

Naeher, Dominik

Article — Published Version

The Social Planning Problem with Costly Information Processing: Towards Understanding Production Decisions in Centralized Economies

Economica

Provided in Cooperation with:

John Wiley & Sons

Suggested Citation: Naeher, Dominik (2022) : The Social Planning Problem with Costly Information Processing: Towards Understanding Production Decisions in Centralized Economies, *Economica*, ISSN 1468-0335, Wiley, Hoboken, NJ, Vol. 90, Iss. 357, pp. 285-314, <https://doi.org/10.1111/ecca.12442>

This Version is available at:

<https://hdl.handle.net/10419/287875>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<http://creativecommons.org/licenses/by/4.0/>

The Social Planning Problem with Costly Information Processing: Towards Understanding Production Decisions in Centralized Economies

By DOMINIK NAEHER

University of Goettingen

Final version received 15 July 2022.

It has long been argued that market economies feature an inherent advantage over centralized economies because they are subject to fewer information processing needs. However, very little work has investigated the role of these needs in explaining differences in optimal production decisions between centralized and market economies. This paper uses a rational inattention approach to study the decision problem of a social planner who faces uncertainty about households' preferences and can reduce this uncertainty by allocating scarce resources to processing information. The model shows that costly information processing has important implications for optimal production decisions, including for the trade-off between consumption and leisure, the optimal range of different goods produced, and the role of correlated consumer preferences. Overall, the results suggest that differences in empirical production decisions between socialist and capitalist countries may be driven by the different information needs and associated costs of processing information inherent to each economic system, rather than by differences in ideology or political preferences.

INTRODUCTION

Since the formulation of the first fundamental theorem of welfare economics by Lerner (1934), Lange (1942) and Arrow (1951),¹ much of the economic literature has focused on discussing the conditions under which the first direction implicit in this theorem—that markets lead to efficient allocations—holds in practice.² In contrast, much less has been written about the empirical plausibility of the second direction implicit in the first welfare theorem, namely that central planning should, in principle, be able to do just as well as the market. Authors who do discuss possible reasons for why this second direction may not hold in practice typically focus on two arguments: lack of incentives (and the associated lack of innovation) in centralized economies, and the enormous information needs inherent to the social planning problem (Hayek 1945; Stiglitz 1996; Feldman and Serrano 2006).³ While some authors discuss these arguments at great length at a qualitative level,⁴ there has been (to the best of my knowledge) no previous attempt to investigate in a structural model the implications of these information needs for optimal production decisions in centralized economies.⁵

This paper begins to fill this gap by studying the decision problem of a central planner who faces uncertainty about households' idiosyncratic consumption preferences and can reduce this uncertainty by allocating scarce resources to processing information. Specifically, I assume that each household prefers a particular consumption good out of a continuum of goods, and that the time resources available in the economy can be used for three purposes: to produce consumption goods, to process information about households' preferences, and for leisure. This feature generates a new link between information-related aspects of the economy (such as the distribution of information and the cost of processing information) and optimal production decisions, with important implications for the trade-off between consumption and leisure, the optimal range of different goods produced, and the role of correlation in consumers' preferences.

In particular, I show that a benevolent social planner who faces opportunity costs associated with reducing uncertainty about households' preferences will optimally allocate fewer resources to producing consumption goods, and thus generate lower levels of per capita consumption than would be achieved in the first-best case where processing information is free (e.g. the standard social planning problem under full information). The intuition behind this result is straightforward. If it is costly for the planner to choose consumption goods that consumers value highly, because reducing uncertainty about households' preferences consumes resources, then generating welfare from leisure becomes relatively more attractive compared to generating welfare from producing (and consuming) goods. Moreover, the model implies that optimally, a centrally planned economy will produce a smaller range of different goods than a market economy. This is due to the fact that the values chosen under imperfect information tend to be biased towards the expected value; that is, the average good preferred by households. Finally, the model shows that the level of social welfare that can be achieved in a centralized economy with costly information processing is higher when households' preferences are correlated. In contrast, in a decentralized market economy, such correlations remain unexploited and do not affect social welfare.

Overall, the model predicts that when other factors are equal, economies involving strong elements of planning will feature (1) lower levels of per capita GDP, (2) fewer working hours, and (3) less product variety than economies based on free markets. I argue that these predictions are consistent with anecdotal evidence as well as with empirical evidence obtained from cross-country panel regressions. At the same time, I stress that obtaining direct, causal evidence on the role of the investigated channel remains a challenge.

In developing the model, I first define the social planning problem with uncertainty about households' preferences and costly information processing at a general level, keeping both the utility and production function as well as the information technology open as much as possible. To solve the model, I focus on a particular type of information technology based on entropy reduction that is used widely in the literature on rational inattention (Sims 2003; Maćkowiak and Wiederholt 2009; Matějka and McKay 2015).⁶ I then use the constructed model to compare the optimal outcomes obtained under central planning with those achieved in a market economy. For this purpose, I consider two different cases of a market economy. The first case is equivalent to the market economy in a standard general equilibrium model with competitive markets and full information. In particular, this benchmark case assumes that firms know the preferences of each household (or that households can transmit information about their preferences to firms for free). The second case relaxes the assumption of full information in the market by incorporating the possibility that firms face uncertainty about households' preferences, and transmitting information between households and firms is costly.⁷ The solutions for these two cases show that the main qualitative results of the model do not depend on the (strong) assumption that the presence of markets reduces the cost of transmitting information in the economy to zero. All that is needed for the results to hold is that the social cost associated with transmitting and processing information about households' preferences is smaller in a decentralized market economy than it is under central planning. Intuitively, this will hold as long as it is generally easier for households to transmit information about their own preferences to firms through markets than it is for a planner to collect information about each household's preferences, process the information in a central place, and assign production and consumption plans to firms and households in the absence of markets.

It should be noted that the model that I build is highly stylized and designed to capture one particular aspect in which centrally planned economies and market economies differ. It is not constructed to provide a complete or realistic picture of either type of economic system. One benefit of this approach is that the mechanisms that I identify are based exclusively

on differences in the aggregate cost of processing information across different types of economic systems. The predictions of the model thus arise independently of other channels through which market economies and centralized economies have been argued to differ in the real world, including the roles of a shortage of basic goods (Roland 2000), lower total factor productivity (Weil 2013), highly specific relations between firms (Blanchard and Kremer 1997), and soft budget constraints (Kornai 1998).

Many recent studies use the rational inattention approach proposed by Sims (2003) to study the role of costly information processing for economic decision making (see the surveys by Handel and Schwartzstein 2018; Maćkowiak *et al.* 2018). The two papers most closely related from that literature are perhaps Angeletos and Sastry (2019) and Lipnowski *et al.* (2020). Both study the role of interventions by a social planner (or principal) in influencing the choices of rationally inattentive agents to increase social welfare. As in most papers in the rational inattention literature, the focus is on the role of costly information processing among market participants (agents) rather than on costly information processing among central authorities (planners). While the latter has been discussed at great length at a qualitative level in the existing literature (see the studies cited in note 4), I present a structural framework that captures, for the first time, the main insights developed in that literature using the rational inattention framework.

The remainder of the paper is organized as follows. Section I explores differences in empirical production decisions across countries with different types of economic organization. Guided by the empirical findings, Section II constructs a model based on costly information processing that offers a possibility to account for some of the observed differences. Section III concludes by discussing the implications and limitations of the model.

I. EMPIRICAL MOTIVATION

This section documents three ways in which production decisions tend to differ across countries with different types of economic organization, that is, across economic systems that involve different degrees of government intervention in markets. Specifically, I find that when keeping other factors fixed, economies involving stronger elements of planning tend to feature (1) lower levels of per capita GDP, (2) fewer working hours, and (3) less product variety than economies based on free markets.

I consider three approaches used in the literature to classify countries according to their type of economic organization. The first approach is based on the classification in the ‘Freedom in the World’ reports (e.g. Freedom House 2003), which essentially relies on a dashboard approach of various indicators and assessment by country experts. This classification has been used widely in the economic literature (including in the seminal works of Barro 1991; Hall and Jones 1996; Sala-i Martin 1997) and is available for the years 1978 to 2002. In each year, countries are assigned into six categories of economic systems ranging from ‘statist’ to ‘capitalist’.⁸ To reduce noise, I combine each two consecutive categories into one.⁹ The indicator used in the analysis thus captures three types of economic system: statist, mixed and capitalist. An exemplary list of countries and their assigned categories in some years is provided in Table A2 in the Appendix.

The second approach uses the Index of Economic Freedom (Heritage Foundation 2019). This index has been available since 1995 and provides a continuous rating of the degree of free markets and absence of government control in each country based on 12 quantitative and qualitative subindicators. I do not make any transformations to the original values of the Index of Economic Freedom, so that the variable used in the analysis ranges from 0 to 100, with higher scores indicating greater economic freedom (see the Appendix for examples).

The third approach is based on the view that strong government intervention into markets implies a large share of employees working in the public sector (Fuchs-Schündeln and Schündeln 2020). I therefore consider the share of public sector employment in total employment as another proxy of countries' type of economic organization. The underlying data come from the World Bank's Worldwide Bureaucracy Indicators database,¹⁰ which covers the years since 2000. Since for many countries these data are available only in some years—e.g. sporadically every three or four years—I interpolate missing values using a linear trend (I do not extrapolate values, that is, I do not impute missing values beyond the period for which data are available for each country).

