological gradient that is a fundamental determinant of prices. The ongoing creation of the technological gradient defines a market structure that combines market power and competition and is essential to understanding industrial economies. The model shows that technology differences are not only important *between* countries but also *within* countries. The purpose of this paper is to construct a stylized synthesis of perfect and monopolistic competition that models this process and analyses the macroeconomic properties of what we define as the *mass market economy*. "Mass production" is often unrealistically linked with "perfect competition," even though perfect competition cannot model large-scale production, innovation or absorption.

As faster technological change and more flexible large scale production encompass broader sectors of the economy, the inefficiencies and inequities associated with their inherent market power become more prevalent. The economy transitions further away from a competitive framework with properties expressed by the welfare theorems, and towards a monopolistic setting with deeper inequalities and inefficiencies. We thus construct a synthesis of these two perspectives that can describe the macroeconomic properties of the resulting mass market economy to understand what policies are optimal for equality and efficiency.

Technological change and automation tend to be associated with large scale production. On the other hand competitive production mainly occurs in small scale firms, which tends to absorb[1] technologies from leading sectors. This implies that there are within-country productivity differences that are important in the determination of income distribution. The feasibility of technological change plays a role in determining these inter-sectoral differences. The dynamic features of this overall technological context shape income and its distribution.

To construct a stylized approach, we distinguish between large-scale innovative firms, operating under monopolistic competition, and small-scale firms, operating under approximately perfect competition, which absorb technologies instead of innovating. Market institutions allow for the coexistence large and small enterprises, and of competition with and without market power. By combining the process of innovation and market power in one sector with absorption and competition in the other, we obtain a new macroeconomic perspective on production, economic growth, income distribution, and optimal market policies, that takes the technology gradient into account. The technology gradient spans from innovation to absorption, and from market power to almost perfect competition. The stylized mass market economy presented here is the simplest model of an economy with a technology gradient and allows us to model the following endogenous features of the economy as well as policies to address them: i) *Inefficiency in production, innovation and absorption*. Technological change is well known to be inefficient (Aghion and Howitt, 1998, Chapter 2). We show

[1] We use technological absorption, diffusion, or adoption interchangeably.

how markups in the large-scale sectors lead to underproduction and how technology absorption and zero profits in the small-scale sector cause productivity lags. ii) *Income Inequality.* We show that wages lag the technological level of the large-scale sector because technology absorption by the small-scale sector, where much of the population works, does not result immediately in comparable productivity enhancements. Concentration of wealth is explained by the market power wielded by large-scale firms operating in a monopolistic competition environment, compared to the relative disadvantages faced by small-scale firms under (almost) perfect competition. iii) *Innovative-distributive policies*. The more prominent technological change is, the more necessary it is to introduce public policies that promote both innovation and income distribution. We show that free market policies are not optimal in the presence of mass production and introduce a *profit rate* tax that reduces the incentives to underproduce and restores income equality. We also conduct: iv) *Empirical Analysis*. A cointegration and weak exogeneity analysis of the impact of the large-scale sector in US states from 1997 to 2011 supports our view of the *mass market economy*. The analysis provides evidence corroborating that large-scale sector employment drives aggregate production, wages and inequality, and that a higher top 1% share results in a steeper technology gradient.

The stylized mass market economy model presented here addresses the following questions. How can wages remain low while technological levels rise? Wages are predicted to be proportional to the average technological level, both in general equilibrium models, and in models of endogenous technological change. Our model shows that wages lag behind the technological level of the large scale sector because the technological level of the small scale, competitive sector, which raises productivity by absorbing technologies, lags behind. Moreover, technological change in the small scale sector has public good properties that allow for improved performance through the application of policy.

How can income concentration reach such high levels in the context of market competition? The average income of the top 0.01% income share in the US was 531 times that of the bottom 90% in 2014.[2] The wealthiest 20 people in the US owned at the end of 2015 more wealth than half the American population (Collins & Hoxie, 2015). This concentration of wealth on a few individuals reflects on the dynamics of income concentration (how the game works out, the structure of the economy) rather than on specific persons.

In the model, innovation profits can be captured by a small number of owners. Its rate of return is higher than the interest rate. We discuss how the stock exchange can serve as a means to bring these innovation profits forward to the present.

The model helps to answer the question, what are good institutions for a market economy? A competitive market economy would approximate the welfare theorems simply on the basis of institutions guaranteeing the functioning of markets. Instead, a market economy with mass production requires institutions which support markets *and* allow for the implementation of innovative-distributive policies to approximate optimality.

1.1 Outline of the History of Industrial Revolutions and Economic Theory

This article argues that market power is an essential variable for understanding industrial economies. In this section we give a historical outline showing that some of the main ideas supporting perfect competition as a primary context for economic analysis evolved *before* some of the crucial contributions of the First and Second Industrial Revolutions to production. Combined with inherent difficulties in mathematical modelling, this has led to a delay in the inclusion of market power as an essential macroeconomic feature.[3]

When Adam Smith (1776) published *An Inquiry into the Nature and Causes of the Wealth of Nations*, explaining the benefits of competition in a free market, he addressed an economy made mostly of small producers using only labor-powered machines.[4]

[2] Data from the World Wealth and Income Database, http://www.wid.world/#Database, read 12/15/2015.

[3] Of course, there is also a logic in political economy. Free markets benefit those with market power.

[4] When he describes production, Smith (1776) mentions machines frequently, but refers neither to engines nor to the use of steam, water or wind power. The first steam locomotive railway was built in 1804 (Rattenbury and Lewis, 2004).

Britain's first true factory, a water-powered mill, was first built in 1771. Two important patents, 1769 and 1775, were involved in first achieving industrial-scale cotton production.[5] Thus Smith formulated his insights on free, competitive markets, cast as preferable to monopoly and other rent-seeking policies,[6] *before* the Industrial Revolution developed widespread, large scale production. The US Constitution, adopted in 1787, also laid the foundations for democracy and a market economy *before* large scale production was introduced in the US in 1790.[7] Perhaps additional checks and balances are necessary than were provided then.

The theory of general equilibrium was posed by Walras in his Elements of Pure Economics in 1874, almost a Century after Smith. Again, it was *after* this that the Second Industrial Revolution (1867-1914), based on scientific innovation, generated the basic manufacturing sectors including steel, oil, mining, telephone, and automobile (Smil, 2005). These manufacturing sectors, as well as the banking sector, consolidated into huge nation-wide enterprises in the late 19th and early 20th Centuries, in waves of mergers also featuring vertical integration (Lipton, 2006; Lamoreaux, 1991). The Sherman Antitrust Act of 1890 gives a flavor of this era that culminated in mass production with Henry Ford's 1913 assembly line producing a Model T every 93 minutes (Domm, 2009).

Nevertheless, the idea of "market economy" became too closely linked with the idea of "perfect competition," even though perfect competition does not model large scale production or innovation. Historically, developing the theory of competitive general equilibrium was already a significant mathematical challenge, without the additional challenge of modelling market power. The existence of general equilibrium was only rigorously established in 1954 by Nobel Prizes Arrow and Debreu, using complex techniques from differential geometry. To establish their intertemporal results they assumed that profits are always zero.

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[5] The mill was built by Richard Arkwright at Cromford, Derbishire, and eventually employed more than 800 workers (Fitton, 1989).

[6] "Monopoly of one kind or another, indeed, seems to be the sole engine of the mercantile system" (Smith, 1776).

[7] This occurred when Samuel Slater brought the secrets of British textile machinery to the US (Everett, 2006).

To this day, a Century after Ford, mass production remains the basis of modern productivity, and the force behind globalization. According to the U.S. Census Bureau, from 1935 to 1992, the average production of the four largest firms in 459 industries was 38.4% of all shipments. Similarly, from 1992 to 2002, the 200 largest manufacturing companies accounted for 40% of manufacturing value added.[8] The world's top 100 non-financial transnational corporations produced 14.1 percent of global output in 2008 (UNCTAD, 2008).

The theory of endogenous technological change, based on allocating resources to R&D, only appeared in 1989 (Romer, 1989; Grossman & Helpman, 1989; Aghion & Howitt, 1989), 76 years after Ford's Model T, and 47 years after Schumpeter (1942) wrote on the role of continuous innovation in capitalism and introduced the concept of creative destruction. In these models market power motivates innovation, and the innovation rate establishes an equilibrium level of profits.

While the assumption that competition reduces profits to zero makes the mathematics more tractable in any modelling context, static or dynamic, in fact profits exist. Corporate profits averaged 9.6% of US GDP between 1947 and 2015, never falling below 6.8%.[9] Similarly, domestic corporate profit as a proportion of domestic value added averaged 9.0% between 1948 and 2015, never falling below 5.2%.[10] Now, accounting profits, which discount investment costs through depreciation, and may be called operating profits, are not the same as the profits defined in Economics, which we may call theoretical profits. We show in the first section of Appendix A that the positive numbers shown here for operating profits imply that theoretical profits are also positive.

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[8] Data from U.S. Census Bureau – Economic Census. 1992. "Concentration Ratios for the U.S." http://www.census.gov/epcd/www/concentration92-47.xls., read 9/7/2010.

[9] Corporate Profits with Inventory Valuation Adjustment (IVA) and Capital Consumption Adjustment (CCAdj) from https://research.stlouisfed.org/fred2/series/CPROFIT and GDP from https://www.bea.gov/national/xls/gdplev.xls, both read 12/14/2015. The 275 observations have a standard deviation of 1.6%, minimum value 6.8%, maximum 13.1%.

[10] Corporate profits with inventory valuation and capital consumption adjustments, domestic industries: Profits after tax with inventory valuation and capital consumption adjustments/(Gross value added of nonfinancial corporate business+Gross value added of financial corporate business) https://research.stlouisfed.org/fred2/graph/?g=vdg,, read 3/12/2016. The 268 observations have a standard deviation of 1.99%, minimum value 5.2%, maximum 13.1%.

Summarizing, the foundations of the competitive theory of economics were laid in 1776, *before* the Industrial Revolution. The theory of general equilibrium was posed in 1874, although it was only rigorously established in 1954. Meanwhile, mass production was achieved by the Second Industrial Revolution in 1913. The study of continuous innovation was only introduced by Schumpeter in 1942, and then the theory of endogenous technological change only appeared in 1989. It is not so surprising that today the understanding derived from the competitive equilibrium paradigm remains the mainstream economic paradigm and mainstay of free market policies, even though this paradigm does not address the macroeconomics of mass production. By today's standards of rigor, a description of the market economy must account for a significant participation of profits. Correspondingly, basic economic policies must deal with the impact of profits on equity and efficiency.

1.2 Mass Production in a Competitive Environment

Mass production is clearly incongruous with perfect competition. The advent of mass production brought with it a qualitative change in the functioning of market economies. Understanding this qualitative change implies shifting from a general equilibrium, classical perspective, to a perspective integrating to this the insights of the theories of technological change and market power. Even today there are significant methodological difficulties associated with such a shift.

To study mass production in the context of competition we construct below a mass market economy model consisting of two sectors, one innovative, with monopolistic competition, and the other absorptive, with perfect competition. The coexistence of large and small enterprises is a feature of both developed and underdeveloped countries. In the US, in 2012 51.6% of the workforce was employed in the 0.3% of firms with 500 or more employees, where they earned 58% of the wage bill. Meanwhile 89.6% of the 5,726,160 firms had less than 20 employees, employed 17.6% of the workforce, and earned 14.2% of the wage bill. In Mexico, in 2008 out of a total of 3,626,954 firms, the 1000 largest firms (that is, 0.027% of firms) employed 19.5% of workers, paid 40.5% of the wage bill, and produced 65.3% of value added.

The mass market economy model applies to any market economy that has an innovating, large scale production sector with market power, and a technologically absorbing, small scale, competitive sector. Thus it applies to industrial market economies in general, both developed and underdeveloped.

While large scale production and innovation generate productivity and growth, through their market power they also generate income concentration and inefficiency. The detrimental impacts of market power on efficiency and distribution are clear at the static level. It is of course crucial to analyze the dynamic context as well. Market power presents detrimental impacts on innovation, for two reasons. First, the input mix of innovative and backward goods is already inefficient, being poor in overpriced innovative goods and too rich in backward goods. Second, market power, expressed as a mark up, implies that costs appear relatively lower and so there are lower incentives to innovate. Goñi and Maloney (2014) cite a series of articles arguing that the return to R&D for advanced countries is so high it would justify many times the investment actually found. Even so, it may be that some market power is optimal. Aghion et al (2001, 2005) investigate this question, asking how much market power is optimal for innovation, and argue that innovation is efficient at intermediate level of competition. We discuss how to implement a public policy for reducing market power to an optimal levels of competition (see the profit rate tax below).

By combining different kinds of competition in one model, we open a new pathway for thinking about and testing the efficiency and equity properties of specific market settings, for example trade. We also suggest public policies that can improve the performance of the mass market economy, in both economic growth and income distribution, complementing free market policies. This analysis is important not only for developed countries, but for the global economy, which approaches a purer form of market functioning than individual countries, since public policies are much weaker at this level. It is also important for underdeveloped countries, since these can also be characterized in terms of these two sectors (Mayer-Foulkes, 2015, 2016).

Schumpeterian theory explains how the innovating sector causes economic growth. It analyzes the role of competition and market structure in optimizing technological change; firm dynamics; development and appropriate growth institutions; and long-term technological waves (Aghion, Akcigitz and Howitt, 2013). However, a complete Schumpeterian analysis requires considering not only the innovating sector, but also the small scale, competitive sector, that does not innovate but instead absorbs technologies. As shown here, the interaction between the two sectors defines the growth rate, the wage level, the aggregate profit rate, and overall efficiency.

The interaction of technological change with labor earnings and their distribution has been extensively studied in the context of labor markets and their changing institutions (e.g. Katz and Autor, 1999; Gordon and Dew-Becker 2008). The determinants of labor earnings include human capital or skills, and the further impact on wages of evolving technologies, skill biased demand shifts and shifting trading opportunities (Acemoglu and Autor, 2011). The different evolution of wages at the top and bottom of the income distribution (Autor, Katz and Kearney, 2006) may be associated with a different evolution of the innovative and competitive sectors. Here we are concerned with the general level of labor earnings across the labor market, and how this is defined by the combination of economy-wide innovation and absorption.

Inequality is not a new phenomenon in the market economy. Piketty (2014) shows that the concentration of income and wealth has been a prominent economic feature since the early 19th Century. However, Piketty mainly presents data. His main analytic tool, the size of the gap between the rate of return on capital r and the economy's growth rate g, which focusses mainly on the financial system, has a limited scope (Piketty, 2015). The model presented here explains the concentration of income and wealth in real terms, not only through the financial system.

Another contribution of the article is to introduce technological change in the small scale sector, extending profit driven Schumpeterian models of technological change to small scale producers that absorb technologies to keep abreast of competition.

In addition, we define a new kind of myopic decision maker with perfect foresight as her time horizon Δt tends to zero. This is both more realistic, particularly for the long-term (there *is* no perfect foresight!), and simpler. It eliminates the need for a second set of variables for the shadow prices of all goods, and the need to predict all prices and levels forever.