The other variables used in the analysis are *Log GDP per capita*, *Hours worked*, and *Product variety*. The construction and data sources of these variables are described in the Appendix, together with basic summary statistics (Table A1).

Figure 1 provides a first impression of how the three considered outcomes differ across economies classified as capitalist, statist or mixed. As shown in panels A and C, statist economies feature lower levels of GDP per capita and less product variety. At the same time, panel B shows that statist economies feature more working hours than capitalist economies. I obtain the same results for more recent years when using the Index of Economic Freedom as a proxy for countries' economic organization.¹¹

Of course, these correlations only represent unconditional relations that are likely driven by many other factors. For example, most of the statist economies in my sample represent low- or middle-income countries, which are known to feature more working hours (Bick *et al.* 2018) and less product variety (Imbs and Wacziarg 2003; Cadot *et al.* 2011) than advanced economies. As Figure A1 in the Appendix shows, this also applies to my sample. Thus the findings from Figure 1 that statism (lack of economic freedom) is positively associated with working hours and negatively associated with product variety could also be driven by differences in other third factors.

To test whether or not this is the case, I estimate the empirical role of the type of economic organization in a panel regression framework that controls for time-invariant country characteristics (e.g. geographical features, history, cultural traits) through the inclusion of country fixed effects. Of course, the observational nature of the underlying data limits my ability to identify causal links, but the results will nevertheless be useful in informing the construction of the model in Section II. The regression model that I estimate can be written as

$$(1) \quad Y_{ct} = \alpha + \beta_x X_{ct} + \gamma_c + \psi_t + \varepsilon_{ct},$$

where the dependent variable is either *Hours worked* or *Product variety* of country c in year t , X_{ct} is one of the three proxies for a country's type of economic organization (i.e. the classification into statist, capitalist or mixed, the *Index of Economic Freedom*, or *Public sector employment*), γ_c denotes country fixed effects, ψ_t denotes year fixed effects, and α is a constant. The error term ε_{ct} is estimated using robust standard errors.

The hypotheses that I test are that economies based on strong government intervention in markets feature fewer working hours and less product variety than market-based economies when other factors are equal (corresponding to the predictions of the model discussed below). Therefore I test whether the coefficient β_x in equation (1) is negative for both *Hours worked* and *Product variety* when X_{ct} is *Public sector employment* or a dummy for a *Statist* economy, and β_x is positive when X_{ct} is the *Index of Economic Freedom*.

Table 1 reports estimates of the regression model specified in equation (1). The dependent variable in columns (1)–(3) is *Hours worked*, and the dependent variable in columns (4)–(6) is *Product variety*. The results in column (1) show that once fixed country characteristics

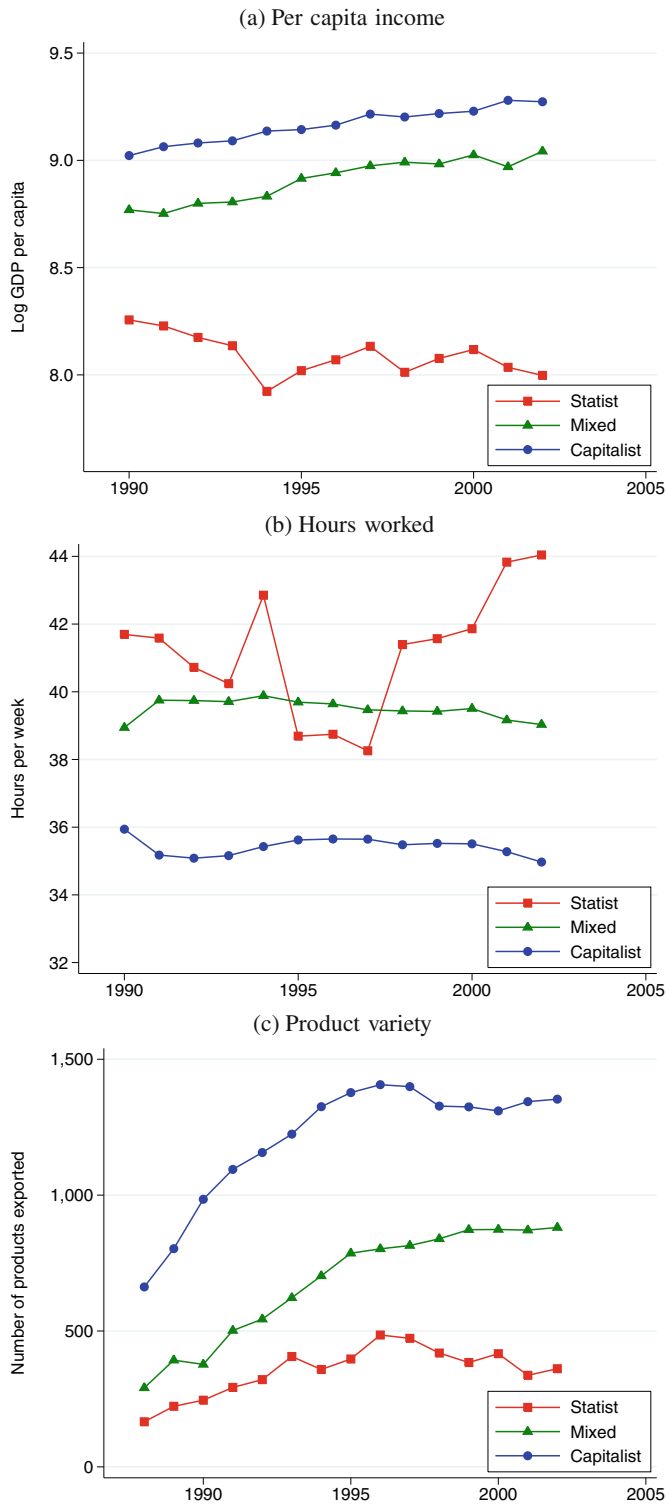


FIGURE 1. Economic outcomes for different types of economic organization.

TABLE 1
RESULTS OF PANEL DATA ANALYSIS

	Hours worked			Product variety		
	(1)	(2)	(3)	(4)	(5)	(6)
Statist	-0.920*** (0.001)			-174.297*** (0.000)		
Capitalist	-0.332 (0.263)			6.076 (0.860)		
Index of Economic Freedom		0.024*** (0.003)			5.696*** (0.000)	
Public sector employment			-0.034** (0.023)			-11.736*** (0.000)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	821	1489	611	2246	3591	1163
R-squared	0.980	0.966	0.976	0.982	0.988	0.995

Notes: p -values are shown in parentheses. The omitted category for type of economic system (in columns (1) and (4)) is 'Mixed'.

*, **, *** indicate $p < 0.10$, $p < 0.05$, $p < 0.01$, respectively.

are accounted for, statist economies feature *fewer* working hours than mixed economies (the omitted category), reversing the direction of the unconditional relationship shown in panel B of Figure 1.¹² At the same time, the results in column (4) confirm that statist countries tend to feature less product variety.¹³

The same conclusions arise from using the other two ways of classifying economic systems. Specifically, the results in columns (2) and (5) of Table 1 show that higher economic freedom is associated with more working hours and greater product variety. The results in columns (3) and (6) show that higher rates of public sector employment are associated with fewer working hours and less product variety, which is in line with the insights obtained from columns (1) and (4). In addition, I obtain largely consistent results when using the logarithms of *Hours worked* and *Product variety* as dependent variables, and when estimating weighted regressions that weight for countries' population size.

I stress again that the observational nature of my data limits my ability to interpret the estimates in Table 1 as causal. At the same time, there appear to be important differences in empirical production decisions across market-based and more centralized economies that are relatively robust across different measures and specifications. The model constructed in the next section focuses on providing a possible way to rationalize these differences.

II. MODEL

Setup

I study a static economy with N households and the same number of firms. There is a continuum of consumption goods, $c \in \mathbb{R}$, of which each household i prefers a specific good, denoted c_i^* . Each household can consume only a single good. Households' preferences are represented by a utility function of the form

$$(2) \quad u(c_i, c_i^*, q(c_i), R_i) = m(c_i, c_i^*) v(q(c_i)) + w(R_i)$$

defined over a similarity measure $m(c_i, c_i^*)$ between the consumed good c_i and the preferred good c_i^* , the quantity $q(c_i)$ of the consumed good, and leisure R_i . The similarity measure $m(\cdot, \cdot)$ is defined as the inverse of a distance metric $d: \mathbb{R} \times \mathbb{R} \rightarrow [0, \infty)$, where $d(c_i, c_i^*) = 0$ if and only if $c_i = c_i^*$, and $d(c_i, c_i^*) > 0$ whenever $c_i \neq c_i^*$. For ease of exposition, let d be such that $m(c_i, c_i^*) \in (1, A)$, where $A > 1$ is a constant (a distance metric with this feature will be specified below). The functions $v(\cdot)$ and $w(\cdot)$ are non-negative, twice continuously differentiable, and strictly increasing and concave. In other words, the household derives higher utility from consuming goods that are more similar to the preferred good, from consuming more of any good (including when $c_i \neq c_i^*$), and from taking more leisure. Each household is endowed with T units of time, which can be used as either leisure or labour.

Each firm j uses labour to produce a single consumption good according to an increasing and concave production function $f(z_j)$, where z_j is the firm's labour input (in units of time), and $f(z_j)$ is the produced quantity.