Let us turn to the small scale sector. By now, in a country like the US, in general terms anything that can be mass-produced will be mass-produced. This implies that small firms are producing goods that for diverse reasons cannot be mass-produced. Examples are medical services, individual house construction, some forms of commercial distribution and services, arts and crafts, etc. So long as individuality is valued and people live in their own houses, have their own relationships, care for their own children, and perhaps pursue an extraeconomic meaning to their life, a fully mass-produced society can hardly be conceived. Nevertheless, the productivity of mass technologies clearly shapes society, for example our rural-urban social habitat, and deeply interacts with identity (e.g. Lunt and Livingstone, 1992, Akerlof and Kranton, 2000).

Thus we characterize the small scale sector as including goods for which innovation cannot be financed by obtaining sufficient profit margins over a significant proportion of their market. This could be either for technological reasons, for example the absence of economies of scale, or because improvements cannot be appropriated. This setting of technological change in the small scale sector implies several sources of inefficiency. First, the technological absorption that is conducted is repeated by all producers, and restricted to a small scale effort. Second, these efforts are not pooled to produce better results. Third, unexcludable innovation is not pursued, including the use of mass production techniques when feasible. We refer to these sources of inefficiency as the *public good nature of technological absorption*. They imply that public policies can be applied to raise the productivity of technological absorption in the small scale sector.

Summarizing, the aggregate product of the mass market economy is a function of the technological levels of both its sectors. While the innovative sector leads economic growth, it generates inequality and inefficiency in both production and innovation. At the same time, the small scale sector absorbs technologies inefficiently. These inefficiencies in production, innovation and absorption explain why wages can lag behind their potential level, since the overall level of wages is a positive function of the technological levels of both sectors and a negative function of market power.[11] The dynamic properties of innovation and absorption thus determine some of the static properties of the economy, relatively low wages in particular. Finally, income concentration is explained by the concentration of mass production and innovation profits in very few hands.

Two public economic policies can improve on free market policies for the mass market economy, simultaneously promoting both equity and productivity. The first promotes both industrial and small scale technologies by supporting innovation using taxes on profits, and absorption using these or other taxes. In the US, the high taxes on profits and the support for science and human capital formation applied during the Great Prosperity, which served to promote both innovation and absorption, corresponds to this combination. These policies are of course independent of Keynesian macroeconomic policies.

The second addresses the essential source of inefficiency and inequity in the mass market economy: the incentives that producers have to underproduce so as to make higher profits. It is customary for a model proving inefficiencies to propose a tax than can restore efficiency. We define such a *profit rate tax*. By taxing profit *rates* above some determined level, this tax provides incentives for producers not to underproduce too much. The profit rate tax generates incentives that reward *production* rather than profit rates. Moreover, its equilibrium taxation revenue is zero. The result is higher efficiency in production and innovation, and higher equity. The profit rate tax also makes it possible to reduce market power to some positive level if this is optimal, as mentioned above.

Neither a general competitive equilibrium model nor a standard model of endogenous technological change include the full set of features we have mentioned. Yet these features are necessary ingredients for understanding the macroeconomic functioning of the industrial, or mass production, market economy, allowing the

[11] For the purposes of this paper, we assume that there is a single, perfect labor market including skilled and unskilled labor. This means that there is a single expected wage level that takes human capital investment costs into account. We abstract from adjustments to the demand and supply of specific skills. These can generate both wage differentials and the creative destruction of employment across skills.

formulation of new policies to attend a series of urgent issues such as pro-poor growth, global income concentration, the increased political influence of large corporations under deregulation, sustainability in the face of both poverty and corporate power, the global economic business cycle, and so on.

The article is organized as follows. Describing the mass market economy in two steps, we present first a two-sector model in section 2 and analyze the impact of a profit rate tax on increasing production efficiency and restoring income equality in section 3. We introduce second technological change in section 4 and obtain the steady state, discussing the inefficiency of innovation and absorption. Empirical section 5 presents a panel cointegration analysis of US states over the period 1997-2011, including a discussion of nonstationary panels and cointegration, a description of the data, and an analysis of tests and estimation results. Section 6 concludes.

2 THE MASS MARKET ECONOMY MODEL

We define the *mass market economy* model, describing a simple, stylized economy with a technology gradient. This must span from innovation to absorption, and from market power to almost perfect competition. The mass market economy model consists of two sectors. It's core is an industrial, technological, large scale production sector characterized by ongoing innovation; innovation is motivated by the acquisition of market power and the generation of market share leading to income concentration.[12] However, not every innovation can be financed for every type of good by obtaining sufficient profit margins over a significant proportion of its market. An important proportion of the working population is employed in the small scale sector, consisting of many small firms that do not innovate significantly and operate competitively. These small, non-innovating firms (including self-employment and informal economic activity), improve their productivity by expending effort on absorbing technologies developed by the industrial sector, which functions as the technological leader.

Relative to each other, the large and small scale sectors display opposite characteristics. While the first is innovative and displays market power, the second

[12] We consider even small, specialized, innovating firms part of the innovation, mass production sector if they produce for an important portion of their market.

absorbs technologies and is competitive. As we shall see, the innovative sector is at the same time physically more productive, employing higher technologies, and economically less efficient, diverting resources from the production of innovative goods through high prices. In turn, the small scale sector is physically less productive, employing lower technologies, and economically more efficient, since it is more competitive.

For simplicity, we keep the boundary distinguishing small scale and large scale sectors exogenous.[13] While it could be modeled according to wage and employment levels, we assume that the distinction depends manly on exogenous, technological determinants which is standard in models of technological change.[14]

Consider an economy with two sectors L and S that produce a continuum of tradeable goods indexed by $\eta \in [0,1]$, where each η refers to a good. Large scale sector goods $\eta \in \Theta_L = [0,\xi)$ use a mass production technology and are therefore modelled with all production concentrated on a single large producer that is able to make a profit, while small scale sector goods $\eta \in \Theta_S = [\xi,1]$ are produced on the small scale, with constant returns to scale, therefore modelled with infinitely many small, identical, competitive producers. We assume $\xi > 0$ for some sectors to innovate, and $\xi < 1$ since not all sectors are amenable to mass production.[15] In each sector technological change is endogenous, with differences due to the different competition structures. For simplicity we abstract from innovation uncertainty and assume that innovation is symmetric within each sector L and S. Thus we are assuming goods $\eta \in \Theta_j$ in each sector $j \in \{L,S\}$ have the same technological level A_{jt}.

[13] Similarly we abstract from horizontal innovation including the appearance of new small or large scale sectors, or of sectors that have their origins in small enterprises that become large.

[14] We abstract from the process of industrial organization leading to any particular equilibrium or determining its parameters, such as the mark-up. Instead we follow assumptions that are standard in models of technological change to examine the efficiency and distribution properties of these types of equilibria.

[15] Thus the mass market model is in the interior of the continuum lying between competitive general equilibrium and endogenous technological growth.

Innovation occurs as follows. In the large scale sector L there is for each good $\eta \in \Theta_L$ a single, infinitely lived innovator who invests in innovation and becomes a monopolist. This innovator is the owner of the firm and its profit. She produces in the presence of a competitive fringe that we assume consists of large scale producers. That is, the large scale sector's technology has left the small scale sector's technology sufficiently far behind. For simplicity we assume that innovation is cheaper for the producing incumbent than for any other innovator, and she therefore has an innovation advantage. Her monopoly therefore persists indefinitely. By contrast, in the small sector S anybody can innovate, so as to reap the productive benefits of new technologies, namely the availability of returns to production factors, in this model labor. We assume that small producers can produce any good, while large producers can only produce goods in sector Θ_L for which mass production technologies are available that are more productive than small scale technologies. Keeping to a simple stylized model with a technology gradient, we also omit any further industrial organization considerations on entry and exit, or transitions between the small and large-scale sectors. Note that all of the variables are real rather than nominal unless otherwise indicated.

2.1 PRODUCTION AND CONSUMPTION

2.1.1 Two kinds of producers

The simplest technology gradient has just two technology levels. A high technology associated to innovation and market power and a low technology associated with absorption and (almost) perfect competition. For simplicity we exclude capital from the production function and limit ourselves to innovation as the only source of market power.[16] Thus we only distinguish the two sectors by their competitive context.

[16] In constructing the model we attempted to use fixed costs and/or increasing returns to scale in addition to innovation, but both gave rise to mathematics that were too complex for the present purpose. It is worth noting that in the case of fixed costs two equilibria arise for the two sector economy developed here, as in Murphy, Shleifer, and Vishny (1989). In this model returns to scale weaken the large scale sector's demand for labor, raising small scale sector employment and therefore reducing wages.

Definition 1. *The production function for goods* $\eta \in \Theta_j$ *in sector* $j \in \{L,S\}$ *is:*

$$y_{jt}(\eta) = A_{jt} l_{jt}(\eta), \quad j \in \{L,S\}. \blacksquare \tag{2.1}$$

Here $y_{jt}(\eta)$ represents the quantity produced of good $\eta \in \Theta_j$. A_{jt} is the technological level in each sector. $l_{jt}(\eta)$ is the quantity of labor input. We assume that the small scale sector can produce any kind of good. The large scale sector is, and must always be, ahead in productivity,

$$A_{Lt} > A_{St}. \tag{2.2}$$

When we include technological change in section 4, this will justify the existence of high and low technology levels A_{Lt} and A_{St} in the steady state. Innovation and absorption are the only investments in this model.

2.1.2 Preferences

Let the instantaneous consumer utility $U = U(C_t)$ depend on a subutility function C_t for an agent consuming $c_t(\eta)$ units of goods $\eta \in [0,1]$, according to the Cobb-Douglass function

$$\ln(C_t) = \int_0^1 \ln(c_t(\eta)) d\eta. \tag{2.3}$$

Suppose a consumer has a nominal budget z_t (which will be her wages) for purchasing quantities c_t^L, c_t^S of goods produced in the large and small scale sectors. We assume large and small scale sector goods $\eta \in \Theta_L$, Θ_S are symmetric so have common prices p_{Lt}, p_{St}. Since the composite good kernel (2.3) is Cobb Douglass, consumers dedicate the same budget to each good $\eta \in [0,1]$. This budget is z_t, so the quantity bought of each type of good is

$$c_t^L = \frac{z_t}{p_{Lt}}, c_t^S = \frac{z_t}{p_{St}}. \tag{2.4}$$

Hence the quantity of composite good produced is given by $\ln C_t = \xi \ln \frac{z_t}{p_{Lt}} + (1-\xi)\ln \frac{z_t}{p_{St}}$, that is, $C_t = \frac{z_t}{p_{Lt}^{\xi} p_{St}^{1-\xi}}$. Given a budget $p_{Lt}^{\xi} p_{St}^{1-\xi}$, the amount of composite good produced is $C_t = 1$. Letting the composite good be the numeraire, this costs 1, so

$$p_{Lt}^{\xi} p_{St}^{1-\xi} = 1. \quad (2.5)$$

2.1.3 Choice of production quantities

Let w_t be the (real) domestic wage level, and suppose now that z_t is the constant (nominal) expenditure level across goods. Note that therefore aggregate net income is $Z_t = \int_0^1 z_t d\eta = z_t$.

In the case of small producers one unit of good $\eta \in \Theta_S$ is produced competitively by infinitely many firms. Wages equal the income from selling the product of one unit of labor, so the price can be written

$$p_{St} = \frac{w_t}{A_{St}}. \quad (2.6)$$

In each sector $\eta \in \Theta_S$ let $l_{St}(\eta)$ be the aggregate employment of all of the firms producing this good. Since the number of units produced is $c_{jt}^S = \frac{z_t}{p_{St}} = A_{St} l_{St}(\eta)$, the labor quantity is constant in η, so we drop η from the notation, and

$$l_{St} = \frac{z_t}{p_{St} A_{St}}. \quad (2.7)$$

In the case of the large scale sector, each producer has two types of potential competitors. The first type of competitors are small-scale producers, who can produce good η using a technological level A_{St}. Hence we will keep to a standard case when $p_{Lt} \le p_{St}$, mass production just being feasible at equality. The second type of competitor, in the competitive fringe, has a lower technological level $\chi^{-1}A_{Lt}$, where $\chi > 1$ represents the competitive edge. This competitor produces on a large scale in a different sector η and could conceivably produce in other large scale sectors as well. However, the markup is low enough for her to be just unwilling to enter. The incumbent will keep to a maximum price level just at the feasibility level for her competitor.

The level of production considered by both the incumbent and her competitor are given by the aggregate expenditure level on this good, $z_t = p_{Lt}(\eta)y_{Lt}(\eta)$. The maximum markup that the incumbent can use will be χ. Unless we are considering a transition for which mass-production comes into existence with low levels of technological advantage, the usual case will be when under the full markup χ nevertheless $p_{Lt} \le p_{St}$. The incumbent will drive her industrial competitor to the zero profit limit, and therefore act as if her productivity were A_{Lt}/χ. Hence instead of (2.6) we have

$$p_{Lt} = \frac{\chi w_t}{A_{Lt}}. \tag{2.8}$$

The incumbent produces the same quantity but employing less labor,

$$l_{Lt} = \frac{z_t}{p_{Lt}A_{Lt}} = \frac{\chi^{-1}z_t}{w_t} \tag{2.9}$$

therefore at a cost $\chi^{-1}z_t$, hence making a profit (nominal, but the numeraire will be 1)

$$\pi_{Lt} = (1-\chi^{-1})z_t. \tag{2.10}$$

2.1.4 Wages and prices

The wage level can now be obtained by substituting (2.8), (2.6) in (2.5), so that $1 = p_{Lt}^{\xi}p_{St}^{1-\xi} = \left[\frac{\chi w_t}{A_{Lt}}\right]^{\xi}\left[\frac{w_t}{A_{St}}\right]^{1-\xi}$. Hence

$$w_t = \chi^{-\xi}A_{Lt}^{\xi}A_{St}^{1-\xi}. \tag{2.11}$$

Substituting back in (2.6), (2.8) and simplifying, we can solve for the prices, in terms of the current technological levels:

$$p_{St} = \left[\frac{\chi^{-1}A_{Lt}}{A_{St}}\right]^{\xi}, \quad p_{Lt} = \left[\frac{A_{St}}{\chi^{-1}A_{Lt}}\right]^{1-\xi}. \tag{2.12}$$

Hence for large-scale production to outcompete small-scale production at a mark up level χ, the technological levels must satisfy:

$$\frac{p_{St}}{p_{Lt}} = \frac{\chi^{-1}A_{Lt}}{A_{St}} > 1. \tag{2.13}$$

We will keep to the case where (2.13) holds, not just (2.2).

2.2 Labor and Income

Let the working population of the economy be P. Let P_L and P_S be the aggregate employment levels in sectors L and S, with $P_L + P_S = P$. Recall that each large-scale sector firm is owned by an infinitely lived innovator. So as to measure income inequality, we assign a population weight θ to the innovators, distributed equally across sectors. For simplicity innovators earn both wages and the firm's profit. We assume θ is small enough that the innovators are only a proportion of their firm's workforce, with $\theta P < P_L$.

Let employment levels for each good be l_{Lt}, l_{St}. When the labor market clears,

$$\xi l_{Lt} = P_L, \quad (1-\xi)l_{St} = P_S, \quad \xi l_{Lt} + (1-\xi)l_{St} = P. \tag{2.14}$$

Now $w_t l_{St} = z_t$, since the participation of labor equals income in sector S, while $w_t l_{Lt} = \chi^{-1} z_t$ in sector L. It follows that higher pricing in the large scale sector shifts employment towards the small scale sector:

$$\frac{l_{St}}{l_{Lt}} = \chi, \tag{2.15}$$

as also follows from (2.7) and (2.9). This is also apparent in the solutions

$$l_{St} = \frac{P}{\chi^{-1}\xi + (1-\xi)}, \quad l_{Lt} = \frac{\chi^{-1}P}{\chi^{-1}\xi + (1-\xi)}. \tag{2.16}$$

From wages and employment income now follows. Using equation (2.11) and (2.16),

$$z_t = w_t l_{St} = \frac{\chi^{-\xi} A_{Lt}^{\xi} A_{St}^{1-\xi} P}{\chi^{-1}\xi + (1-\xi)}. \tag{2.17}$$

The average wage participation is

$$\frac{w_t P}{z_t} = \chi^{-1}\xi + (1-\xi). \tag{2.18}$$

Wage participation in the large scale sector is lower than in the small scale sector, so as ξ rises, wage participation drops.

2.3 Efficiency and Equity Under Market Power

While in some situations there may be a trade-off between efficiency and equity, market power simultaneously results in less efficiency and less equity. This holds at the macroeconomic level in a mass market economy. The static distortions due to the presence of market power are the following.

Theorem 1. *Market power distorts the static mass market economy as follows:*

1) Aggregate income is decreasing in market power.

2) The profit to income ratio is increasing in market power.

3) Wages and aggregate wage participation are decreasing in market power.

4) Employment intensity l_{Lt} *in the large scale sector is decreasing in market power, while employment intensity* l_{St} *in the small scale sector is increasing in market power.*

5) The Gini coefficient is $(1-\theta)\frac{\xi\pi_{Lt}}{\xi\pi_{Lt} + w_t P} = (1-\theta)\xi(1-\chi^{-1})$. ■

All proofs are in the second section of Appendix A.

Recall that innovators have a population weight □. The smaller this weight is, the higher the Gini coefficient, which is increasing in the ratio of aggregate profits to aggregate wages $\xi\pi_{Lt}/(w_t P)$, in market power χ, and in the measure of innovation sectors ξ.

When the proportion ξ of mass producing sectors increases, the presence of market power implies that wages do not rise in proportion to the increased productivity. Let us examine how the relative size of the large scale sector ξ affect wages in the presence of market power χ.

Theorem 2. *The static response of wages to an increase in the size of the large scale sector is:*

$$\frac{\partial \ln w_t}{\partial \xi} = \frac{\partial}{\partial \xi}\left(-\xi \ln \chi + \xi \ln A_{Lt} + (1-\xi)A_{St}\right) = \ln \frac{A_{Lt}}{\chi A_{St}} < \ln \frac{A_{Lt}}{A_{St}}. \blacksquare \qquad (2.19)$$

Note that the impact of mass production on wages can be low if market power is near its maximum feasible level $\chi = \frac{A_{Lt}}{A_{St}}$, when the large scale sector faces low large scale competition. Furthermore, if new large scale sectors do not face competition from small scale sectors, so that χ can be larger than $\frac{A_{Lt}}{A_{St}}$, the impact on wages could be negative.

2.4 Market Power and Efficiency in the Presence of Capital

The stylized model for a mass market economy does not require the inclusion of capital. However, if we include capital we are able to show that the economy wide capital to labor ratio and the wage level are distorted by market power. Let us suppose that we replace Definition 1 with:

Definition 2. *In the presence of capital the production function for goods* $\eta \in \Theta_j$ *in sector* $j \in \{L, S\}$ *is:*

$$y_{jt}(\eta) = \frac{1}{\varepsilon}\left[k_{jt}(\eta)\right]^{\alpha}\left[A_{jt} l_{jt}(\eta)\right]^{\beta}, \quad j \in \{L, S\}, \tag{2.20}$$

where $\alpha + \beta = 1$, $\varepsilon = \alpha^{\alpha}\beta^{\beta}$. ■

Here $k_{jt}(\eta)$ represents units of composite good (2.3) defined for consumption, also used now for capital investment. I assume capital markets are perfect so that the interest rate equals the marginal return of capital. Writing K_t for aggregate capital, it can be shown that the interest rate and wages are given by:

$$r_t = \left(\chi^{-\xi} A_{Lt}^{\xi} A_{St}^{1-\xi} \frac{\alpha P}{\beta K_t}\right)^{\beta}, \quad w_t = \left(\frac{\beta K_t}{\alpha P}\right)^{\alpha} \left(\chi^{-\xi} A_{Lt}^{\xi} A_{St}^{1-\xi}\right)^{\beta}. \tag{2.21}$$

These can be verified simply by observing that the large scale sector acts as if its technological level were A_{Lt}/χ, so that the effective average technological level across goods is $\chi^{-\xi} A_{Lt}^{\xi} A_{St}^{1-\xi}$.

Suppose for this discussion that the equilibrium interest rate r^* is determined by intertemporal preferences setting $r^* = \rho$. Then the optimal capital to labor ratio is given by:

$$\frac{K^*}{P} = \frac{\alpha \chi^{-\xi} A_{Lt}^{\xi} A_{St}^{1-\xi}}{\beta \rho^{1/\beta}}. \tag{2.22}$$

At this level of capital per worker the corresponding wage level is:

$$w^* = \chi^{-\xi} A_{Lt}^{\xi} A_{St}^{1-\xi} \rho^{-\alpha/\beta}. \tag{2.23}$$

Hence we have shown:

Theorem 3. *A market power level* χ *reduces both* $\frac{K^*}{P}$ *and* w^* *by a factor* $\chi^{-\xi}$. ■

Note that the profit rate exists above and beyond the interest rate. At the two extremes, if interest income were equally distributed across the population, the Gini coefficient would be $\frac{(1-\theta)\xi\pi_{Lt}}{\xi\pi_{Lt}+r_t K_t + w_t P}$, while if all capital were owned by the innovators, the Gini coefficient would be $\frac{(1-\theta)(\xi\pi_{Lt}+r_t K_t)}{\xi\pi_{Lt}+r_t K_t + w_t P}$, both analogously to Theorem 1.

The interaction of innovation profits in the large scale sector with the interest rate on capital in the small scale, competitive sector, provides a context for understanding the role of the stock market in bringing forward innovation profits, capitalizing innovation income streams according to the prevailing interest rate, and concentrating them on innovators. In the presence of capital, innovation investment yields a profit rate π_{Lt} that is higher than the interest r_t. A capital market provides innovators with an instrument to bring their profit flow to the present. They can sell through the stock market a project producing an income flow through their innovation. Small investors will purchase this income flow capitalized at a value determined (net of risk) by the interest rate. This brings the innovator's profit flows to the present, included in the project's value. The price of the innovative goods will still reflect the original markup. However, the project's book values will not register innovation profits, only a cost for the purchase of technology that already includes the profit accrued to the innovator. Examples when profits are brought forward are: when a company goes public, when a start up is sold, or when mergers or other reorganizations occur. Hence the study of operating profits through accounting books does not address the full impact of innovation profits. This also means the aggregate average corporate profit rate mentioned in the introduction is an understatement, since it does not include innovation profits accrued when issuing new stock in Initial Public Offerings, if these are assessed as capital gains.[17]

[17] For a back of the envelope calculation of the domestic aggregate efficiency measure $\chi^{-\xi}$ of Theorem 3, suppose the aggregate average profit rate is $\xi\pi_{Lt} = \xi(1-\chi^{-1}) = 0.09$ (as documented above for the period 1947 to 2015, which as we just noted is an understatement). Then $\chi = 1/(1-\frac{0.09}{\xi})$ so

There is a considerable, controversial, literature on the efficiency costs of monopoly power. In a well known article, Harberger (1954) concentrates on the misallocation costs of monopoly, and arrives at a very low estimate of $\frac{1}{10}\%$ of GDP. The data is obtained from accounting books for seventy three manufacturing industries for the period 1924-1928. In that article a benchmark operating profit rate of 10% is considered normal and its efficiency costs are not estimated. The article concentrates on the allocation impact of adjusting higher or lower profit rates to the 10% level. Because it concentrates on a section of the innovating sector, only estimates the impact of these allocation adjustments, and takes its information from accounting books, this article does not address the issues we raise here. Cowling and Mueller (1978) weaken Harberger's (1954) assumptions and arrive at social cost estimates of 7 to 13%.[18]

Our model explains some of the inequality pointed out by Piketty (2014) for mass market economies. The reasons are the following. First, in our model Piketty's interest rate r in fact refers to the profit rate, which is even more easily greater than the growth rate g. Second, the concentration process we describe works in terms of the returns to real investments; it does not depend on large financial accounts obtaining a preferential rate of return. Instead, large real investments access the profit rate through innovation rather than just the competitive interest rate through capital investment. However, the preferential rate of return emphasized by Piketty's (2014) is linked with the market power features of the financial system. One tool to diminish this effect is the profit rate tax described below, which can be applied to financial corporations to reduce extraordinary profit margins and income concentration. While discussing the historical aspects of Piketty's (2014) work is beyond the scope of this article, we would hypothesize that convergence to equilibrium inequality levels or

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$\chi^{-\xi} = (1-\frac{0.09}{\xi})^{\xi}$. For $\xi \in [0.3,1]$ this lies on the interval $[0.89852, 0.91]$. If also the aggregate average profit ranges over $\pi_{Lt} \in [0.052, 0.131]$ (the minimum and maximum between 1947 and 2015) then $\chi^{-\xi} \in [0.842, 0.948]$, with higher efficiency for lower profits. The corresponding inefficiency rates lie on the interval $[0.052, 0.158]$.

18 These inefficiency estimates are similar to those in the previous footnote.

capital to income ratios is faster than posited by Piketty, and responds significantly in a couple rather than in quite a few decades to substantial changes in profit level determinants. Thus, while the two World Wars may have had the most salient (negative) impacts on capital accumulation, other changes such as the rise and fall of the economic framework of the Great Prosperity (including taxes on profits, human capital investment, financial regulation and welfare), or epochal changes in globalization, have also had highly significant impacts.

3 A PROFIT RATE TAX

As shown, the presence of market power in our model implies inefficiencies in both production and income. levels and wages. If incentives can be found for producers not to diminish their production so as to raise prices and profits, aggregate economic efficiency will rise. We define a profit rate tax whose incentives are to decrease market power up to the socially designated profit rate. While no taxes are levied at equilibrium, the inclusion of a profit rate tax increases production and improves both production efficiency and income equality.

Suppose some markup χ is prevalent for large scale producers. For any feasible markup $\theta \in [1, \chi]$ profits will be $\pi_{Lt} = (1-\theta^{-1})z_t$. Note the profit to input rate is $\frac{1-\theta^{-1}}{\theta^{-1}} = \theta - 1$. Let $\tau(\theta)$ be the tax schedule

$$\tau(\theta) = \begin{cases} \tau_0(\theta-\theta_0)+\phi_L^\pi & \theta \geq \theta_0, \\ \phi_L^\pi & \theta < \theta_0. \end{cases} \tag{3.1}$$

Besides the constant profit tax rate ϕ_L^π,[19] above the profit rate $\theta_0 - 1$, where $\theta_0 \in (1, \chi)$, taxes rise with the profit rate. For this reason this tax is refered to as a profit rate tax. The result is that from this point on producers receive higher after tax profits for higher production levels rather than for higher gross profits.

[19] This constant rate may respond to other reasons for taxation, including all types of public and social goods and equity, which may raise the preference for taxes (Forslid, 2005). However, a more efficient and equitable society has less unsatisfied needs and may therefore need less taxes.

Theorem 4.

1) Under a profit rate tax schedule $\tau(\theta)$*, if* $\tau_0 > \frac{1}{\theta_0(\theta_0 - 1)}$*, the economy behaves as if market power has lowered to* $\chi_0 = \theta_0$*. In this example the marginal tax on profits as the profit rate increases at* θ_0 *is less than 1 so long as the profit rate is less than* 61.8%*.*

2) The economy can approximate the first best for which $\chi = 1$*. Define instead tax schedule (3.1) using* $\theta_0 = 1$*. To avoid the tax, large scale production adjusts to a markup* $\theta^*(\tau_0) = \sqrt{1 + \frac{1}{\tau_0}}$*, which also tends to* 1 *as* $\tau_0 \to \infty$*.*■

4 TECHNOLOGICAL CHANGE

4.1 Innovation in the Large Scale Sector

We define the process of endogenous change for the technological levels A_{Lt}, A_{St} in this two sector economy, in the process explaining how this leads to a steady state technological gradient. As mentioned above, there is in each mass production sector a single, infinitely lived innovator who can produce an innovation for the next period. We consider an innovator with perfect myopic foresight. This means she maximizes profits in the short term Δt by choosing an innovation input flow, and then lets $\Delta t \to 0$. Mayer-Foulkes (2015) shows that this is equivalent to defining perfect myopic foresight as having perfect knowledge of the current economic variables' time derivatives.[20] The

[20] We use myopic innovation because by eliminating the multipliers involved in an infinite horizon problem, our dynamic model is reduced from a four to a two dimensional problem. Even the two dimensional dynamics are non-trivial because the technological level of the lagging, small-scale sector determines the size of the economy and therefore the decisions of the large-scale innovator, so that there is a two-way feedback between the technological levels of the two sectors. Moreover, we assume that innovation are funded by retained profits (i.e. there in demand for credits) and that works do not save (i.e. and thus have an instantaneous utility function).

myopic agent thus maximizes the current time derivative of her profits (2.10), using her knowledge of the near future.

The effectiveness of innovation investment of the product η entrepreneur has two components. The first is derived from knowledge and is proportional to the skill level $S_{Lt} = A_{Lt}$ that she has been able to accumulate in production, which we assume is the technological level of her firm. The second component is a material input flow v. Innovation occurs with certainty combining these components to obtain a technological level rate of change at time t given by:

$$\tfrac{\partial}{\partial \Delta t} \tilde{A}_L(t+\Delta t, v)\Big|_{\Delta t=0} = \mu_L S_{Lt}^{\upsilon} v^{1-\upsilon}, \qquad (4.1)$$

where $\mu_L > 0$, $0 < \upsilon < 1$. Here $\tilde{A}_L(t+\Delta t, v)$, where $\Delta t > 0$, is a technology trajectory envisaged by the incumbent over a small time interval into the future, given an expenditure level v on innovation. Note that at $\Delta t = 0$, $\tilde{A}_L(t, v) = A_{Lt}$. The parameter μ_L represents the innovation productivity of the combined inputs.