Social planning problem with uncertainty about household preferences

I start by studying the decision problem of a benevolent central planner who seeks to maximize the total sum of households' utility but does not readily observe the parameters c_i^* that define each household's consumption preferences.¹⁴ For now, I focus on the case where households' preferences are fully idiosyncratic; that is, c_i^* is drawn independently from some distribution for each i (this assumption will be relaxed in the final subsection of this section). To reduce uncertainty about c_i^* , the planner can assign part of the labour force to collecting and processing information. These activities are costly in that they consume time and represent a second form of labour to households, in addition to the labour spent on producing consumption goods at a firm. Processing information is modelled as generating a signal s_i on the value of c_i^* . Signals will be specified below. For now, simply consider signals to be a function s of households' true values of c_i^* and the time allocated to processing information about c_i^* . Let κ_i denote the amount of time that household i spends on collecting and processing information (about the preferences of any households), and let $\bar{\kappa}(c_i^*)$ denote the total amount of time across households that is allocated to processing information about a particular c_i^* .¹⁵ The precision of s_i depends positively on $\bar{\kappa}(c_i^*)$. Moreover, the planner faces the following time budget constraint for each household:

$$(3) \quad \kappa_i + l_i + R_i \leq T,$$

where κ_i is the amount of time that household i spends on processing information, l_i is the amount of time spent on producing consumption goods, and R_i is leisure.

The timing of the model is such that the central planner first chooses the allocation of time subject to constraint (3), then receives the signals, and finally decides which good each firm produces and each household consumes, based on the received signals. Formally, the social planner's problem with uncertainty about households' preferences and costly information processing can be written in the form

$$(4) \quad \max_{\kappa_i, l_i, R_i \geq 0} \sum_{i=1}^N E [u(c_i, c_i^*, q(c_i), R_i)]$$

subject to

$$(5) \quad c_i = \arg \min_{c \in \mathbb{R}} E [d(c, c_i^*) | s_i],$$

$$(6) \quad s_i = s(c_i^*, \bar{\kappa}(c_i^*)),$$

$$(7) \quad q(c_i) \leq \sum_{j=1}^N f^{c_i}(z_j),$$

$$(8) \quad \sum_{j=1}^N z_j \leq \sum_{i=1}^N l_i,$$

$$(9) \quad \sum_{i=1}^N \bar{\kappa}(c_i^*) \leq \sum_{i=1}^N \kappa_i,$$

$$(10) \quad \kappa_i + l_i + R_i \leq T.$$

Condition (5) states that the social planner chooses for each household the consumption good that is closest in expectation to the household's optimal good given the signal obtained according to condition (6).¹⁶ Condition (7) describes the available production technology for consumption goods (recall that $q(c_i)$ is the quantity of the good c_i produced for household i , and z_j is the labour input of firm j , where f^{c_i} indicates that a firm produces good c_i). Conditions (8) and (9) are the time constraints for production and information processing, and condition (10) is the time budget constraint facing each household. The objective of the central planner is to maximize households' expected welfare defined by expressions (4) and (2). Overall, the central planner allocates the available time resources NT so as to maximize households' welfare subject to the given constraints.

Notice that the central planner faces the following two trade-offs. First, the planner can tailor the economy's production and consumption schedules to better match individual households' preferences by allocating more resources to processing information. This comes at the cost of fewer resources being available for the production of the chosen goods (resulting in lower quantities $q(c_i)$) and for leisure. In some sense, this might be seen as a trade-off between the quantity and 'quality' of consumption (where quality refers to the match with household-specific consumption preferences, not to any intrinsic attributes that reflect higher quality of the produced goods in general). Second, the economy can enjoy more leisure at the cost of lower utility from consumption (in terms of both quantity and how well the produced goods match households' preferences).¹⁷ Importantly, these two trade-offs will in general be linked to each other. For example, if the central planner chooses to learn relatively much about which good each household values most, then it also becomes attractive to allocate relatively more resources to the production of consumption goods than to leisure.

Of course, the optimal allocation of resources will depend on the specifications of the utility function and production function as well as the available information technology (i.e. the structure and cost of signals). To shed some light on the role of each of these components, the next four subsections will proceed in the following way. First, I will characterize the mechanisms underlying the solution of the model for a particular information technology based on entropy reduction (from the rational inattention literature), keeping the utility and production function as general as possible. Next, I will compare the resulting allocation to the allocation achieved in a decentralized market economy. Then I will consider a specific utility and production function that provides an intuitive numerical illustration of the model's solution. Finally, I will sketch a simplified decision problem that abstracts from

the mechanism by which the planner can reduce uncertainty while maintaining a general form of the utility and production function (see the final subsection of the Appendix). In particular, this stylized model will help to demonstrate that many of the key qualitative insights derived in this paper are not specific to the case of a rationally inattentive central planner.¹⁸

Rationally inattentive social planner

A possible way to capture the information processing costs arising in a centralized economy is to model a central planner who is rationally inattentive in the sense defined by Sims (2003). In particular, this means that the central planner faces an entropy-based information technology where the signal structure is determined endogenously. Following a notion in the rational inattention literature, I assume that the fundamentals c_i^* are independent realizations of a Gaussian random variable, that is, $c_i^* \sim \mathcal{N}(0, \sigma_c^2)$. In addition, I focus on a special case where the similarity measure $m(c_i, c_i^*)$ is based on the squared difference of c_i and c_i^* , so that the utility function takes the form

$$(11) \quad u(c_i, c_i^*, q(c_i), R_i) = [A - (c_i - c_i^*)^2] v(q(c_i)) + w(R_i).$$

It can be shown (see the second subsection of the Appendix) that the term in square brackets multiplying $v(q(c_i))$ in equation (11) takes values that range between $A - \sigma_c^2$ and A in optimum. To guarantee that this term is positive, I focus on parameter values $\sigma_c^2 \in (0, A)$.

The rationally inattentive social planner knows the structure of the model economy, including the distribution of c_i^* , but faces uncertainty about the realizations of c_i^* for each household. To reduce this uncertainty, the planner can allocate part of the available resources to collecting and processing information. The planner then receives a signal $s_i \in \mathbb{R}$ on the realization of c_i^* . To make the model tractable, I restrict signals to be normally distributed.¹⁹ In this case, s_i is given by

$$(12) \quad s_i = c_i^* + \varepsilon_i, \quad \text{where } \varepsilon_i \sim \mathcal{N}(0, \sigma_\varepsilon^2).$$

The precision of the signal is chosen by the central planner. More precise signals help the planner to tailor the economy's production better to households' idiosyncratic preferences, which increases expected social welfare. However, more precise signals are also more costly since they require more resources devoted to processing information (which are then unavailable for producing goods or enjoying leisure). In line with the rational inattention literature, the cost function of information processing is proportional to the informativeness of the chosen signal. This is captured by the constraint

$$(13) \quad H(c_i^*) - E[H(c_i^*|s_i)] = \mu \bar{\kappa}(c_i^*),$$

where $H(c_i^*)$ is the prior entropy of the random variable c_i^* , $E[H(c_i^*|s_i)]$ is the expected entropy after processing information, and μ is a parameter.²⁰ Equation (13) states that the more resources κ are devoted to processing information about c_i^* , the larger is the expected reduction in uncertainty (measured by entropy) about the realization of c_i^* .

The parameter μ captures the amount of entropy reduction that can be achieved with one unit of κ , where higher values of μ indicate that fewer resources are needed to achieve a given reduction in entropy. One can thus think of μ as capturing characteristics of an economy that facilitate or complicate uncertainty reduction about households' preferences.²¹ In addition, μ will play a central role in the comparison between centralized economies and market economies considered below. To facilitate such a comparison, I focus on parameter

value ranges that ensure that there exists a closed-form solution for the comparative statics with respect to μ (otherwise the comparative statics could be derived only numerically). As shown in the second subsection of the Appendix, this is the case if

$$\mu > \max \left\{ \frac{v_l}{v} \left(\frac{e}{\sigma_c^2} - \frac{1}{2} \right), -\frac{v_l^3}{2v^2 v_{ll}} \right\},$$

where v_l and v_{ll} denote the first and second partial derivative of v with respect to l at the optimum.²²

Notice that the optimization problem of the rationally inattentive planner contains the standard social planning problem with full information (when the planner faces no uncertainty about households' preferences) as a special case where the cost of processing information equals zero (i.e. when $\mu \rightarrow \infty$). In this case, the planner knows the preferred good c_i^* of each household and there is no need to devote any resources to processing information. The planner thus sets $c_i = c_i^*$ and $\kappa_i = 0$ for all households, so that the planning problem reduces to a standard textbook problem where the utility of each household is given as $u(q(c_i), R_i) = A v(q(c_i)) + w(R_i)$.

The solution to the planner's problem when information processing is costly is derived in the second subsection of the Appendix. One benefit of assuming an entropy-based information technology is that it allows for intuitive and fairly tractable solutions (see also Maćkowiak *et al.* 2018; Kőszegi and Matějka 2020). In particular, the second subsection of the Appendix shows that under the assumptions made, the solution to the decision problem of the rationally inattentive planner is characterized by two optimality conditions that together give rise to the following implications.

Proposition 1. The larger μ is—that is, the less costly it is for the planner to reduce uncertainty about households' preferences—the more resources l_i are allocated to the production of consumption goods, and the higher are the quantities $q(c_i)$ of the good consumed by each household.

Proof. See the Appendix. □

Proposition 1 implies that centralized economies that feature properties that make it less costly for planners to reduce uncertainty about households' consumption preferences will tend to feature higher levels of per capita consumption. Note that this result stems from two effects in the model when μ increases. First, the society becomes relatively richer in productive resources as less resources are needed for processing information to achieve the same reduction in uncertainty. The freed-up resources tend to increase both l_i and R_i (one may think about this as a type of 'income effect'). Second, an increase in μ makes spending time on producing consumption goods relatively more attractive compared to taking leisure, as the produced goods tend to be valued more highly by households (the produced goods are closer to households' preferred goods in expectation). This effect works towards a shift of resources from R_i to l_i ('substitution effect'). Hence larger values of μ lead unambiguously to larger values of l_i , and thus larger values of $q(c_i)$, in optimum.²³

Besides differences in the quantity of consumed goods, the model also implies that the expected range of different goods consumed will be smaller under costly information processing, where range is defined as the difference between the maximum and minimum value of c_i among all households. This result is summarized in the next proposition.

Proposition 2. When processing information is costly, the type of good consumed by household i in the planned economy with uncertainty about households' preferences is given by

$$c_i = (1 - e^{-2\mu\kappa_i})(c_i^* + \varepsilon_i),$$

where $(1 - e^{-2\mu\kappa_i}) \in [0, 1]$ and $\varepsilon_i \sim \mathcal{N}(0, \sigma_\varepsilon^2)$ as defined in equation (12). The expected range of different goods c_i produced in the economy is smaller than the range of preferred goods c_i^* that would be produced in the case of full information.

Proof. See the Appendix. □

The intuition behind the result in Proposition 2 stems from a general insight in the rational inattention literature that the values chosen under imperfect information tend to be 'dampened' (i.e. biased towards the expected value) relative to the distribution of the optimal target values (see Maćkowiak *et al.* 2018). In the context studied here, this feature leads to the result that the values of c_i chosen by a central planner facing costly information processing tend to be smaller in magnitude (i.e. biased towards zero) than the optimal values c_i^* , so that the expected range of different goods consumed across all households is smaller than the range of the preferred goods (recall that c_i denotes the type, not the quantity, of the consumed good, and c_i^* is the household's preferred good).

One way to interpret this finding is that the model suggests a link between the costliness of information processing and optimal product variety (corresponding to the number of different products produced, for example, classified using the 6-digit HS level as described in the first subsection of the Appendix). If a higher number of different products produced tends to be associated with a greater maximum distance between products (based on some measure of similarity according to which these products can be ordered), then the result in Proposition 2 implies that centralized economies with higher cost of information processing will tend to feature less product variety. To see this, consider the extreme case where processing information is so costly that no information is processed, that is, $\kappa_i = 0$ for all i . In this case, the planner optimally sets c_i equal to zero (the expected value of c_i^*) for all households, so that only a single good is produced. In contrast, if information processing were free (i.e. in the standard social planning problem with full information about households' preferences), then the planner would set $c_i = c_i^*$ for all i so that the range of goods produced would be equal to the range of preferred goods.

One may be concerned about the robustness of the results in Propositions 1 and 2 with respect to the weights in the planner's objective function. Indeed, focusing on equal weights is crucial in deriving the analytical results as it allows us to transform the planner's general decision problem into a much simpler problem (see equations (A12) and (A13) in the Appendix), which can be analysed using the implicit function theorem. At the same time, allowing for different weights for households in the planner's objective would not change fundamentally the main (qualitative) results in Propositions 1 and 2. To see this, suppose that the planner weights households differently and we have found the optimal allocation for some value of μ . If μ now increases (i.e. processing information becomes less costly), the planner will be able to achieve the same allocation as before, using fewer resources assigned to processing information. Some of these freed-up resources will go into producing higher quantities, so that the main insight from Proposition 1 will still apply (with the qualification that now possibly only a subset of households will benefit from the increase in μ , for example, because some households may carry a weight of zero in the planner's objective). A similar argument can be made for the result in Proposition 2. If processing information is free, then

the planner can simply set $c_i = c_i^*$ for each household, so that the range of consumed goods equals the range of the preferred goods. But if costly information processing is a binding constraint to the planner, then there will be at least some households for which $c_i \neq c_i^*$. The general feature of the rational inattention framework underlying the result in Proposition 2 implies that the chosen values of c_i in this case will be biased towards the mean (i.e. towards zero), so that the main insight from Proposition 2 regarding the range of goods remains qualitatively intact even under different weights.

Central planning versus market economy

I now turn to analysing how the optimal allocation of resources and associated outcomes differs between planned economies and decentralized market economies. For this purpose, two different cases of a market economy are considered. The first case is equivalent to the market economy in a standard general equilibrium model with competitive markets and full information. In particular, this benchmark case assumes that firms know the preferences of each household (or that households can transmit information about their preferences to firms for free). It is well known that for utility and production functions with standard properties, the allocation achieved in such a market economy features the same level of welfare as the first-best allocation chosen by the social planner with full information (the first welfare theorem). Applying the insights from Propositions 1 and 2 thus directly implies that such a market economy will feature higher levels of consumption, more time resources allocated to production, and greater product variety than a centrally planned economy with costly information processing (see also the numerical illustration in the next subsection).

Importantly, however, these results can also be obtained when the strong assumption of full information (or zero information processing cost) in the market economy is relaxed. This can be shown by considering a second case of a market economy that incorporates the possibility that firms face uncertainty about households' preferences, and transmitting information between households and firms is costly. Specifically, for this case I assume that firms face uncertainty about the realized values of c_i^* (which are known to each household), households can transmit information about their realization of c_i^* to firms by sending noisy signals, and the informativeness of the signal depends positively on the amount of time devoted to sending the signal. To keep the analysis tractable and to abstract from potential strategic interactions between households and firms, I consider a simple 'on-demand' economy where firms are ready to produce any particular good that will be purchased by a household, each household orders its preferred good from a particular firm by sending a signal about its realization of c_i^* , and the prices and quantities of the produced goods as well as wages are determined by demand and supply in competitive markets.

Let κ_i denote the amount of time that household i spends on transmitting information about c_i^* .²⁴ The information technology is the same as for the central planner considered above; that is, the cost that each household incurs to provide a firm with a signal about its preference takes the same entropy-based form as specified in equation (13). Formally, each household chooses κ_i , l_i , R_i , c_i and $q(c_i)$ so as to maximize expected utility

$$(14) \quad E [u(c_i, c_i^*, q(c_i), R_i)] = E [A - (c_i - c_i^*)^2] v(q(c_i)) + w(R_i)$$

subject to the budget constraint

$$(15) \quad q(c_i) \leq \omega(T - \kappa_i - R_i) + \pi$$

and the information technology

$$(16) \quad H(c_i^*) - E[H(c_i^*|s_i)] \leq \mu \kappa_i,$$

where ω is the real wage (using the price of the consumption good as numeraire), and π represents (real) dividends.

Each firm j chooses its labour input z_j so as to maximize its profits subject to the available production technology $f(z_j)$.

As shown in the fourth subsection of the Appendix, these specifications allow for a straightforward comparison of the roles of costly information processing in market economies and centralized economies. In particular, for both types of economies, the cost incurred by society to achieve a given reduction in uncertainty about households' consumption preferences can be captured fully by the parameter μ . Thus the widely held view that market economies feature an inherent advantage over planned economies because they are subject to less information processing needs (e.g. Hayek 1945; Stiglitz 1996; Feldman and Serrano 2006) can be incorporated into the model by specifying that μ takes a higher value for market economies (\tilde{M}) than for planned economies (\tilde{SP}); that is, $\mu^{\tilde{M}} > \mu^{\tilde{SP}}$.²⁵ The focus of the analysis below is to investigate how this feature affects optimal production decisions in centralized economies compared to market economies.²⁶

One way to think about this approach is that it captures the idea that prices are not perfectly informative about scarcity (as in Grossman and Stiglitz 1980), thus there is a need for engaging in costly activities to process and transmit information even in the presence of free markets.²⁷ In deriving the results of the model under the made assumption that $\mu^{\tilde{M}} > \mu^{\tilde{SP}}$, it does not matter whether prices provide zero information or partial information about each household's preferences. If prices provide partial information, then the amount of information (quantified by entropy) that needs to be processed via costly activities will be smaller in a market economy than in a planned economy, so that a market economy will naturally have to commit fewer resources for processing information to achieve comparable allocations. If prices provide no information, then the amount of information that needs to be processed via costly activities will be the same in each type of economy. In this case, the assumption $\mu^{\tilde{M}} > \mu^{\tilde{SP}}$ corresponds to the idea that centralized learning is costlier than localized (decentralized) learning. For example, this will be the case if it is easier for households to transmit information about their own preferences directly to firms than it is for a central authority to collect information about each household's preferences, process the information in a central place, and make production assignments to each firm.

The main insights derived from comparing the outcomes in a market economy with those achieved under central planning can be summarized as follows.

Proposition 3. Consider the optimal allocations under central planning with full information (SP), central planning with costly information processing (\tilde{SP}), a market economy with full information (M), and a market economy with costly information processing (\tilde{M}), as described above. With the assumptions made, including that $\mu^{\tilde{M}} > \mu^{\tilde{SP}}$, it holds that $l_i^{\tilde{SP}} < l_i^{\tilde{M}} < l_i^M = l_i^{SP}$ and $q_i^{\tilde{SP}}(c_i) < q_i^{\tilde{M}}(c_i) < q_i^M(c_i) = q_i^{SP}(c_i)$. The level of social welfare and the range of different goods produced are larger in market economies than in planned economies with costly information processing.