Let $\phi_L^{\pi}, \phi_L^{\iota} \in (0,1)$ represent a profit tax and an innovation subsidy, positive or negative proxies for all distortions and policies affecting profits and the incentives to innovate, and writing $\varsigma = (1-\upsilon)/\upsilon$, define the effective innovativity:

$$\tilde{\mu}_L = \left(\tfrac{(1-\upsilon)\left(1-\phi_L^{\pi}\right)}{1-\phi_L^{\iota}} \right)^{\varsigma} \mu_L^{1+\varsigma}. \qquad (4.2)$$

Proposition 1. *Under perfect myopic foresight, the incumbent sets the rate of change of her technological level* A_{Lt} *at:*

$$\frac{d}{dt} \ln A_{Lt} = \tilde{\mu}_L \left(\frac{z_t}{\chi A_{Lt}} \right)^{\varsigma}. \ \blacksquare \qquad (4.3)$$

Since z_t depends on both A_{Lt} and A_{St} a relative scale effects is introduced that complicates the dynamics under perfect foresight once technological change in both variables is considered. This aspect is simplified by using continuous myopic foresight, which precludes the need to predict both variables.

Note that innovation is *decreasing* in market power χ, because, as can be seen by following the proof, the higher the market power, the relatively lower costs are compared to profits and therefore the lower the impact of the cost of technological improvement on profits. In other words, the easier it is to make profits, the relatively less worthwhile to spend on cost-saving innovation.

4.2 Innovation in the Small Scale Sector

We introduce technological change in the small scale sector. We thus extend Schumpeterian models of technological change, usually driven by profits, to small scale producers that absorb technologies just to keep abreast of competition. However, these small firms with limited resources can only apply a limited set of techniques to produce their technological change. The entrepreneur might for example dedicate some of her time to search for new techniques and solutions to adapt to his productive context. Although we exclude human capital from our model, it would be possible to think of an entrepreneur who has or could hire human capital for this purpose. Recall that each small scale sector is characterized by the property that innovation cannot be financed by obtaining sufficient profit margins over a significant proportion of its market. Thus the nature of this sector makes it inviable to establish large research crews using more sophisticated techniques, and excludes from consideration the techniques of large scale or mass production.[21] Productivity therefore lags behind in the small scale sector in the steady state.

Assume that the entrepreneurs running small scale firms can invest a flow of v units of material input to obtain a technological level $\tilde{A}_S(t+\Delta t, v)$ similar to the one we just saw for the large scale sector, given by an innovation function analogous to (4.1),

$$\tfrac{\partial}{\partial \Delta t} \tilde{A}_S(t+\Delta t, v)\Big|_{\Delta t=0} = \mu_S \left(\frac{A_{Lt} - A_{St}}{A_{Lt}} S_{St} \right)^{\upsilon} v^{1-\upsilon}. \tag{4.4}$$

[21] Franchises may be contexts in which an innovator has devised a way to transform a small scale sector into a large scale sector.

Here μ_S is analogous to μ_L, except that it reflects a limited kind of innovation, the kind of innovation that can be carried out on a small rather than large scale $\mu_S < \mu_L$. This is analogous to the distinction between implementation and R&D in Howitt and Mayer-Foulkes (2005), in that in the small scale innovation is unlikely to use an R&D lab, employ scientists, and so on, and is more likely simply to implement technologies created in the large scale sector.[22] S_{St} is the skill level of the firm (entrepreneur, workers and installed productivity), which we consider equal to A_{St}. Here, however, the small scale sector, which in this setting always lag behind the large scale sector, experiences a technological spillover from the large scale technology A_{Lt}, represented by the factor $\frac{A_{Lt} - A_{St}}{A_{Lt}}$.

Recall that the defining characteristic of the small scale sector is that firms cannot obtain sufficient profit margins over a significant proportion of their market. Thus a significant level of market power cannot be achieved, and we assume producers are price takers. However, they cannot be infinitesimally small and still invest in technological absorption. Thus we assume there is some large number of firms N, which represents an approximation to perfect competition. For simplicity all small scale firms are the same size. Therefore their sales are $z_t = \frac{Z_t}{N}$. Let

$$\tilde{\mu}_S = \frac{1}{N}\left(\frac{1-\upsilon}{1-\phi_S^{\iota}}\right)^{\varsigma} \mu_S^{1+\varsigma}. \tag{4.5}$$

Note that the effective technological absorptivity $\tilde{\mu}_S$ is decreasing in N.

Proposition 2. *Under perfect myopic foresight, small scale producers set their rate of technological absorption at:*

[22] These new technologies may often already be embodied in capital or inputs, although we abstract from these in this simplified model.

$$\frac{d}{dt}\ln A_{St} = \tilde{\mu}_S \frac{A_{Lt}-A_{St}}{A_{Lt}}\left(\frac{A_{Lt}}{A_{St}}\frac{z_t}{A_{Lt}}\right)^{\varsigma}. \blacksquare \tag{4.6}$$

4.3 The Steady State

We now find the steady state growth rate and the steady state relative lag of the small scale sector.

Definition 3. *Define the relative state variable* $a_t = \frac{A_{St}}{A_{Lt}}$. ■

Writing income (2.17) in the form

$$\frac{z_t}{A_{Lt}} = \frac{\chi^{-\xi} a_t^{1-\xi} P}{\xi\chi^{-1} + (1-\xi)}, \tag{4.7}$$

substitute in (4.3), (4.6) to express the rates of technological change in terms of the relative technological level a_t,

$$\frac{d}{dt}\ln A_{Lt} = \tilde{\mu}_L\left(\frac{\chi^{-1-\xi} a_t^{1-\xi} P}{\xi\chi^{-1}+(1-\xi)}\right)^{\varsigma}, \quad \frac{d}{dt}\ln A_{St} = \tilde{\mu}_S \frac{A_{Lt}-A_{St}}{A_{Lt}}\left(\frac{\chi^{-\xi} a_t^{-\xi} P}{\xi\chi^{-1}+(1-\xi)}\right)^{\varsigma}.$$

The dynamics of the relative technological level a_t between small and large scale production can now be written,

$$\frac{d}{dt}\ln a_t = H(a_t) \equiv \left(\frac{\chi^{-\xi} P}{\xi\chi^{-1}+(1-\xi)}\right)^{\varsigma}\left(\tilde{\mu}_S(1-a_t)a_t^{-\varsigma\xi} - \tilde{\mu}_L \chi^{-\varsigma} a_t^{\varsigma(1-\xi)}\right). \tag{4.8}$$

For simplicity we now assume that the small scale sector cannot overtake the large scale competitive fringe, that is, $\tilde{\mu}_S\left(1-\chi^{-1}\right) < \tilde{\mu}_L \chi^{-\varsigma}$, so $H(a_t) < 0$ for $a_t > \chi$. This also implies that condition (2.13) is maintained, so that the large scale sector maintains the market power implied by its markup χ.

Theorem 5. *Suppose that the small scale sector cannot overtake the large scale competitive fringe. The relative technological level* a_t *of the small to the large scale sector* *has a unique positive steady state* $a^* < \chi^{-1}$*, therefore defining a steady state technological gradient, with growth rate growth rate* $\gamma^* = \frac{d}{dt} \ln A_{Lt} \Big|_{a_t = a^*}$ *given by*

$$\frac{\tilde{\mu}_L^{1/\varsigma} a^*}{\tilde{\mu}_S^{1/\varsigma} \left(1 - a^*\right)^{1/\varsigma}} = \chi, \tag{4.9}$$

$$\gamma^* = \left(\frac{\chi^{-\xi} P}{\xi \chi^{-1} + (1-\xi)} \right)^{\varsigma} \tilde{\mu}_S \left(1 - a^*\right) a^{*(-\varsigma\xi)}. \tag{4.10}$$

The steady state a^* *and growth rate* γ^* *satisfy:*

$$\begin{array}{llll} \frac{\partial a^*}{\partial \chi} > 0, & \frac{\partial a^*}{\partial \xi} = 0, & \frac{\partial a^*}{\partial \tilde{\mu}_S} > 0, & \frac{\partial a^*}{\partial \tilde{\mu}_L} < 0, \\ \frac{\partial \gamma^*}{\partial \chi} < 0, & \frac{d\gamma^*}{d\xi} > 0, & \frac{\partial \gamma^*}{\partial \tilde{\mu}_S} > 0, & \frac{\partial \gamma^*}{\partial \tilde{\mu}_L} > 0. \end{array} \tag{4.11}$$

Increases in $\tilde{\mu}_S = \frac{1}{N} \left(\frac{1-\upsilon}{1-\phi_S^l} \right) \mu_S^{1+\varsigma}$ *can be obtained by addressing the public good nature of small scale innovation, mentioned above.* ■

4.4 Inefficiency of Innovation

Is the private assignment of innovation resources optimal in the mass market economy? We answer this question by examine the innovation incentives for a benevolent government. We show that it is possible to improve income growth by subsidizing innovation, and explain under what conditions this subsidy can be paid for by taxing profits.

In accordance with perfect myopic foresight, let the government maximize $Z_{t+\Delta t}$, deducting expenses in innovation incurred for raising $Z_{t+\Delta t}$. Note that this optimization assumes market exchange takes place in the presence of market power, so the question posed is only seeking a second best. More precisely, at any time t the government maximizes

$$\max_{v_{Lt},v_{St}} \tfrac{\partial}{\partial \Delta t}\tilde{Z}(t+\Delta t, v_{Lt}, v_{St})\big|_{\Delta t=0} - [\xi v_{Lt} + (1-\xi) N v_{St}] \tag{4.12}$$

Here $\tilde{Z}(t+\Delta t, v_{Lt}, v_{St})$, where $\Delta t > 0$, is an income trajectory envisaged by the government over a small time interval into the future, given an expenditure levels v_L in innovation investment in each large scale sector, and v_S in innovation investment by each of the N firms in each small scale sector. The maximization is subject to the physical equations for technological change (4.1) and (4.4). Note that the N small firms still repeat innovation in this government maximization.

Now, using expression (2.17), $\frac{d \ln Z_t}{dt} = \xi \frac{d}{dt} \ln A_{Lt} + (1-\xi)\frac{d}{dt}\ln A_{St}$. Hence the government maximization takes the form

$$\max_{v_{Lt},v_{St}} \{\xi\left[\mu_L\left(\frac{v_{Lt}}{A_{Lt}}\right)^{1-\upsilon} - \frac{v_{Lt}}{Z_t}\right] + (1-\xi)\left[\mu_S\left(\frac{A_{Lt}-A_{St}}{A_{Lt}}\right)^{\upsilon}\left(\frac{v_{St}}{A_{St}}\right)^{1-\upsilon} - \frac{N v_{St}}{Z_t}\right]\}. \tag{4.13}$$

The first order conditions for (4.13) are:

$$\frac{(1-\upsilon)\mu_L}{A_{Lt}}\left(\frac{v_{Lt}}{A_{Lt}}\right)^{-\upsilon} = \frac{1}{Z_t}, \quad \frac{(1-\upsilon)\mu_S}{A_{St}}\left(\frac{A_{Lt}-A_{St}}{A_{Lt}}\right)^{\upsilon}\left(\frac{v_{St}}{A_{St}}\right)^{-\upsilon} = \frac{N}{Z_t}. \tag{4.14}$$

Hence the government would assign innovation expenditures as follows:

$$\tfrac{v_{Lt}}{A_{Lt}} = \left(\mu_L(1-\upsilon)\tfrac{Z_t}{A_{Lt}}\right)^{\frac{1}{\upsilon}}, \tag{4.15}$$

$$\tfrac{v_{St}}{A_{St}} = \left(\mu_S \tfrac{(1-\upsilon)Z_t}{NA_{St}}\right)^{\frac{1}{\upsilon}} \tfrac{A_{Lt}-A_{St}}{A_{Lt}}. \tag{4.16}$$

When these are compared to (8.16) and (8.18), the conditions for obtaining the same resource assignment for innovation are:

$$\tfrac{1-\phi_L^{\pi}}{\left(1-\phi_L^{\iota}\right)\chi} = 1, \quad \tfrac{1}{1-\phi_S^{\iota}} = 1. \tag{4.17}$$

These equalities are satisfied if $\phi_S^{\iota} = 0$ and $\frac{1-\phi_L^{\pi}}{1-\phi_L^{\iota}} = \chi$. The latter implies $\phi_L^{\iota} > \phi_L^{\pi}$.

Thus, except for the N -fold repetition of absorption that occurred in the small scale sector, the fact that these efforts were not pooled, and that non excludable innovation was not pursued, absorption is efficient in the small scale sector. However, large scale innovation is not efficient. The reason was stated above. The easier it is to make profits, the relatively less it is worth spending on innovation.

The following efficiency results for appropriate government incentives for innovation in the large and small scale sectors can now be stated.

Theorem 6.

1) As market power tends to zero, when $\chi \to 1$, privately assigned innovation tends to efficiency.

2) When the profit rate tax is applied, as $\theta_0 \to 1$, case 1) is approached in the limit.

3) Suppose that in the large scale sector profits are quantitatively higher than optimal innovation investment. Then taxes and subsidies ϕ_L^{π}, $\phi_L^{i} \in (0,1)$ exist for which the government's budget is balanced and innovation is optimal. If profits are not that high, a lump sum tax on wages is needed to obtain optimal innovation with a balanced budget.

4) The steady state trajectories of both A_{Lt} and A_{St} lag behind what is economically feasible.

5 A Cointegration Analysis of the Model

The main implications of the *mass market economy* model are that innovation in the large-scale sector drives aggregate productivity growth and therefore aggregated employment and wages, and that market power, expressed in profits, diminishes this impact. We conduct a cointegration analysis and obtain evidence of a positive correlation between the relative size of the large-scale sector and aggregate economy indicators, and their impact on income inequality across US states over the period 1997-2011. Macroeconomic indicators over time typically show a clear trend. Unit root tests usually confirm the nonstationarity of such data, whereas the error term of the pooled regression equation may or may not be stationary. If the error term is stationary, variables are cointegrated and weak exogeneity tests validate the inference of the cointegration vector, which yields evidence of (weak) causality. When dealing with nonstationary panels, Stock and Watson (1993) propose using the dynamic OLS estimator to estimate long-run relationships.

5.1 Nonstationary Panels and Cointegration

5.1.1 Data

Macroeconomic data on production by firm size is available for the 50 US states plus Washington DC over the period 1997 to 2011. These data are provided by the Census Bureau under *Statistics of US Business* (2014). While this data includes employment and payrolls, it does not include information on production, capital, human capital or profits. Thus there is no information at the state level (i.e. production, capital, labor, and human capital) to estimate technological knowledge or changes in it. The closest proxy we have is the ratio of employment in the large-scale sector to aggregate employment, where changes reflect the implementation of new technologies. Throughout business cycles, for example, increased employment in upswings tends to coincide with the implementation of new technologies in large-scale sectors. To test the impact on income inequality, we use the top ten percent income shares on a state level as presented in Frank (2009).

For each state, the aggregate variables used are log average wage rate (w), log employment over population ($l-p$), and log payroll over population ($w+l-p$). While there are several size categories available for firms, we select firms with 500 or more employees to represent the large-scale sector. To represent the proportion of the large-scale sector in the economy, we use the following ratio variables: log employment in the large-scale sector over aggregate employment ($l_L - l$), log payroll in the large-scale sector over aggregate payroll ($w_L + l_L - (w+l)$), and log average wage rate in the large-scale sector over average wage rate in the aggregate economy ($w_L - w$), referred to below as "large-to-aggregate" employment, payroll and wage ratios respectively.[23] We use the top 1 percent income shares (*top1*) as an indicator of income inequality because it is closely linked to profits and their concentration.