Proof. See the Appendix. □

Proposition 3 implies that, other factors being equal, market economies will tend to feature higher levels of per capita consumption, more time resources allocated to production, and

greater product variety than economies with strong elements of planning, including when transmitting and processing information is not completely free in market economies. The intuition behind these results is twofold. First, due to higher information processing costs, centralized economies require more resources to attain production and consumption schedules that are associated with the same expected level of utility as the allocations attained in market economies. These resources are then unavailable for other economic activities such as production and leisure. Second, it is cheaper for market economies to produce goods that consumers value highly. Thus optimally, market economies generate relatively more utility from producing goods than from leisure compared to centralized economies.

Importantly, note that the results in Proposition 3 do not rely on an assumption that processing information is free in market economies, or that costly information is not a binding constraint also in market economies. All that is needed for the results to hold is that the social cost associated with transmitting and processing information about households' preferences is smaller in a decentralized economy with markets than it is under central planning (i.e. that the presence of markets helps at least marginally in managing uncertainty).²⁸

Notice also that the model has the feature that if the aggregate cost of processing information was equal in centralized and market economies (i.e. $\mu^{\tilde{M}} = \mu^{\tilde{SP}}$), then the achieved allocations would be the same. However, this is not a general feature. For example, relaxing the assumed symmetry of households, the allocations achieved under central planning and competitive markets will be different, in general, if households have different time endowments.

Illustration

To illustrate the differences in optimal production decisions between market and centralized economies arising from the model, it is helpful to introduce an explicit utility and production function. This makes it possible to solve for the equilibrium values in the model directly, rather than having to rely on implicit optimality conditions. For this purpose, let $A = 2$, let $v(\cdot)$ and $w(\cdot)$ be logarithms so that the utility function (11) takes the form

$$(17) \quad u(c_i, c_i^*, q(c_i), R_i) = [2 - (c_i - c_i^*)^2] \ln(1 + q(c_i)) + \ln(1 + R_i),$$

and let the production function be given as

$$f(l_i) = l_i.$$

In this special case, it holds that $v(f(l_i)) = \ln(1 + l_i)$, $v_l(f(l_i)) = 1/(1 + l_i)$ and $w_R(R_i) = 1/(1 + R_i)$, so that the two optimality conditions (i.e. equations (A14) and (A15) in the Appendix) for the social planner's problem take the form

$$(18) \quad \kappa_i = \frac{1}{2\mu} \ln(2\sigma_c^2 \mu(1 + R_i) \ln(1 + l_i)),$$

$$(19) \quad R_i = \frac{l_i - 1}{2} + \frac{1}{4\mu \ln(1 + l_i)}.$$

Combining equations (18) and (19), and plugging the results into the time budget constraint (10), leads to

$$(20) \quad \frac{l_i - 1}{2} + \frac{1}{4\mu \ln(1 + l_i)} + \frac{1}{2\mu} \ln\left(\sigma_c^2 \mu(1 + l_i) \ln(1 + l_i) + \frac{\sigma_c^2}{2}\right) + l_i = T.$$

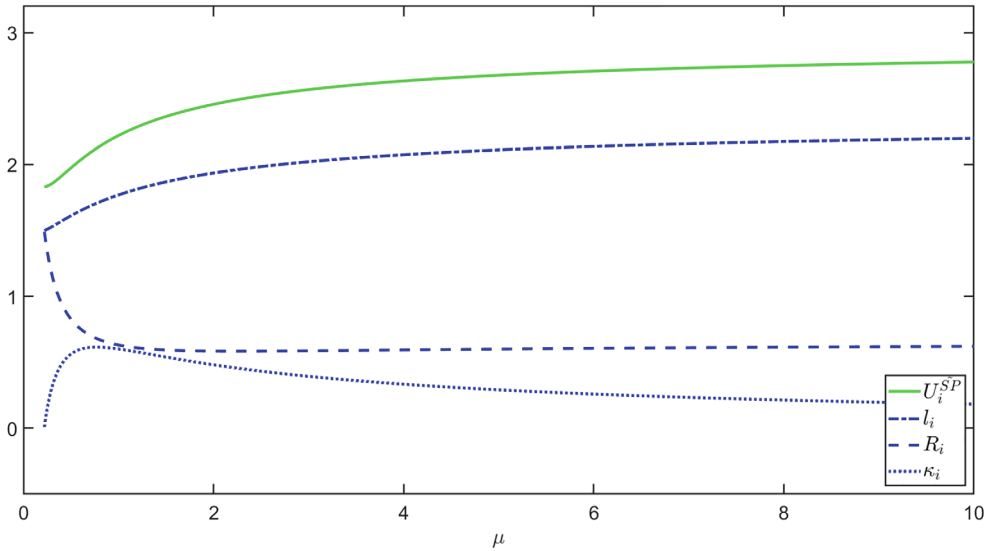


FIGURE 2. Optimal allocation and expected utility for different values of μ .
 Notes: Simulations are performed by varying μ for fixed parameter values $T = 3$ and $\sigma_c^2 = 1$.

This equation implicitly pins down the optimal value of l_i for given parameter values T , μ and σ_c^2 .

For example, solving equation (20) for fixed parameter values $(T, \sigma_c^2) = (3, 1)$ and different values of μ leads to the solution shown in Figure 2. When μ is very small—i.e. reducing uncertainty about households’ preferences is very costly—it is optimal not to allocate any resources to processing information. In this case, the term in square brackets multiplying $\ln(1 + q(c_i))$ in equation (17) equals 1 (recall the proof of Proposition 1), so that half of the available resources T are allocated to production and to leisure, respectively (see the left-hand edge of Figure 2). As μ increases, more resources are allocated to the production of consumption goods so that l_i increases (in line with Proposition 1). For example, when $\mu = \mu^{SP} = 1$, the optimal allocation of resources chosen by the central planner with costly information processing is given by $(\kappa_i, l_i, R_i)^{SP} \approx (0.60, 1.77, 0.63)$, and the expected welfare of each household is $U_i^{SP} \approx 2.2$.

Let us first compare $(\kappa_i, l_i, R_i)^{SP}$ to the allocation chosen by a central planner who does not face uncertainty about households’ preferences, that is, the standard social planning problem under full information. In this case, the planner is able to set $c_i = c_i^*$ for each household without devoting any resources to processing information. For the numerical example with $(T, \sigma_c^2) = (3, 1)$ considered above, the optimal allocation is then given by $(\kappa_i, l_i, R_i)^{SP} = (0, 2\frac{1}{3}, \frac{2}{3})$, and the associated welfare of each household achieved by the social planner with full information is $U_i^{SP} \approx 2.9$. Of course, it holds that $U_i^{SP} > U_i^{SP}$. In addition, notice that in line with Proposition 1, the social planner sets a higher value of l_i under full information than in the case of costly information processing.

Next, let us compare $(\kappa_i, l_i, R_i)^{SP}$ to the allocation achieved in a market economy where consumption and production decisions are made locally by those actors who are in the immediate possession of the relevant information (e.g. consumption decisions are made by households according to knowledge about their own preferences), so that there is no need to collect and process information centrally. For the benchmark case of a market economy with full information, the optimal allocation of resources is equivalent to the first-best allocation

chosen by the social planner with full information (the first welfare theorem applies). In the example considered above, the market allocation under full information is thus given by $(\kappa_i, l_i, R_i)^M = (0, 2\frac{1}{3}, \frac{2}{3})$, with welfare $U_i^M \approx 2.9$.

Now consider the case of a market economy where the assumption of full information is relaxed and $\mu^M > \mu^{SP} = 1$. For example, if $(T, \sigma_c^2) = (3, 1)$ as above, and $\mu^M = 2$ (i.e. achieving the same reduction in entropy requires twice as many resources under central planning than with decentralized markets), then the optimal allocation for the market economy is given by $(\kappa_i, l_i, R_i)^M \approx (0.48, 1.94, 0.58)$. The associated welfare of each household is $U_i^M \approx 2.5$. In line with the results in Proposition 3, it holds that $l_i^{SP} < l_i^M < l_i^M = l_i^{SP}$ (and thus also $q^{SP}(c_i) < q^M(c_i) < q^M(c_i) = q^{SP}(c_i)$), and $U_i^{SP} = U_i^M > U_i^M > U_i^{SP}$.

Correlated preferences

Until now, the analysis has assumed that households’ consumption preferences are fully idiosyncratic, that is, the fundamentals c_i^* are independently distributed across households. To provide some additional insights, I now allow for the possibility that the variables c_i^* are correlated across households.²⁹

In the model, the total uncertainty that the central planner faces about households’ preferences can be quantified by the joint entropy of the set of random variables $\{c_1^*, \dots, c_N^*\}$. If c_1^*, \dots, c_N^* are independent, then the joint entropy is given by the sum of individual entropies

$$(21) \quad H(c_1^*, \dots, c_N^*) = \sum_{i=1}^N H(c_i^*).$$

If c_1^*, \dots, c_N^* are correlated, then the joint entropy is given by

$$H(c_1^*, \dots, c_N^*) = \sum_{i=1}^N H(c_i^* | c_{i-1}^*, \dots, c_1^*),$$

which is strictly smaller than the joint entropy of independent variables specified in equation (21) (see Cover and Thomas 1991, p. 40). Given the information technology specified in equation (13), it thus holds that correlated preferences are associated with lower information processing costs to achieve the same reduction in uncertainty. The level of social welfare that can be attained in a centrally planned economy is thus higher if consumption preferences are correlated across households (and planners are aware of it).