In the following, we conduct a pairwise cointegration analysis of the interaction of the large-to-aggregate ratios and aggregate economy indicators and their relationship with income inequality. We also test for weak exogeneity between these pairs of variables, in order to obtain evidence of the direction of causality.

5.1.2 Testing Procedures and Estimations Techniques

We keep the nonstationary panel issues to a minimum and only briefly discuss the nonstationary testing procedures and estimation techniques used in this article. For a more detailed discussion, see Baltagi (2008). In testing for unit roots one usually comes across with the "first generation tests" such as those conducted by Levin, Lin and Chu (2002) (LLC) and Im, Pesaran and Shin (2003) (IPS) among others, along with cross-sectional de-meaning or averages to deal with the problem of dependencies across units introduced by "second generation tests" such as Pesaran (2007) (PES). If the pooled data is shown to be nonstationary, one can collect the residuals from pooled regressions to test for stationarity of the error term ("residual-based tests") or use the corresponding error correction (EC) terms in EC models to test whether the EC term is significant ("error-correction based tests"). Westerlund (2007), for example, tests whether the EC term in EC models (ECMs) is significant for individual group or full panel models by the using four different cointegration tests and accounting for cross-sectional dependence. The validity of the inference of the cointegration vector obtained from conditional ECMs in a panel context depends, as in time series analysis, on the assumption of weak exogeneity. According to Moral-Benito and Servin (2014), there

[23] Table B.2 in Appendix B gives descriptive statistics on the variables for all states and large-scale firms and their number of firms and establishments. The means of all variables used for the empirical analysis are not close to either their minimum or maximum value, which indicates that there is no disproportion. The standard deviations of the variables are relatively large and the values are widely dispersed around the mean. Note that the District of Columbia was not an outlier in any evident way.

are different testing procedures in a panel context, ranging from testing weak exogeneity on average across all cross-sectional units to joining individual tests into a panel-wide test. In principle, the conditional ECM is valid and correctly specified if one of the long-run adjustment coefficients is negative and significant, while the other(s) are zero. An initial equilibrium error is balanced by adjustment of the dependent variable, whereas the development of all other variables are independent of the error term (i.e. weakly exogenous).

As the presence of cointegration and unit roots considerably affects the asymptotic distributions in both time series and panel analysis, we follow Kao and Chiang (2000) and use the dynamic OLS estimator from Stock and Watson (1993). This technique uses leads and lags of first differences to account for serial correlation in the error term and for endogeneity:

$$y_{i,t} = \delta_t' d_t + x_{i,t}' b + \sum_{j=-q_1}^{q_2} c_{ij} \Delta x_{i,t+j} + e_{i,t}, \quad i = 1,..., N \text{ and } t = 1,..., T, \qquad (5.1)$$

where d_t represents the deterministic components (i.e. constant, trend), $x_{i,t}$ is a K-dimensional vector (K being the number of explanatory variables), and $e_{i,t}$ is a stationary error term with zero mean. In the case of $d_t = 0$ there is no deterministic term, whereas in the case of $d_t = 1$ or $d_t = (1,t)'$ there is a constant, or a constant and a trend, respectively.

5.2 Empirical Analysis

We first test whether the pooled data has unit roots, and second whether serial correlation and cross-sectional dependencies exist. We than use Westerlund's (2007) four different panel cointegration tests to test whether the panel is cointegrated, using conditional ECMs in the bivariate case and conduct weak exogeneity tests, the latter gives evidence of (weak) causality. Finally, we estimate the long-run bivariate relationships using Stock and Watson's (1993) dynamic OLS estimator. Specifically, we are interested in the cointegrated long-run (cointegrated) relationships (i) between large-to-aggregate ratios and aggregate economy indicators, and (ii) within large-to-aggregate ratios and aggregate economy indicators. We postpone the detailed empirical discussion of the testing and estimations to the appendix B and provide their test statistics and estimation results in Tables B.3-B.7 respectively.

For each pair between and within large-to-aggregate ratios and aggregate economy indicators, we report the test results of cointegration and weak exogeneity and the estimation results of dynamic OLS in Table 1 if at least one out of four cointegration tests is significant. We first report the number of significant cointegration results without using asterisks. Second, we report the sign and significance level of two dynamic OLS estimations (one contemporaneous and one with one lag) if both coefficients have the same sign. The significance is the lower of the two significance levels. We have written $-(w_L - w)$ instead of $w_L - w$ because this simplifies the signs in Table 1, rendering them all positive except for one non-trivial case. Third, we highlight in bold those entries for which the weak exogeneity criterion is met (i.e., an (in)significant negative coefficient of the endogeneous (exogenous) variable indicating that an initial equilibrium error is balanced by adjustments of the dependent variable). Note that the variables listed on the left in Table 1 are tested for cointegration or exogeneity with respect to the variables listed on the top (or to put it differently, the variables on the top (=*y*) are a function of the variables on the left (=*x*)). Figure 1 presents the same results as Table 1, in graphical form.

Table 1: Pairwise cointegration and weak exogeneity (see Tables B.4-B.6 in the Appendix B) Annual data for 50 states plus Washington DC from 1997-2011.

	$l_L - l$	$(w_L+l_L) - (w+l)$	$-(w_L-w)$	*top1*	$w+l-p$	$l-p$	w
$l_L - l$		<u>4 (+)***</u>	<u>1 (+)***</u>	1 (+)			4 (+)***
$(w_L+l_L) - (w+l)$	3 (+)***		1 (+)***	2 (+)			1 (+)***
$-(w_L - w)$				<u>1 (+)</u>	2 (+)***	<u>1 (+)***</u>	3 (+)
top1			<u>1 (–)***</u>		1 (+)***		<u>2 (+)***</u>
$w+l-p$				<u>3 (+)***</u>			
$l-p$				3 (+)***			<u>2 (+)***</u>
W							

Notes: The number represents the number of significant cointegration test results (i.e. from a row variable (x) to a column variable (y)). The absence of an entry means that the null hypothesis of "cointegration" in cointegrated panel EC was rejected. Significant "weak exogeneity" is indicated in bold and underlined. The sign and significance level of the long-run relationships are estimated by two dynamic OLS estimations – one contemporaneous and one with one lag. A sign and its significance level are assigned if both coefficients have the same sign, the significance level being the lower of the two. The variables l_L, w_L are log employment and wages in firms with 500 or more workers. l and w are log aggregate employment and average wages and p is log population. $w_L + l_L$ and $w + l$ represent log payrolls respectively. *top1* is the log of the top ten percent income share.

All the signs in Table 1 are positive except for the impact of *top1* on $-(w_L - w)$. If we place the large-to-aggregate ratios and aggregate economy indicators in the order:

$$l_L - l,\ (w_L + l_L) - (w + l),\ -(w_L - w),\ w + l - p,\ l - p,\ w, \qquad (5.2)$$

then for every pair with a cointegration relationship, the variable to the right is a closer function of the variable to the left than the other way around.[24] This includes the statement that $(w_L + l_L) - (w + l)$ is a closer function of $l_L - l$ than the other way around because it has four significant cointegration results as compared to three in the opposite direction (and $l_L - l$ is proven to be weakly exogeneous, which is discussed below). In particular, each step of the sequence:

[24] Note that cointegration by definition is a symmetrical relationship, so that if variable y is cointegrated with variable x, then variable x is cointegrated with variable y. In fact when cointegration is tested empirically, test results can be different as shown by the off-diagonals in Table 1. Suppose that test statistics confirm that that variable x is cointegrated with variable y, but reject cointegration the other way round. Hence, the error term is considered stationary only if y is expressed as a linear function of x (and therefore y is more closely related to x than the other way around).

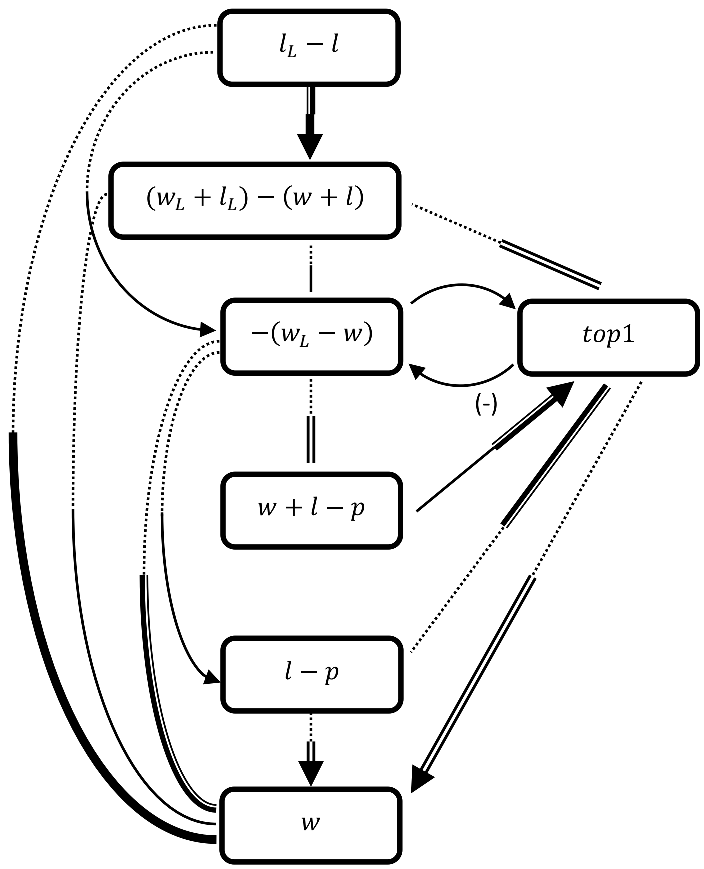
$$l_L - l,\ -(w_L - w),\ l - p, w, \tag{5.3}$$

consists of a pair of variables with a weakly exogenous, cointegrated, and significantly positive relationship. This means that when the relative employment level in the large scale sector increases, its wage level relative to the full economy decreases (this may be because it is pulling in a wider range of workers with a lower average wage), aggregate employment rises, and the overall wage level in the economy rises. These links reflect economic transmission through the labor market. Thus, employent in the large scale sector, which is ahead in the technology gradient, drives overall employment and wage levels, as the model predicts. The opposite links from aggregate employment and wages to large scale sector employment and wages are absent. While we do not have data for technological change, this is consistent with innovation shocks in the large scale sector driving aggregate employment and wages.

Turning to inequality, there is a weakly exogenous, cointegrated, and significantly negative impact of *top1* on $-(w_L - w)$ and – with a positive coefficient – of top1 on $w + l - p$. Finally, $w + l - p$ itself is the sum of $l - p$ and w, which are downstream from $-(w_L - w)$. This loop clearly reduces the impact from increases in large scale sector employment on aggregate employment and wages. Since employment represents the process of technology transfer, the empirical result means that profit concentration steepens the technology gradient. In so far as *top1* represents the profit share, this is consistent with Theorem 1. We do not obtain evidence for Theorem 6, that states that innovative efficiency increases with the mix of innovative versus other goods and therefore with decreases in market power. What is obtained, however, is that employment in the large-scale sector is indifferent to *top1*, suggesting *top1* can be reduced without adversely affecting the leading sector.

Figure 1: Pairwise cointegration and weak exogeneity (see Tables B.4-B.6 in the Appendix B)

Annual data for 50 states plus Washington DC from 1997-2011.



Notes. For each pair of variables x, y, each segment (straight or curved) is divided in two halves representing the results of cointegration tests of x on y (half segment near y) and of y on x (half segment near x). The type of segment represents the number of significant entries for each cointegration test: 1 —; 2 ═; 3 ≡; or 4 ▬. A dotted line is used when there is no significant cointegration result: the corresponding entry in Table 1 is empty. The relationships are positive unless indicated with a negative sign. The sign is assigned using DOLS estimates as described in the text and in Table 1. An arrow at the end of a half segment indicates the direction of contemporaneous causality implied by weak exogeneity. The variables l_L, w_L are log employment and wages in firms with 500 or more workers. l and w are log aggregate employment and average wages, and p is log population. $w_L + l_L$ and $w + l$ represent log payrolls respectively.

The dotted line in Table 1 shows the block upper triangular structure of the weakly exogenous, cointegrated relationships, that run from 1) the large-to-aggregate ratios to

2) the aggregate economy indicators excluding wages together with inequality, and finally to 3) economy wide wages.

Conclusions

The *mass market economy* model applies to any economy that has an innovating, large-scale production sector with market power, and a technology-absorbing, small-scale, competitive sector – in short, it applies to any industrial economy. Such an economy has a technology gradient between these two sectors which is associated with market structure and different kinds of inefficiencies. The existence and use of market power in the large-scale sector generate inefficiencies in production and innovation, as well as income inequality through concentrated profits. The small scale sector also generates inefficiencies, because technological absorption has public good features that slow it down. Its efforts in technological absorption are restricted to small scale endeavors that are not pooled to produce better results. In addition, unexcludable innovation is not conducted. Thus the model shows that technology differences are important not only *between* countries but also *within* countries.

Market power reduces steady state capital accumulation and wage levels, first, with respect to achieved technological levels, and second, with respect to their potential, first best levels.

Innovation and market power imply that a causal structure runs from the large-scale sector to aggregate economic variables such as overall employment, wages and income inequality, with higher inequality slowing the process and therefore steepening the technology gradient. This is corroborated by cointegration and weak exogeneity results from a panel of US states from 1997 to 2011.

Large scale production has been a feature of the market economy since the Industrial Revolution, and developed into mass production with the Second Industrial Revolution, when innovation became a systematic endeavor based on science. The modern large scale sector engages in mass production and innovation and wields market power. At the same time the small scale, competitive sector, absorbs the continual flow of new technologies, yet lags behind.

The current levels of income concentration, wages and poverty are not the only possible ones. The model shows that efficiency and equity in production and innovation can be promoted together by reducing market power—the essence of Adam Smith's democratic insights on competition — and by recognizing the public good nature of technological absorption in the small scale sector.

A profit rate tax can be defined that encourages production rather than profit rates and can therefore generate a more equitable market economy, levying zero taxes in equilibrium. This provides one tool for distributing the wealth produced by automation. Direct taxes on profits can also be used to generate efficiency and equity through investments in innovation and absorption, as during the Great Prosperity.

The challenge is to make mass production, the workhorse of modern wealth, equitable and truly responsive to pressing economic needs. One policy aim can be to reduce the technology gradient that runs across the economy, therefore raising wages and reducing inequality. The mass market economy model and awarness of the technology gradient can serve as a basis for understanding the economic and political issues implicit in the set of impacts that innovation and competition have on welfare and distribution: income concentration, increased corporate political influence under deregulation, the battle for sustainability in the face of rising poverty and growing corporate power, the global business cycle, and so on.

Appendix

APPENDIX A. PROOFS

A.1. Operating and Theoretical profits

Consider a firm investing a flow of $I(t)$ units, so that

$$\dot{K} = I - \delta K. \tag{8.1}$$

Let $K(0) = 0$, so there might be an initial investment phase during which the firm operates at a loss. Under the usual notation, let $F(K, L)$ be the firm's production function and let p be the price of the product. Operating profits can be defined as income from selling the product, minus costs. Costs consist of wages paid, investment costs, and capital depreciation. Hence

$$\pi^O = pF(K, L) - wL - I - \delta K. \tag{8.2}$$

Theoretical profits can be defined as income from selling the product, minus wages paid, minus the capital share of income, minus capital depreciation,

$$\pi = pF(K, L) - wL - rK - \delta K. \tag{8.3}$$

Suppose the investor has perfect foresight so that the present value of the investment flow from $t = 0$ to $t = t_0$ equals the present value of the expected return of the capital, plus the value of the capital at time t_0,

$$\int_0^{t_0} I(t)\exp(-rt)dt = \int_0^{t_0} rK(t)\exp(-rt)dt + K(t_0)\exp(-rt_0). \tag{8.4}$$

We can now obtain the relation between operating and theoretical profits.

$$\int_0^{t_0} \pi \exp(-rt)dt = \int_0^{t_0} \left(pF(K, L) - wL - rK - \delta K\right)\exp(-rt)dt \tag{8.5}$$

$$= \int_0^{t_0} \left(\pi^O - rK + I\right)\exp(-rt)dt \tag{8.6}$$

$$= \int_0^{t_0} \pi^O \exp(-rt)dt + K(t_0)\exp(-rt_0). \tag{8.7}$$

Note that any investment capital $K(t_0)$ held at time t_0 will produce an operating profit in the future. At any time t_0, if the discounted value of operating profits over $[0, t_0]$ have been positive and the firm has a positive capital value, the discounted value of theoretical profits have also been positive. If the project ends at t_0, so that $K(t_0) = 0$, over the life of the project the present value of theoretical profits will equal the present value of operating profits.

In particular, as was mentioned in the introduction, the discounted value of operating profits over any subperiod of 1947-2015 was positive, as was the discounted value of capital at the end of any such subperiod. Hence the present value of theoretical profits over any subperiod of 1947-2015 was higher than the present value of the operating profits, and therefore positive.

A.2. Proofs of Theorems and Propositions

Proof of Theorem 1. 1) $\frac{d}{d\chi}\left(\chi^{-(1-\xi)}\xi + \chi^{\xi}(1-\xi)\right) = \xi\chi^{\xi-1}\left(1-\chi^{-1}\right)(1-\xi) > 0$, so from (2.17), $\frac{dZ_t}{d\chi} < 0$. 2) See (2.10). 3) See (2.11). 4) See (2.16). 5) Since all workers earn the same wage rate, and profits are uniformly distributed across innovators, the area under the Lorenz curve is made of two triangles, one with height $\frac{w_t P}{\xi\pi_{Lt} + w_t P}$ and base 1 and the other with height $\frac{\xi\pi_{Lt}}{\xi\pi_{Lt} + w_t P}$ and base θ. This implies the Gini coefficient is $1 - \frac{w_t P}{\xi\pi_{Lt} + w_t P} - \theta\frac{\xi\pi_{Lt}}{\xi\pi_{Lt} + w_t P}$ from which the result follows. The simplification follows from equations (2.10) and (2.18).■

Proof of Theorem 2. Differentiate (2.11) and note (2.13).■

Proof of Theorem 4. 1) Below θ_0, since $\theta_0 < \chi$, the incentives are to raise prices to increase profits. Hence firms will select the mark up θ_0. Above θ_0, the derivative with respect to θ of $(1-\tau(\theta))\pi_{Lt}(\theta) = (1-\tau_0(\theta-\theta_0))(1-\theta^{-1})z_t$ is negative if

$$0 > -\tau_0(1-\theta^{-1}) + (1-\tau_0(\theta-\theta_0))\theta^{-2} \tag{8.8}$$

$$\Leftrightarrow 0 > -\tau_0(\theta^2-\theta) + 1 - \tau_0(\theta-\theta_0). \tag{8.9}$$

For $\theta_0 > 1$ to satisfy the inequality we need $\tau_0(\theta_0^2-\theta_0) > 1$, that is, $\tau_0 > \frac{1}{\theta_0(\theta_0-1)}$. The inequality remains valid for $\theta > \theta_0$ since the next derivative with θ, $-\tau_0(2\theta-1)-\tau_0 < 0$ for these values. Observe that the marginal tax on profits at θ_0 is

$$\left.\frac{\frac{d}{d\theta}\left[(1-\tau(\theta))\pi_{Lt}(\theta)\right]}{\pi_{Lt}(\theta)}\right|_{\theta=\theta_0} = \frac{\theta_0^{-2}}{1-\theta_0^{-1}} < 1 \tag{8.10}$$

when $\theta_0^2 - \theta_0 - 1 > 0$, that is, so long as $\theta_0 < \frac{1}{2}\sqrt{5} + \frac{1}{2} = 1.618$, which will only stop holding in this stylized case when the profit rate is above 61.8%.

2) Let $\theta_0 = 1$. Then the derivative of $(1-\tau(\theta))\pi_{Lt}(\theta)$ is negative if

$$0 > -\tau_0(\theta^2-\theta) + 1 - \tau_0(\theta-1) = 1 - (1+\theta)\tau_0(\theta-1), \tag{8.11}$$

that is, for $\theta > \theta^*(\tau_0) = \sqrt{1+\frac{1}{\tau_0}}$.■

Proof of Proposition 1. The incumbent's mark up, at time $t+\Delta t$ will be $\frac{\chi A_L(t+\Delta t, v)}{A_{Lt+\Delta t}}$.

Thus, using myopic perfect foresight, at any given time t she maximizes her expected rate of change of profit

$$\max_v \left[\frac{d}{d\Delta t} \left[\left(1-\phi_L^\pi\right)\left(1-\left(\frac{\chi A_L(t+\Delta t, v)}{A_{Lt+\Delta t}}\right)^{-1}\right) z_{t+\Delta t} \right]\Bigg|_{\Delta t=0} - \left(1-\phi_j\right)v \right]. \qquad (8.12)$$

where $\phi_L^\pi, \phi_L^\iota \in (0,1)$ are the profit tax and innovation subsidy.

The first order condition is:

$$0 = \frac{\partial}{\partial v} \left[\frac{d}{d\Delta t} \left[\left(1-\phi_L^\pi\right)\left(1-\left(\frac{\chi A_L(t+\Delta t, v)}{A_{Lt+\Delta t}}\right)^{-1}\right) z_t \right]\Bigg|_{\Delta t=0} - \left(1-\phi_j\right)v \right] \qquad (8.13)$$

$$= \left(1-\phi_L^\pi\right)\left(\frac{\chi A_L(t,v)}{A_{Lt}}\right)^{-2} \frac{\chi \frac{\partial}{\partial v}\frac{d}{d\Delta t} A_{Lt}(v)}{A_{Lt}} z_t - \left(1-\phi_j\right), \qquad (8.14)$$

since all other terms are zero. Note that since $\tilde{A}_L(t,v) = A_{Lt}$, $\frac{\partial}{\partial v}\tilde{A}_L(t,v) = 0$. Substituting (4.1) and simplifying,

$$0 = \left(1-\phi_L^\pi\right)\left(1-\upsilon\right)\mu_L S_{Lt}^\upsilon v^{-\upsilon} \frac{z_t}{\chi A_{Lt}} - \left(1-\phi_j\right). \qquad (8.15)$$

Letting $\hat{\mu}_L = \frac{(1-\upsilon)\left(1-\phi_L^\pi\right)}{\left(1-\phi_L^\iota\right)}\mu_L$, material inputs v are given by:

$$v_L = \left(\frac{\hat{\mu}_L}{\chi}\frac{z_t}{A_L}\right)^{\frac{1}{\upsilon}} S_{Lt}, \qquad (8.16)$$

where we add a subscript L for reference. Substituting in (4.1), and writing $\varsigma = (1-\upsilon)/\upsilon$

,

$$\frac{\partial}{\partial \Delta t}\tilde{A}_L(t+\Delta t, v)\Big|_{\Delta t=0} = \mu_L S_{Lt}^\upsilon \left(\left(\frac{\hat{\mu}_L}{\chi}\frac{z_t}{A_L}\right)^{1/\upsilon} S_{Lt}\right)^{1-\upsilon} = \mu_L \left(\frac{\hat{\mu}_L}{\chi}\frac{z_t}{A_L}\right)^{\frac{1-\upsilon}{\upsilon}} S_{Lt}. \qquad (8.17)$$

Note now that perfect myopic foresight implies $\frac{\partial}{\partial \Delta t}\tilde{A}_L(t+\Delta t, v)\Big|_{\Delta t=0} = \frac{d}{dt}A_{Lt}$.

Substituting $S_{Lt} = A_{Lt}$ and setting $\tilde{\mu}_L = \mu_L \hat{\mu}_L^\varsigma$ according to (4.2), (4.3) is obtained.■

Proof of Proposition 2. Small scale innovation (4.4) is now analogous to large scale innovation (4.1) except that μ_L becomes $\mu_S\left(\frac{A_{Lt}-A_{St}}{A_{Lt}}\right)^{\upsilon}$, z_t becomes $z_t = \frac{z_t}{N}$, and we consider an innovation subsidy $\phi_S^{\iota} \in (0,1)$, but not a profit tax ϕ_S^{π}. Hence the same derivation yields, after simplification, material inputs given by:

$$v_S = \left(\mu_S \tfrac{z_t}{N}\right)^{\frac{1}{\upsilon}}\left(\tfrac{A_{Lt}-A_{St}}{A_{Lt}}\right)A_{St}^{-\varsigma}. \tag{8.18}$$

and rate of technological change given by (4.6).■

Proof of Theorem 5. Since $\lim_{a_t \to 0} H(a_t) = \infty$, $H' < 0$ and $H(1) < 0$ there is a unique steady state $a^* \in (0,1)$ given by $H(a^*) = 0$. Moreover $a^* < \chi^{-1}$ since $H(\chi^{-1}) < 0$. The steady state level a^* is given by (4.9). Since the RHS is increasing, $\frac{\partial a^*}{\partial \chi} > 0$. The growth rate is given by

$$\gamma^* = \frac{d}{dt}\ln A_{Lt}\Big|_{a_t = a^*} = \frac{d}{dt}\ln A_{St}\Big|_{a_t = a^*}, \tag{8.19}$$

which simplifies to (4.10). Now, this expression is decreasing in a^*, and also decreasing in χ, because $\frac{d}{d\chi}\frac{\chi^{-\xi}}{\xi\chi^{-1}+(1-\xi)} = -\frac{\xi(1-\xi)(\chi-1)}{\chi^{\xi}(\xi+\chi-\xi\chi)^2} < 0$. Since $\frac{\partial a^*}{\partial \chi} > 0$, it follows that $\frac{\partial \gamma^*}{\partial \chi} < 0$.

Addressing changes in ξ, note from (4.9) that $\frac{\partial a^*}{\partial \xi} = 0$. Then from (4.10)

$$\frac{1}{\varsigma}\frac{d}{d\xi}\ln \gamma^* = -\ln(\chi a^*) + \frac{\chi - 1}{\xi + \chi - \xi\chi} > 0, \tag{8.20}$$

since $\chi a^* < 1$ and $\frac{d}{d\xi}\ln\left(\xi\chi^{-1} + (1-\xi)\right) = -\frac{\chi - 1}{\xi + \chi - \xi\chi}$.

Next, by (4.9), $\chi^{\varsigma}\tilde{\mu}_S = \frac{\tilde{\mu}_L a^{*\varsigma}}{\left(1-a^*\right)}$ so, differentiating by $\tilde{\mu}_S$,

$$\chi^{\varsigma} = \tilde{\mu}_L \frac{d}{da^*}\left(\frac{a^{*\varsigma}}{1-a^*}\right)\frac{\partial a^*}{\partial \tilde{\mu}_S} = \tilde{\mu}_L a^{*(\varsigma-1)}\frac{a^* + \varsigma\left(1-a^*\right)}{\left(1-a^*\right)^2}\frac{\partial a^*}{\partial \tilde{\mu}_S}. \tag{8.21}$$

Hence $\frac{\partial a^*}{\partial \tilde{\mu}_S} > 0$. Note that applying (4.9) to (4.10),

$$\gamma^* = \left(\frac{\chi^{-\xi}P}{\xi+(1-\xi)\chi}\right)^{\varsigma}\tilde{\mu}_L a^{*\varsigma(1-\xi)}, \tag{8.22}$$

so it follows that $\frac{\partial \gamma^*}{\partial \tilde{\mu}_S} > 0$. Similarly $\frac{\chi^{\varsigma}}{\tilde{\mu}_L} = \frac{a^{*\varsigma}}{\tilde{\mu}_S\left(1-a^*\right)}$ so, differentiating by $\tilde{\mu}_L$, $\frac{\partial a^*}{\partial \tilde{\mu}_L} < 0$.

Differentiating (4.10) with $\tilde{\mu}_L$, $\frac{\partial \gamma^*}{\partial \tilde{\mu}_L} = \frac{\partial \gamma^*}{\partial a^*}\frac{\partial a^*}{\partial \tilde{\mu}_L} > 0$.■

Proof of Theorem 6.

1) When $\phi_L^{\pi} = \phi_L^{\iota} = 0$ and $\chi \to 1$, $\frac{1-\phi_L^{\pi}}{\left(1-\phi_L^{\iota}\right)\chi} \to 1$ so innovation tends to efficiency.

2) When the incentives of a market power tax hold, χ is replaced by θ_0. Thus in the limit the previous case applies.

3) Observe that the function $\phi_L^{\pi} = f\left(\phi_L^{\iota}\right) = 1 - \varphi_L + \chi\phi_L^{\iota}$ (for which $\frac{1-\phi_L^{\pi}}{1-\phi_L^{\iota}} = \chi$) satisfies $f\left(\frac{\varphi_L - 1}{\varphi_L}\right) = 0$, $f(1) = 1$ and $f'\left(\phi_L^{\iota}\right) = \chi > 1$. The government surplus or deficit in establishing taxes and subsidies ϕ_L^{π}, ϕ_L^{ι} is given by

$$G\left(\phi_L^{\iota}\right) = \xi\left[f\left(\phi_L^{\iota}\right)\left(1-\chi^{-1}\right)z_t - \phi_L^{\iota}v_{Lt}\right] \tag{8.23}$$

Let us evaluate this government surplus or deficit at $\phi_L^\iota = \frac{\chi - 1}{\chi}$ and $\phi_L^\iota = 1$. In the first case $\phi_L^\pi = 0$, while $\phi_L^\iota > 0$, so $G(\frac{\varphi_L - 1}{\varphi_L}) < 0$. In the second case

$$G(1) = \xi\left[(1 - \chi^{-1})z_t - v_{Lt}\right] \tag{8.24}$$

Since this quantity, aggregate profits minus optimal innovation costs, is positive by assumption,

$$G'(\phi_L^\iota) = \xi\left[\chi(1 - \chi^{-1})z_t - v_{Lt}\right] > \xi\left[(1 - \chi^{-1})z_t - v_{Lt}\right] \geq 0 \tag{8.25}$$

by the same assumption. Hence by the Intermediate Value Theorem there exists $\phi_L^\iota \in (\frac{\chi - 1}{\chi}, 1)$ for which the government budget is balanced. At this value ϕ_L^π, $\phi_L^\iota \in (0,1)$. If instead $G(1) < 0$ a lump sum tax on wages is needed to obtain optimal innovation with a balanced budget.