In contrast, in a decentralized market economy, correlated preferences do not necessarily increase the level of social welfare. If the good that a firm produces for a particular household depends only on the signal received from that household (i.e. there are no spillovers in uncertainty reduction), then the correlation in households’ preferences remains unexploited, and the level of social welfare is the same as with fully idiosyncratic preferences.

Proposition 4. The level of social welfare that can be achieved in a centralized economy with costly information processing is higher when households’ preferences are correlated, that is, when c_1^*, \dots, c_N^* are not independent. In a market economy with costly information processing and no spillovers in uncertainty reduction, social welfare is the same irrespective of whether preferences are correlated or not.

Proof. The result for centralized economies follows from the fact that with correlated preferences, the social planner can achieve any allocation that can be achieved with independent preferences, but with fewer resources κ . The statement about market economies holds because, in the absence of spillovers, every household and firm behaves identically to the situation when preferences are not correlated. \square

Obviously, with full information it does not matter whether preferences are correlated or not. When information processing is costly, however, Proposition 4 implies that consumers in centralized economies will tend to fare better if their preferences happen to be correlated. Intuitively, this is due to the fact that with correlated preferences, learning which good a particular household prefers also helps the planner to learn about the preferred goods of other households.³⁰ In contrast, in market economies, this feature will remain unexploited given that the good produced for a particular household depends only on the signal sent by that household, which remains unaffected by the presence of correlation in preferences.³¹

Proposition 4 also implies that if it were possible to influence consumers in a way that induces correlation in their preferences, then this might indeed be optimal for a benevolent social planner to do (including some scope for potential costs associated with such efforts). While I do not have data to test this prediction empirically, it appears to correspond well to anecdotal evidence of efforts of leaders in socialist countries to promote certain ideals that make consumer behaviour more uniform.³² While in practice such efforts are often justified with a particular ideology (e.g. communism), the model suggests that these efforts may also be the result of mere economic considerations. Specifically, the fundamental structure of economic organization in socialist countries with strong elements of central planning may give rise to an intrinsic motive for aligning consumer preferences in order to reduce the costs for planners associated with choosing goods that consumers value highly.³³

III. CONCLUSION

To the best of my knowledge, this paper presents the first attempt to investigate in a structural model the implications of the long-held view that the presence of markets provides a natural advantage over economic systems based on central planning, as the latter involve large information processing needs that do not (or only to a lesser extent) exist in market economies.

The stylized model that I construct shows that the optimal outcome in a centralized economy with uncertainty about households' preferences and costly information processing is characterized by a lower share of resources allocated to production, lower levels of per capita consumption and welfare, and a smaller range of different goods produced than the optimal outcome achieved in a market economy. Importantly, these results do not depend on the assumption that information processing is free in market economies, or that costly information is not a binding constraint also in market economies. All that is needed is that centralized learning is costlier than localized learning—that is, that collecting information about households' idiosyncratic preferences, processing the information in a central place, and assigning production and consumption plans to firms and households requires more resources than allowing households and firms to coordinate their consumption and productions plans directly with each other through interaction on markets.

The intuition behind the results is based on two effects in the model. First, centralized economies require more resources to attain production and consumption schedules that are associated with the same expected level of utility as the outcomes attained in market economies (income effect). Second, given that it is more costly for centralized economies to produce goods that consumers value highly, optimally, centralized economies generate

relatively more utility from leisure than from producing goods compared to market economies (substitution effect). The magnitudes of these effects are less severe when central authorities require fewer resources to reduce uncertainty about households' preferences, for example, when better information infrastructure is available or when households' preferences are correlated with each other.

Overall, the model captures the idea that the existence of markets in an economy helps to align decision-making with the way information is distributed. For example, consumption decisions are made by those actors (households) who are also in the immediate possession of information about consumption preferences. In contrast, in centralized economies, parts of these decisions are made by central authorities who are not in immediate possession of the needed information and thus have to engage in costly activities to collect, process and transmit information.³⁴ Hence the model reflects the view that in addition to their role in balancing demand and supply through prices, markets also constitute an effective mechanism to minimize the social cost of information processing in an economy. This feature also implies that the existence of markets is part of a society's information infrastructure, and societies that start to replace elements of central planning with market interaction should be expected to achieve reductions in the economic burden associated with information processing, leading to higher levels of overall efficiency and welfare.

At the same time, it is important to stress that this paper focuses on a highly stylized, static model of a centrally planned economy with a single factor of production, which abstracts from many features of centralized economies that are likely crucial in shaping real-world production decisions. Future work concerned with developing a more general theory of optimal production decisions in centralized economies with costly information processing might consider embedding some of the ideas presented here into a dynamic framework, and incorporating additional aspects (such as sticky production decisions or soft budget constraints) that have been argued to play important roles in centralized economies.

APPENDIX

Data

Data on average annual hours worked by persons engaged are taken from the Penn World Table (version 9.1; see Feenstra *et al.* 2015). These data are available for about 65 countries in every year since 1990 (for earlier years, significantly fewer countries are covered).

Measuring product variety, that is, the range of different goods produced in an economy, is less straightforward as there are no indicators readily available that are comparable across countries. I therefore follow the approach taken by Funke and Ruhwedel (2001) and use the number of different products exported (counted at the 6-digit HS level) as reported in trade data to proxy domestic product variety. This approach has the limitation that some intermediate goods produced at home may not be traded internationally and are thus not captured in trade data. On the other hand, using trade data has the benefits that the classification of goods is largely consistent across countries, and that data are available for a wide range of countries and years. Funke and Ruhwedel (2001) also argue that most of the important goods in a country are probably either exported or imported (see also Feenstra and Kee 2004). The indicator that I use in the analysis is the number of different products (at the 6-digit HS level) exported in a given year from the World Integrated Trade Solution database, which is based mainly on data from the United Nations' Commodity Trade Statistics. Data on this indicator are available for at least 150 countries each year since 1988.

Data on GDP per capita come from the World Bank and are measured in constant international 2011 dollars (PPP adjusted). These data are available from 1990 onwards.

Table A1 reports summary statistics together with the number of countries and years covered in the analysis. Table A2 provide an exemplary list of countries and the data used to classify different types of economic organization (the list includes all countries in the sample with a population of more than

TABLE A1
SUMMARY STATISTICS

Variable	Mean	Min	Max	S.D.	Countries	Years
<i>Economic system</i>						
Statist	0.271	0	1		190	1978–2002
Mixed	0.311	0	1		190	1978–2002
Capitalist	0.418	0	1		190	1978–2002
Index of Economic Freedom	59.813	15.600	90.500	10.764	180	1995–2017
Public sector employment	15.926	1.862	47.261	10.347	126	2000–2017
Log GDP per capita	8.991	5.889	11.813	1.222	191	1990–2017
Hours worked	36.770	26.036	51.476	5.22	70	1990–2017
Product variety	1002.895	1	4883	1308	187	1988–2017

TABLE A2
DATA ON TYPE OF ECONOMIC ORGANIZATION

Country	Economic system (Freedom House)		Index of Economic Freedom	Public sector employment
	1990	2002	2010	2010
Afghanistan	Statist	Statist		9.7
Algeria	Statist	Statist	56.9	
Angola	Statist	Statist	48.4	9.2
Argentina	Mixed	Capitalist	51.2	16.2
Australia	Capitalist	Capitalist	82.6	
Bangladesh	Mixed	Mixed	51.1	4.5
Belgium	Capitalist	Capitalist	70.1	33.7
Bolivia	Mixed	Capitalist	49.4	10.0
Brazil	Mixed	Mixed	55.6	12.0
Burkina Faso	Statist	Statist	59.4	2.2
Cambodia	Statist	Statist	56.6	5.6
Cameroon	Capitalist	Capitalist	52.3	6.2
Canada	Capitalist	Capitalist	80.4	21.0
Chad	Capitalist	Capitalist	47.5	4.3
Chile	Capitalist	Capitalist	77.2	7.3
China	Statist	Statist	51.0	15.7
Colombia	Mixed	Mixed	65.5	4.3
Congo, Dem. Rep.	Mixed	Statist	41.4	5.6
Côte d'Ivoire	Capitalist	Capitalist	54.1	
Czech Republic	Statist	Capitalist	69.8	18.4
Ecuador	Mixed	Mixed	49.3	9.4
Egypt	Statist	Statist	59.0	24.2
Ethiopia	Statist	Statist	51.2	4.4
France	Capitalist	Capitalist	64.2	31.8
Germany	Capitalist	Capitalist	71.1	
Ghana	Mixed	Mixed	60.2	5.8
Greece	Capitalist	Capitalist	62.7	22.0
Guatemala	Mixed	Mixed	61.0	5.5
Guinea	Capitalist	Capitalist	51.8	3.2
Hungary	Statist	Capitalist	66.1	22.9

TABLE A2
(CONTINUED)

Country	Economic system (Freedom House)		Index of Economic Freedom	Public sector employment
	1990	2002	2010	2010
India	Mixed	Mixed	53.8	
Indonesia	Mixed	Mixed	55.5	
Iran	Mixed	Mixed	43.4	
Iraq	Statist	Statist		
Italy	Mixed	Mixed	62.7	18.6
Japan	Capitalist	Capitalist	72.9	
Kazakhstan	Statist	Mixed	61.0	37.2
Kenya	Capitalist	Capitalist	57.5	
Korea, Rep.	Mixed	Mixed	69.9	
Madagascar	Statist	Statist	63.2	2.6
Malawi	Capitalist	Capitalist	54.1	5.2
Malaysia	Capitalist	Capitalist	64.8	
Mali	Statist	Statist	55.6	
Mexico	Mixed	Mixed	68.3	11.3
Morocco	Mixed	Mixed	59.2	
Mozambique	Statist	Statist	56.0	3.3
Myanmar	Statist	Statist	36.7	
Nepal	Capitalist	Capitalist	52.7	
Netherlands	Capitalist	Capitalist	75.0	
Niger	Capitalist	Capitalist	52.9	4.0
Nigeria	Mixed	Capitalist	56.8	
Pakistan	Mixed	Mixed	55.2	7.7
Peru	Mixed	Mixed	67.6	8.2
Philippines	Mixed	Mixed	56.3	8.2
Poland	Statist	Capitalist	63.2	19.1
Portugal	Capitalist	Capitalist	64.4	21.5
Romania	Statist	Mixed	64.2	12.8
Russia	Statist	Mixed	50.3	
Rwanda	Statist	Statist	59.1	
Saudi Arabia	Mixed	Mixed	64.1	
Senegal	Capitalist	Capitalist	54.6	
South Africa	Mixed	Mixed	62.8	15.7
Spain	Capitalist	Capitalist	69.6	22.7
Sri Lanka	Mixed	Capitalist	54.6	16.1
Sudan	Capitalist	Mixed		
Tanzania	Statist	Statist	58.3	2.7
Thailand	Capitalist	Mixed	64.1	9.1
Tunisia	Capitalist	Capitalist	58.9	21.1
Turkey	Mixed	Mixed	63.8	12.9
Uganda	Mixed	Mixed	62.2	3.0
UK	Capitalist	Capitalist	76.5	30.1
Ukraine	Statist	Capitalist	46.4	38.8
USA	Capitalist	Capitalist	78.0	
Uzbekistan	Statist	Statist	47.5	
Venezuela	Mixed	Mixed	37.1	
Vietnam	Statist	Statist	49.8	9.6
Yemen	Mixed	Mixed	54.4	
Zambia	Statist	Statist	58.0	6.2
Zimbabwe	Mixed	Mixed	21.4	6.1

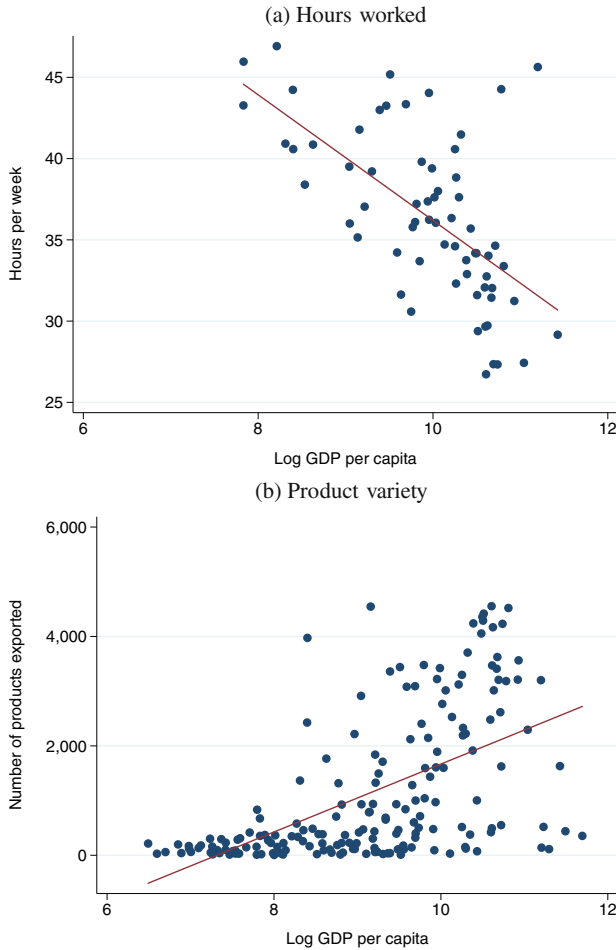


FIGURE A1. Hours worked and product variety for different income levels, 2010.

Notes: Product variety is measured as the number of different products exported in a given year, counted at the 6-digit HS level. GDP per capita is measured in constant international 2011 dollars, purchasing power parity adjusted. All values are for the year 2010.

10 million people). Figure A1 shows the correlations between per capita GDP and working hours as well as product variety.

Proof of Proposition 1

With the assumptions made in Section II, including the properties of $v(\cdot)$ and $w(\cdot)$ specified in the first subsection, the decision problem of the rationally inattentive central planner can be written as

$$(A1) \quad \max_{\kappa_i, J_i, R_i \geq 0} \sum_{i=1}^N E [A - (c_i - c_i^*)^2] v(q(c_i)) + w(R_i)$$

subject to

$$(A2) \quad c_i = \arg \min_{c \in \mathbb{R}} E [(c_i - c_i^*)^2 | s_i], \quad \text{with } c_i^* \sim \mathcal{N}(0, \sigma_c^2),$$

$$(A3) \quad s_i = c_i^* + \varepsilon_i, \quad \text{with } \varepsilon_i \sim \mathcal{N}(0, \sigma_\varepsilon^2),$$

$$(A4) \quad \mu \bar{\kappa}(c_i^*) = H(c_i^*) - E[H(c_i^* | s_i)],$$

$$(A5) \quad q(c_i) \leq \sum_{j=1}^N f^{c_i}(z_j),$$

$$(A6) \quad \sum_{j=1}^N z_j \leq \sum_{i=1}^N l_i,$$

$$(A7) \quad \sum_{i=1}^N \bar{\kappa}(c_i^*) \leq \sum_{i=1}^N \kappa_i,$$

$$(A8) \quad \kappa_i + l_i + R_i \leq T.$$

Notice that households are identical except for their value of c_i^* , and firms are identical except for the type of good that they produce. Given that each household can consume only a single good, each firm can produce only a single good, and both the production function and the information technology are the same for all goods, the optimal production and consumption plans must be symmetric across firms and households. Specifically, it will hold that each firm uses the same amount of labour input z , each household consumes the same quantity q of some consumption good (where the good itself and the derived utility may differ across households, whereas the *ex ante* expected utility is the same for all households), and the central planner allocates an equal amount of time κ to reducing uncertainty about the consumption preferences of each household.

To see that this must hold, suppose that there was a solution that featured two households with different values of $q(c_i)$ and R_i . Since the central planner does not observe the values of c_i^* (which are drawn independently from the same distribution for all households) when deciding on the allocation of time for each household, all households are *ex ante* (i.e. before processing any information) identical to the planner. Given that the utility function is strictly concave and the choice set is convex for each household, there exists a unique solution for each household. Therefore any allocation that features two households with different values of $q(c_i)$ and R_i could be improved by adjusting these values for at least one household.

Since firms and goods are homogeneous in the sense that the production function $f(z_j)$ is the same for every good, it does not matter by which particular firm a given good is produced, nor for which firm a household works (recall that each firm can produce only a single good, and there are as many firms as households). In the same way, it does not matter which households are assigned to process information about any particular household's consumption preferences. Without loss of generality, let firm $j = 1$ produce the good consumed by household $i = 1$ with the labour supplied by household 1, let firm 2 produce the good consumed by household 2 with the labour supplied by household 2, and so on, such that it holds that $z_j = l_i$ for $j = i$, and $q(c_i) = f(l_i)$. Analogously, since the total amount of time allocated to processing information about c_i^* is the same as the time spent by household i on processing information (about the preferences of any household), let κ_i replace $\bar{\kappa}(c_i^*)$ in the notation used so far.³⁵

Also notice that equation (A2) implies that the value of c_i chosen by the central planner equals $E[c_i^* | s_i]$. Using this property, the term $E[(c_i - c_i^*)^2]$ from the planner's objective (A1) can be written as

$$(A9) \quad E[(E[c_i^* | s_i] - c_i^*)^2] = \sigma_{c_i^* | s_i}^2,$$

where $\sigma_{c_i^* | s_i}^2$ is the conditional variance of c_i^* given s_i . In addition, using the definition of entropy, equation (A4) can be written as

$$(A10) \quad \mu \kappa_i = \frac{1}{2} \ln \left(\frac{\sigma_c^2}{\sigma_{c_i^* | s_i}^2} \right).$$

Combining equations (A9) and (A10) shows that

$$(A11) \quad E[(c_i - c_i^*)^2] = \sigma_c^2 e^{-2\mu\kappa_i}.$$

Notice that this implies that the term $E[A - (c_i - c_i^*)^2]$ in the planner’s objective (A1) takes values that range between $A - \sigma_c^2$ (when $\kappa_i = 0$) and A (when $\kappa_i \rightarrow \infty$). The parameter value restriction $\sigma_c^2 \in (0, A)$ specified in the third subsection of Section II thus guarantees that the term multiplying $v(q(c_i))$ in the planner’s objective is positive (and bounded from above by A).