4) The previous statements show this for A_{Lt}. As for A_{St}, in Theorem 5 we showed that by addressing the public good nature of technological absorption and therefore raising $\tilde{\mu}_S$, the small scale sector technological steady state could be raised.■

APPENDIX B. ESTIMATION RESULTS

B.1. General Remarks

We first test whether the pooled data has unit roots, and second whether serial correlation and cross-sectional dependencies exist. We then test for the existence of cointegration relationships amongst the integrated variables and conduct weak exogeneity tests, the latter gives evidence of (weak) causality. Finally, we apply the DOLS estimator to estimate the signs of the long-run cointegrated correlations. Specifically, we are interested in the cointegrated long-run (cointegrated) relationships

(i) between large-to-aggregate ratios and aggregate economy indicators, and (ii) within large-to-aggregate ratios and aggregate economy indicators.

Unit roots test should confirm that the pooled data exhibit unit roots and follow a nonstationary path. We first apply the LLC (2002) and IPS (2003) mitigating the effects of cross-sectional dependence by de-meaning, and we then apply the PES (2007) test as an alternative. Test statistics, p-values in parenthesis and specifics are given in Table B.3. Accordingly, unit root test statistics in the case of the IPS (2003) and PES (2007) testing procedures confirm unit roots for one or two lags in almost every variable, as the null hypothesis of nonstationarity is not rejected at least at a 5% level. Bearing in mind that the IPS (2002) and PES (2007) testing procedures allow for heterogeneous autoregressive coefficients, we conclude that the variables are nonstationary in levels. Turning to the first differences, test statistics from all tests reject the null hypothesis of nonstationarity for all variables using one or two lags. Since our variables are I(1), we conclude that the pooled data have unit roots and follow a nonstationary path around a trend.

Turning to cointegration and long-run relationships, test statistics in Westerlund (2007) allows serial correlation and cross-sectional dependence in the data for different deterministic components. Hence, we test first for "no first-order autocorrelation" by the Woolridge (2002) testing procedure and second for "cross-sectional independence" by the Pesaran (2004) testing procedure. We than use Westerlund's (2007) four different panel cointegration tests to test whether the panel is cointegrated, using conditional ECMs in the bivariate case. Analysis of the full ECM model is not required, if one of the long-run adjustment coefficients is negative and significant, while the other is zero. This is done through weak exogeneity tests. Specifics, test statistics and p-values in parenthesis are given for Wooldrige (2002) and Pesaran (2004) in Tables B.4.1 - B.4.2, for Westerlund (2007) in Tables B.5.1 - B.5.2 and for weak exogeneity tests in Tables B.6.1 - B.6.2. Accordingly, there is overall evidence of first-order autocorrelation and cross-sectional dependencies as the null hypotheses are rejected in both cases. Cointegration test statistics from Westerlund (2004) combined with the analysis of weak exogeneity in conditional ECMs confirm causalities running mainly from large-to-aggregate ratios to aggregate economy indicators. Finally, we estimate the long-run bivariate relationships using Stock and Watson's (1993) dynamic OLS estimator. Estimates of coefficient, sign and significance of two estimations - one contemporaneous and one with one lag - given in Tables B.7.1 - B.7.2 - confirm long-run relationships running both directions: from large to aggregate ratios to the aggregate economy indicators and vice versa.

B.2. Descriptive Analysis

Notes: Except for the number of establishment and the number of firms, all variables in lower letters are used as logarithms and, if measured as a nominal value, are deflated. Large scale firms (*L*) are defined by employment above 500. Running a simple regression of each variables regarding time detects time tendencies. Coefficients with the standard deviation are given parenthesis in the last column.

Table B.2: Descriptive analysis
Annual data for 50 states plus DC from 1997-2011.

		Obs.	Mean	Std. Dev.	Min	Max	Trend
All Firms:							
y	income	765	17.063	1.037	14.975	19.613	0.024 (2.76)***
y-l	income per employee	765	2.936	0.176	2.637	3.634	0.017 (12.59)***
w	average wage rate	765	1.879	0.169	1.514	2.436	0.01 (7.03)***
l	employment	765	14.126	1.029	11.994	16.443	0.007 (0.8)
w+l	payroll	765	16.005	1.104	13.638	18.561	0.017 (1.79)*
Number of establishments		65	143,065	152,959	17,680	891,997	915.093 (0.71)
Number of firms		65	116,542	125,261	15,632	730,789	438.749 (0.42)
Firms with 500 or more employees (*L*):							
w_L	average wage rate	765	1.991	0.172	1.622	2.518	0.01 (7.17)***
l_L	employment	765	13.376	1.117	10.81	15.719	0.011 (1.15)
w_L+l_L	payroll	765	15.368	1.184	12.731	17.967	0.021 (2.10)**
Number of establishments		765	20,881	21,764	1,584	120,396	445.296 (2.45)***
	Number of firms	765	2,249	1,222	456	5,820	15.254 (1.49)

Notes: see above.

B.3 Unit Root Test Results

Notes: All variables are used as logarithms (i.e. are given in low letters). The null hypothesis is nonstationarity, while the alternative hypothesis for LLC is that all individual series and for IPS and PES is that some individual series are stationary with individual first order autoregressive coefficient. The adjusted test statistics for LLC (adjusted t*), IPS (*w[t-bar]*), PES (*z[t-bar]*), and convergence asymptotically to a standard normal distribution. The *p*-values are given in parenthesis. Test statistics account for cross-sectional dependence by removing cross-sectional means from the series in the case of LLC and IPS and by augmenting cross-sectional averages of lagged levels and first differences of the individual series in the case of PES. Tests are implemented with a constant and a trend, and tests are implemented with one or two lags in the test regression.

Table B.3: Panel unit root tests with cross-sectional dependence by LLC (2002), IPS (2003) and PES (2007); levels and differences
Annual data for 50 states plus DC from 1997-2011.

	LLC, L(1)	**IPS, L(1)**	**PES, L(1)**	**LLC, L(2)**	**IPS, Lag(2)**	**PES, L(2)**
Aggregate Economy						
W	-8.8018 (0)	-3.0035 (0)	-0.431 (0.33)	-9.8547 (0)	-5.4653 (0)	3.459 (1)
l-p	-6.1139 (0)	0.2949 (0.62)	0.611 (0.73)	-4.6341 (0)	-1.3921 (0.08)	2.037 (0.98)
w+l-p	-9.1112 (0)	-2.3248 (0.01)	1.116 (0.87)	-6.4925 (0)	-2.4453 (0.01)	6.661 (1)
Large to Aggregate Ratios						
$(w_L+l_L)-(w+l)$	-7.3068 (0)	-0.9596 (0.17)	-4.618 (0)	-6.8702 (0)	-1.6437 (0.05)	-1.986 (0.02)
l_L-l	-8.7488 (0)	-2.2418 (0.01)	-3.036 (0)	-4.7447 (0)	-1.2613 (0.1)	0.511 (0.7)
w_L-w	-6.5954 (0)	-1.0797 (0.14)	0.756 (0.78)	-4.5714 (0)	-0.5444 (0.29)	2.962 (1)
Income Inequality						
top1	1.976 (0.98)	4.1766 (1)	-5.705 (0)	11.015 (1)	7.2152 (1)	2.703 (1)

	LLC, L(1)	**IPS, L(1)**	**PES, L(1)**	**LLC, L(2)**	**IPS, Lag(2)**	**PES, L(2)**
Aggregate Economy						
d.w	-13.6655 (0)	-10.4273 (0)	-7.138 (0)	-13.5651 (0)	-10.796 (0)	0.563 (0.71)
d.(l-p)	-8.0786 (0)	-6.0768 (0)	-4.124 (0)	-4.3754 (0)	-4.7102 (0)	-0.906 (0.18)
d.(w+l-p)	-11.4319 (0)	-7.6646 (0)	-3.793 (0)	-10.9091 (0)	-6.9474 (0)	2.616 (1)
Large to Aggregate Ratios						
$d.((w_L+l_L)-(w+l))$	-12.6587 (0)	-9.8821 (0)	-8.754 (0)	-4.9956 (0)	-6.1338 (0)	-4.725 (0)
$d.(l_L-l)$	-11.9123 (0)	-9.1286 (0)	-6.547 (0)	-5.0654 (0)	-6.0336 (0)	-1.72 (0.04)
$d.(w_L-w)$	-13.4824 (0)	-11.8791 (0)	-5.078 (0)	-1.2798 (0.1)	-5.7672 (0)	1.601 (0.95)
Income Inequality						
d.top1	-16.5169 (0)	-11.3548 (0)	-4.987 (0)	-13.1909 (0)	-11.109 (0)	-2.089 (0.02)

Notes: see above. .

B.4. Serial Correlation and Cross-Sectional Dependence Test Results

Notes: All variables are used as logarithms (i.e. are given in low letters). Serial Correlation: Tests are implemented pairwise using the residuals from a regression in first differences. The null hypothesis is no first-order autocorrelation in panel data by Wooldrige (2002). F-test statistics and p-values (in parenthesis) are given. Cross-sectional dependencies: Tests are implemented pairwise with a constant and a trend in the test regression using a fixed-effect (FE) or random-effect (RE) model specification. The null hypothesis is no systematic difference in coefficients in the case of Hausman (1978), while a cross-sectional independence in panel data is assumed for the null hypothesis in the case of Pesaran (2004). Chi-test statistics and F-test statistics with their p-values (in parenthesis) are given respectively.

Table B.4.1: Serial correlation tests by Wooldrige (2002) and cross-sectional dependence tests by Peseran (2004) in panel-data models; large-to-aggregate ratios, aggregate economy indicators and income inequality
Annual data for 50 states plus DC from 1997-2011.

	w	*l-p*	*w+l-p*	*top1*
Serial Correlation:				
$(w_L+l_L)-(w+l)$	409.26 (0)	1171.02 (0)	1102.75 (0)	15.681 (0)
l_L-l	199.52 (0)	988.44 (0)	742.99 (0)	15.378 (0)
w_L-w	882.96 (0)	763.61 (0)	1629.85 (0)	15.638 (0)
top1	457.238 (0)	293.592 (0)	763.776 (0)	
Cross-Sect. Dep.:				
Hausman-Test				
$(w_L+l_L)-(w+l)$	1.54 (0.46)	0 (1)	0.49 (0.78)	9.92 (0)
l_L-l	0.79 (0.67)	5.08 (0.08)	0.45 (0.8)	11.45 (0)
w_L-w	0.35 (0.84)	0 (1)	0.13 (0.94)	1.46 (0.48)
top1	-2.08 (n.a.)	0.66 (0.72)	-7.28 (n.a.)	
Pesaran, FE				
$(w_L+l_L)-(w+l)$	52.083 (0)	70.891 (0)	67.55 (0)	93.511 (0)
l_L-l	46.925 (0)	79.427 (0)	67.411 (0)	93.049 (0)
w_L-w	54.481 (0)	64.784 (0)	55.702 (0)	92.775 (0)
top1	52.806 (0)	31.839 (0)	44.867 (0)	
Pesaran, RE				
$w_L+l_L)-(w+l)$	52.032 (0)	70.879 (0)	67.658 (0)	93.472 (0)
l_L-l	46.766 (0)	78.622 (0)	67.432 (0)	93.196 (0)
w_L-w	54.412 (0)	64.789 (0)	55.626 (0)	92.825 (0)
top1	52.869 (0)	31.734 (0)	44.743 (0)	

Notes: see above.

Table B.4.2: Serial correlation tests by Wooldrige (2002) and cross-sectional dependence tests by Peseran (2004) in panel-data models; large-to-aggregate ratios, aggregate economy indicators and income inequality
Annual data for 50 states plus DC from 1997-2011.

	$(w_L+l_L)-(w+l)$	*l_L-l*	*w_L-w*	*top1*
Serial Correlation:				
w	97.698 (0)	187.344 (0)	40.233 (0)	14.562 (0)
l-p	104.592 (0)	310.981 (0)	25.354 (0)	10.688 (0)
w+l-p	135.665 (0)	242.046 (0)	28.706 (0)	9.902 (0)
top1	96.53 (0)	323.461 (0)	27.954 (0)	
Cross-Sect. Dep.:				
Hausman-Test				
w	0.04 (0.98)	0.10 (0.95)	1.75 (0.42)	2.18 (0.34)
l-p	0.46 (0.79)	0.05 (0.97)	1.23 (0.54)	1.96 (0.37)
w+l-p	0.45 (0.79)	0.01 (0.99)	1.78 (0.41)	0.87 (0.65)
top1	5.59 (0.061)	6.74 (0.0343)	1.49 (0.4744)	
Pesaran, FE				
w	36.379 (0)	36.526 (0)	17.693 (0)	93.766 (0)
l-p	40.514 (0)	57.926 (0)	15.363 (0)	76.087 (0)
w+l-p	41.717 (0)	51.031 (0)	11.253 (0)	84.222 (0)
top1	35.092 (0)	42.628 (0)	15.36 (0)	
Pesaran, RE				
w	36.350 (0)	36.467 (0)	16.8 (0)	93.832 (0)
l-p	40.670 (0)	57.986 (0)	15.1 (0)	77.008 (0)
w+l-p	41.898 (0)	51.056 (0)	11.435 (0)	84.776 (0)
top1	35.051 (0)	42.601 (0)	15.39 (0)	

Notes: see above.

B.5. Panel Cointegration Test Results

Notes: All variables are used as logarithms (i.e. are given in low letters). Westerlund (2007) presents four different panel cointegration tests with a null hypothesis of no cointegration. While G_τ and G_α test the alternative hypothesis of least one unit is cointegrated (i.e. group mean tests), P_τ and P_α test if the panel is cointegrated as a whole (i.e. panel mean tests). Short run dynamics are restricted to one lag and one lead. The "kernel with" is chosen according to the formula of 4(T/100)^2/9 and therefore to 3. All tests are implemented pairwise with a constant and a trend in the test regression. The robust p-values are given in parenthesis and are based on a bootstrapped distribution using 800 bootstrap replications in order to deal with cross-sectional dependencies.

Table B.5.1: Panel cointegration tests by Westerlund (2007) between large-to-aggregate ratios, aggregate economy indicators and income inequality; lag (0)
Annual data for 50 states plus DC from 1997-2011.

	w	*l-p*	*w+l-p*	*top1*		*(w_L+l_L)-(w+l)*	*l_L-l*	*w_L-w*	*top1*
(w_L+l_L)-(w+l)					*w*				
G_τ	1.093 (0.38)	3.521 (1)	6.253 (0.87)	3.409 (0.39)	G_τ	4.428 (0.74)	2.533 (0.43)	-0.911 (0.22)	8.243 (0.82)
G_α	7.559 (0.23)	11.083 (1)	9.532 (0.76)	9.184 (0.33)	G_α	10.12 (0.99)	10.26 (0.99)	9.821 (0.95)	10.64 (0.84)
P_τ	2.652 (0.23)	11.11 (0.97)	5.777 (0.62)	3.670 (0.07)	P_τ	11.19 (0.67)	6.596 (0.26)	3.126 (0.34)	9.375 (0.33)
P_α	4.764 (0.05)	8.282 (0.94)	6.487 (0.40)	5.772 (0.05)	P_α	8.429 (0.98)	7.613 (0.36)	7.681 (0.89)	8.155 (0.33)
l_L-l					*l-p*				
G_τ	-3.85 (0.07)	15.643 (1)	6.113 (0.86)	8.309 (0.78)	G_τ	3.127 (0.57)	5.869 (0.81)	-1.344 (0.25)	0.322 (0.12)
G_α	6.966 (0.01)	10.54 (0.95)	9.473 (0.64)	9.244 (0.3)	G_α	10.65 (0.99)	10.42 (0.97)	9.151 (0.76)	9.66 (0.03)
P_τ	-0.707 (0.04)	11.61 (0.96)	6.184 (0.66)	5.924 (0.12	P_τ	6.654 (0.72)	5.595 (0.39)	5.148 (0.58)	2.753 (0)
P_α	3.84 (0.01)	7.431 (0.61)	6.357 (0.26)	5.674 (0.03)	P_α	8.111 (0.94)	7.395 (0.57)	6.967 (0.72)	7.039 (0.01)
w_L-w					*w+l-p*				
G_τ	-1.798 (0.18)	9.083 (0.95)	0.34 (0.32)	9.833 (0.9)	G_τ	5.898 (0.84)	5.938 (0.84)	1.289 (0.41)	1.708 (0.11)
G_α	6.071 (0)	8.582 (0.27)	7.406 (0.04)	9.362 (0.37)	G_α	10.31 (0.99)	10.47 (0.99)	8.251 (0.35)	9.896 (0.04)
P_τ	0.724 (0.11)	7.561 (0.7)	3.529 (0.34)	8.17 (0.4)	P_τ	9.497 (0.94)	8.301 (0.81)	5.16 (0.57)	8.447 (0.01)
P_α	4.232 (0.01)	5.777 (0.08)	4.586 (0.02)	6.379 (0.08)		8.799 (0.99)	8.04 (0.85)	7.086 (0.75)	7.767 (0.02)

Notes: see above

Table B.5.2: Panel cointegration tests by Westerlund (2007); within large-to-aggregate ratios and aggregate economy indicators. Annual data for 50 states plus DC from 1997-2011.

	$(w_L+l_L)-(w+l)$	l_L-l	w_L-w
$(w_L+l_L)-(w+l)$			
G_τ	-/-	-5.094 (0.05)	-5.097 (0.05)
G_α	-/-	6.062 (0.01)	8.223 (0.26)
P_τ	-/-	3.106 (0.36)	3.644 (0.32)
P_α	-/-	3.587 (0.02)	6.3 (0.33)
l_L-l			
G_τ	-3.901 (0.07)	-/-	-3.9 (0.07)
G_α	6.963 (0.08)	-/-	8.149 (0.53)
P_τ	0.371 (0.08)	-/-	2.176 (0.15)
P_α	3.776 (0.02)	-/-	5.507 (0.26)
w_L-w			
G_τ	1.596 (0.4)	1.598 (0.43)	-/-
G_α	9.335 (0.74)	9.45 (0.76)	-/-
P_τ	4.697 (0.49)	4.826 (0.51)	-/-
P_α	6.887 (0.51)	6.971 (0.52)	-/-
top1			
G_τ	-1.102 (0.23)	-1.327 (0.25)	-6.312 (0.08)
G_α	9.683 (0.77)	9.718 (0.8)	8.66 (0.65)
P_τ	7.32 (0.79)	4.813 (0.54)	2.009 (0.24)
P_α	7.942 (0.89)	7.618 (0.82)	6.554 (0.62)

	w	$l-p$	$w+l-p$
w			
G_τ	-/-	5.988 (0.79)	5.988 (0.75)
G_α	-/-	10.24 (0.91)	8.802 (0.51)
P_τ	-/-	9.081 (0.76)	8.003 (0.68)
P_α	-/-	6.795 (0.35)	5.748 (0.15)
$l-p$			
G_τ	-2.862 (0.11)	-/-	-2.862 (0.13)
G_α	8.367 (0.27)	-/-	8.071 (0.29)
P_τ	-0.068 (0.08)	-/-	0.158 (0.11)
P_α	5.356 (0.1)	-/-	5.412 (0.13)
$w+l-p$			
G_τ	5.735 (0.78)	5.735 (0.78)	-/-
G_α	8.726 (0.48)	9.122 (0.75)	-/-
P_τ	6.112 (0.57)	4.974 (0.48)	-/-
P_α	5.914 (0.16)	6.633 (0.38)	-/-
top1			
G_τ	-6.654 (0.04)	5.482 (0.74)	-2.698 (0.16)
G_α	7.807 (0.25)	8.531 (0.84)	8.057 (0.95)
P_τ	-1.828 (0.03)	7.232 (0.77)	0.681 (0)
P_α	5.341 (0.16)	6.17 (0.61)	5.279 (0.49)

Notes: see above

B.6 Weak Exogeneity Test Results

Notes: All variables are used as logarithms (i.e. are given in low letters). The long-run adjustment coefficients (i.e. α_y and α_x) for the single equation ECM system are given in the first column and the Wald test statistics are given in the second column for each dependent variable (i.e. column variable (*y*)) respectively. The null hypothesis of the Wald test is weak exogeneity of a cointegrated panel EC-Model (i.e. of all US-states). The single equation ECM system is correctively specified and the independent variable (i.e. row variable (*x*)) is weakly exogenous if the long-run adjustment $\alpha_y < 0$ and significant and $\alpha_x = 0$). Tests for the single equation ECM (conditional) are implemented with a constant and a trend in the test regression using the equilibrium error and lagged first differences both lagged by one period. The first column of results for each dependent variable presents the coefficient and then *p*-values in parenthesis. The second column of results for each dependent variable presents Wald test values and then chi-test statistics in parenthesis.

Table B.6.1: Weak exogeneity in EC-Models, within large-to-aggregate ratios and aggregate economy indicators. Annual data for 50 states plus DC from 1997-2011.

	$(w_L+l_L)-(w+l)$		*l_L-l*		*w_L-w*	
$(w_L+l_L)-(w+l)$						
α_y	-/-		-0.026 (0.09)	2.88 (0.09)	-0.071 (0)	31.02 (0)
α_x			0.045 (0.01)	7.9 (0)	-0.045 (0.01)	7.20 (0.01)
l_L-l						
α_y	-0.07 (0)	13.62 (0)	-/-		-0.071 (0)	22.04 (0)
α_x	0.001 (0.95)	0 (0.95)			0.001 (0.95)	0 (0.95)
w_L-w						
α_y	-0.025 (0)	17.65 (0)	-0.025 (0)	18.95 (0)	-/-	
α_x	0 (1)	0 (1)	0 (1)	0 (1)		
	W		*l-p*		*w+l-p*	
w						
α_y	-/-		-0.022 (0.01)	7.88 (0.01)	-0.015 (0.14)	2.17 (0.14)
α_x			0.006 (0.32)	0.99 (0.32)	0.006 (0.32)	0.99 (0.32)
l-p						
α_y	-0.011 (0.03)	4.55 (0.03)	-/-		-0.007 (0.46)	0.55 (0.46)
α_x	0.005 (0.46)	0.55 (0.46)			0.005 (0.46)	0.55 (0.46)
w+l-p						
α_y	-0.017 (0.09)	2.95 (0.09)	-0.026 (0.04)	4.47 (0.04)	-/-	
α_x	0.009 (0.6)	0.28 (0.6)	-0.009 (0.6)	0.28 (0.6)		

Notes: see above

Table B.6.2: Weak exogeneity in EC-Models, between large-to-aggregate ratios, aggregate economy indicators and income inequality. Annual data for 50 states plus DC from 1997-2011.

	w		*l-p*		*w+l-p*		*top1*	
(w_L+l_L)-(w+l)								
α_y	-0.004 (0.44)	0.61 (0.43)	-0.009 (0.17)	1.92 (0.17)	-0.001 (0.76)	0.1 (0.76)	-0.183 (0)	77.20 (0)
α_x	0.006 (0.12)	2.45 (0.12)	0.007 (0.16)	2.02 (0.16)	0.004 (0.11)	2.53 (0.11)	0.013 (0)	12.81 (0)
l_L-l								
α_y	-0.005 (0.29)	1.14 (0.29)	-0.008 (0.23)	1.44 (0.23)	-0.002 (0.64)	0.22 (0.64)	-0.186 (0)	76.72 (0)
α_x	0.002 (0.55)	0.36 (0.55)	0 (0.96)	0 (0.96)	0 (0.94)	0.01 (0.94)	0.012 (0)	11.14 (0)
w_L-w								
α_y	-0.007 (0.11)	2.6 (0.11)	-0.013 (0.07)	3.36 (0.07)	-0.008 (0.1)	2.79 (0.1)	-0.21 (0)	99.95 (0)
α_x	0.005 (0.1)	2.74 (0.1)	0.005 (0.17)	1.9 (0.17)	0.003 (0.09)	2.83 (0.09)	-0.001 (0.67)	0.18 (0.67)
top1								
α_y	-0.008 (0.06)	3.58 (0.06)	-0.008 (0.17)	1.91 (0.17)	-0.005 (0.22)	1.53 (0.22)		
α_x	0.048 (0.03)	4.91 (0.03)	0.02 (0.44)	0.59 (0.44)	0.024 (0.08)	3.11 (0.08)		
	(w_L+l_L)-(w+l)		*l_L-l*		*w_L-w*		*top1*	
w								
α_y	-0.024 (0)	15.97 (0)	-0.025 (0)	26.38 (0)	-0.071 (0)	34.68 (0)	-0.21 (0)	97.42 (0)
α_x	-0.015 (0.03)	4.72 (0.03)	-0.01 (0.08)	3.04 (0.08)	0.006 (0.74)	0.11 (0.74)	0.001 (0.74)	0.11 (0.74)
l-p								
α_y	-0.021 (0)	12.51 (0)	-0.021 (0)	17.65 (0)	-0.063 (0)	25.11 (0)	0.226 (0)	105.68 (0)
α_x	-0.035 (0)	16.22 (0)	0.032 (0)	18.69 (0)	0.052 (0.03)	4.82 (0.03)	0.022 (0)	19.19 (0)
w+l-p								
α_y	-0.021 (0)	12.14 (0)	-0.02 (0)	15.91 (0)	-0.064 (0)	27.91 (0)	-0.217 (0)	94.69 (0)
α_x	-0.049 (0)	17.96 (0)	-0.043 (0)	19.40 (0)	0.055 (0.06)	3.47 (0.06)	-0.027 (0)	13.88 (0)
top1								
α_y	-0.021 (0)	13.98 (0)	-0.025 (0)	29.11 (0)	-0.073 (0)	37.15 (0)		
α_x	-0.012 (0.69)	0.16 (0.69)	-0.014 (0.6)	0.27 (0.6)	-0.059 (0.5)	0.46 (0.5)		

Notes: see above

B.7. Dynamic OLS Estimation Results

Notes: All variables are used as logarithms (i.e. are given in low letters). The bias corrected *t*-statistics of the coefficients are reported in parenthesis. * (**) [***] denotes that the coefficient is significantly different from zero at a 10% (5%) [1%] level. All equations include unreported, state-specific constants and a trend.

Table B.7.1: Dynamic OLS by Stock and Watson (1993) with lag(1) and lead (1) of first differences; between large-to-aggregate ratios, aggregate economy indicators and income inequality. Annual data for 50 states plus DC from 1997-2011.

	w	*l-p*	*w+l-p*	*top1*
$(w_L+l_L)-(w+l)$				
L(0)	0.619 *(11.69)****	0.274 *(5.75)****	0.893 *(10.21)****	0.096 *(1.53*
L(1)	0.611 *(11.12)****	0.249 *(5.06)****	0.859 *(9.48)****	0.036 *(0.54)*
l_L-l				
L(0)	0.464 *(9.96)****	0.289 *(7.15)****	0.753 *(9.99)****	*0.135 (2.49)****
L(1)	0.459 *(9.52)****	0.271 *(6.51)****	0.73 *(9.36)****	*0.066 (1.17)*
w_L-w				
L(0)	-0.158 *(-0.99)*	-0.926 *(-7.18)****	-1.083 *(-4.27)****	-0.316 *(-1.77)**
L(1)	-0.167 *(-1.02)*	-0.884 *(-6.62)****	-1.052 *(-4)****	-0.264 *(-1.43)*
top1				
L(0)	0.243 (6.13)***	0.219 (6.62)***	0.462 (7.29)***	
L(1)	0.265 (6.32)***	0.212 (6.02)***	0.477 (7.08)***	
	$(w_L+l_L)-(w+l)$	*l_L-l*	*w_L-w*	
w				
L(0)	0.275 (*11.43)****	0.288 (*9.91)****	-0.013 (-*1.33)*	0.22 *(5.17)****
L(1)	0.28 (*11.25)****	0.29 (*9.71)****	-0.01 (-*1.01)*	0.182 *(4.17)****
l-p				
L(0)	0.184 (*6.24)****	0.269 (7.82*)****	-0.084 (-*7.54)****	*0.263 (5.42)****
L(1)	0.208 (6.79*)****	0.289 (*8.13)****	-0.081 (-*7.03)****	*0.188 (3.86)****
w+l-p				
L(0)	0.152 *(10.36)****	0.179 *(10.35)****	-0.027 (-*4.60)****	*0.153 (6.2)****
L(1)	0.161 *(10.62)****	0.186 *(10.41)****	-0.025 (-*4.12)****	*0.122 (4.95)****
top1				
L(0)	*0.041 (1.49)*	*0.067 (2.08)***	*-0.026 (-2.59)****	
L(1)	*0.061 (2.09)***	*0.088 (2.59)****	*-0.027 (-2.59)****	

Notes: see above.

Table B.7.2: Dynamic OLS by Stock and Watson (1993) with lag(1) and lead (1) of first differences; within large-to-aggregate ratios, aggregate economy indicators and income inequality. Annual data for 50 states plus DC from 1997-2011.

	$(w_L+l_L)-(w+l)$	l_L-l	w_L-w
$(w_L+l_L)-(w+l)$			
L(0)	-/-	1.135 *(83.45)****	-0.135 *(-9.94)****
L(1)	-/-	1.124 *(80.91)****	-0.124 *(-8.95)****
l_L-l			
L(0)	0.809 *(81.4)****	-/-	-0.191 *(-19.17)****
L(1)	0.812 *(80.39)****	-/-	-0.188 *(-18.63)****
w_L-w			
L(0)	-0.965 *(-9.63)****	-1.965 *(-19.61)****	-/-
L(1)	-0.97 *(-9.47)****	-1.97 *(-19.24)****	-/-
	w	$l-p$	$w+l-p$
w			
L(0)	-/-	0.461 *(16.67)****	1.461 *(52.85)****
L(1)	-/-	0.452 *(15.88)****	1.452 *(51.04)****
$l-p$			
L(0)	0.667 *(17.06)****	-/-	1.667 *(42.66)****
L(1)	0.68 *(16.68)****	-/-	1.68 *(41.19)****
$w+l-p$			
L(0)	0.558 *(53.2)****	0.442 *(42.07)****	-/-
L(1)	0.563 *(52.3)****	0.437 *(40.57)****	-/-

Notes: see above.

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