The planner’s problem given by expressions (A1)–(A8) can thus be written as

$$(A12) \quad \max_{\kappa_i, l_i, R_i \geq 0} \sum_{i=1}^N (A - \sigma_c^2 e^{-2\mu\kappa_i}) v(f(l_i)) + w(R_i)$$

$$(A13) \quad \text{subject to } \kappa_i + l_i + R_i \leq T.$$

Using λ to denote the Lagrange multiplier of the time budget constraint (A13), the first-order conditions of this problem are given by

$$\begin{aligned} \{\kappa_i\} : \quad & 2\sigma_c^2 \mu e^{-2\mu\kappa_i} v(f(l_i)) = \lambda, \\ \{l_i\} : \quad & (A - \sigma_c^2 e^{-2\mu\kappa_i}) v_l(f(l_i)) = \lambda, \\ \{R_i\} : \quad & w_R(R_i) = \lambda, \end{aligned}$$

where $v_l(f(l_i))$ is the partial derivative of $v(f(l_i))$ with respect to l_i , and $w_R(R_i)$ is the partial derivative of $w(R_i)$ with respect to R_i . Combining these three equations and simplifying the results leads to the two optimality conditions

$$(A14) \quad \kappa_i = \frac{1}{2\mu} \ln \left(\frac{2\sigma_c^2 \mu v(f(l_i))}{w_R(R_i)} \right),$$

$$(A15) \quad w_R(R_i) = \frac{2A\mu v(f(l_i)) v_l(f(l_i))}{2\mu v(f(l_i)) + v_l(f(l_i))}.$$

The result in Proposition 1 can now be derived as follows. First, rewrite equations (A14) and (A15) in the form

$$(A16) \quad f(l, R, \mu) = 2\sigma_c^2 \mu e^{-2\mu(T-l-R)} v(f(l_i)) - w_R(R_i) = 0,$$

$$(A17) \quad g(l, R, \mu) = \frac{1}{w_R(R_i)} - \frac{1}{A v_l(f(l_i))} - \frac{1}{2A\mu v(f(l_i))} = 0,$$

where l and R are variables, μ is a parameter that may change, and A , T and σ_c^2 are constants. Equations (A16) and (A17) define implicitly l and R as functions of μ . A solution $(l^*(\mu), R^*(\mu))$ to the system of two equations (A16) and (A17) must fulfil $f(l^*(\mu), R^*(\mu), \mu) = 0$ and $g(l^*(\mu), R^*(\mu), \mu) = 0$ for all μ . Without specifying explicitly $v(\cdot)$ and $f(\cdot)$, it is not possible to solve for $l^*(\mu)$ and $R^*(\mu)$. Nevertheless, for small changes in μ , the associated changes in $l^*(\mu)$ and $R^*(\mu)$ can be calculated using the implicit function theorem. Taking the differential on each side of the equations $f(l, R, \mu) = 0$ and $g(l, R, \mu) = 0$ gives

$$\begin{aligned} f_l \cdot dl + f_R \cdot dR + f_\mu \cdot d\mu &= 0, \\ g_l \cdot dl + g_R \cdot dR + g_\mu \cdot d\mu &= 0. \end{aligned}$$

Solving for $dl/d\mu$ leads to the expression

$$(A18) \quad \frac{dl}{d\mu} = \frac{-g_R \cdot f_\mu + f_R \cdot g_\mu}{f_l \cdot g_R - f_R \cdot g_l}.$$

The partial derivatives in equation (A18) can be calculated as

$$\begin{aligned} f_l &= 2\mu\sigma_c^2 e^{-2\mu(T-l-R)}(2\mu v + v_l), \\ f_R &= 4\mu^2\sigma_c^2 v e^{-2\mu(T-l-R)} - w_{RR}, \\ f_\mu &= 2\sigma_c^2 v e^{-2\mu(T-l-R)}[1 - 2\mu(T-l-R)], \\ g_l &= \frac{v_{ll}}{Av_l^2} + \frac{v_l}{2A\mu v^2}, \\ g_R &= -\frac{w_{RR}}{w_R^2}, \\ g_\mu &= \frac{1}{2Av\mu^2}. \end{aligned}$$

Note that, for ease of exposition, the arguments of the partial derivatives have been omitted. Strict concavity of the functions $v(\cdot)$ and $w(\cdot)$ implies that $f_l, f_R, g_R, g_\mu > 0$. In addition, the parameter restrictions introduced in the third subsection of Section II ensure that $f_\mu, g_l < 0$. Using these results in equation (A18) shows that $dl/d\mu > 0$. Thus the equilibrium value of l depends positively on the parameter μ . This completes the proof of Proposition 1.

Proof of Proposition 2

As shown in the previous subsection, the rationally inattentive social planner selects for each household i the consumption good $c_i = E[c_i^*|s_i]$, where the signal is given by $s_i = c_i^* + \varepsilon_i$ with $c_i^* \sim \mathcal{N}(0, \sigma_c^2)$ and $\varepsilon_i \sim \mathcal{N}(0, \sigma_\varepsilon^2)$. In the Gaussian case considered here, the conditional expectation of c_i^* given s_i equals

$$(A19) \quad E[c_i^*|s_i] = E[c_i^*] + \frac{\text{cov}(s_i, c_i^*)}{\text{var}(s_i)} (s_i - E[s_i]).$$

It can be verified easily that $\text{cov}(s_i, c_i^*) = \sigma_c^2$ and $\text{var}(s_i) = \sigma_c^2 + \sigma_\varepsilon^2$. Plugging these expressions into equation (A19) gives

$$(A20) \quad E[c_i^*|s_i] = \frac{\sigma_c^2}{\sigma_c^2 + \sigma_\varepsilon^2} (c_i^* + \varepsilon_i).$$

For normally distributed random variables, it also holds that the conditional variance takes the form

$$(A21) \quad \sigma_{c_i^*|s}^2 = \text{var}(c_i^*) - \frac{\text{cov}(c_i^*, s_i) \text{cov}(s_i, c_i^*)}{\text{var}(s_i)}.$$

Using the results from above to simplify equation (A21) leads to

$$(A22) \quad \sigma_{c_i^*|s}^2 = \sigma_c^2 \left(1 - \frac{\sigma_c^2}{\sigma_c^2 + \sigma_\varepsilon^2} \right).$$

From equation (A10), we also know that

$$(A23) \quad \sigma_{c_i^*|s}^2 = \sigma_c^2 e^{-2\mu\kappa_i}.$$

Finally, using equations (A22) and (A23) to simplify the expression in equation (A20) shows that the good consumed by household i is given by

$$c_i = (1 - e^{-2\mu\kappa_i})(c_i^* + \varepsilon_i),$$

where $(1 - e^{-2\mu\kappa_i}) \in [0, 1]$. Hence the value of c_i is dampened in magnitude relative to c_i^* (as well as noisy), and the range of goods c_i consumed across all households is smaller than the range of the preferred goods c_i^* . This completes the proof of Proposition 2.

Proof of Proposition 3

Plugging the information technology (16) into the utility function (14) by using the same derivations as shown in equations (A9)–(A11), and letting θ denote the Lagrange multiplier of constraint (15), the first-order conditions of the household's maximization problem can be derived as

$$\begin{aligned} \{\kappa_i\} : \quad & 2\sigma_c^2 \mu e^{-2\mu\kappa_i} v(q(c_i)) = \theta\omega, \\ \{q(c_i)\} : \quad & (A - \sigma_c^2 e^{-2\mu\kappa_i}) v_q(q(c_i)) = \theta, \\ \{R_i\} : \quad & w_R(R_i) = \theta\omega. \end{aligned}$$

Combining these three equations and simplifying the results leads to the two optimality conditions

$$(A24) \quad \kappa_i = \frac{1}{2\mu} \ln \left(\frac{2\sigma_c^2 \mu v(q(c_i))}{w_R(R_i)} \right),$$

$$(A25) \quad w_R(R_i) = \frac{2A\mu\omega v(q(c_i)) v_q(q(c_i))}{2\mu v(q(c_i)) + \omega v_q(q(c_i))}.$$

Each firm j chooses its labour input z_j so as to maximize its profits subject to the available production technology $f(z_j)$. With competitive markets, the firms' optimal labour demand is thus given by

$$f_z(z_j) = \omega.$$

In the market equilibrium, each firm produces the good for exactly one household (recall that households prefer different goods, each firm can produce a single good, and there are as many firms as households). Since each firm has access to the same production technology and there is competition among firms, the equilibrium price of every produced good will set the firm's profit equal to zero. Moreover, firms are indifferent for which particular household they produce (and households are indifferent by which firm their good is produced). In the same way, it does not matter for which firm a household works as wages are the same across firms. Thus any bijective mapping between households and firms is consistent with the optimality conditions of households and firms. Without loss of generality, let $z_j = l_i$ for $j = i$, and $q(c_i) = f(l_i)$.

Plugging $\omega = f_l(l_i)$ into equations (A24) and (A25), and noting that in equilibrium, $v(q(c_i)) = v(f(l_i))$ and $v_q(q(c_i))\omega = v_l(f(l_i))$, shows that the allocation achieved in a market economy is characterized by the same optimality conditions as the allocation chosen by a rationally inattentive social planner (i.e. equations (A14) and (A15)). Thus as long as market economies feature higher values of μ than planned economies, one can use the derivations described in the second part of the proof of Proposition 1 (i.e. starting with equations (A16) and (A17)) to show that $l_i^M > l_i^{SP}$ and $q_i^M(c_i) > q_i^{SP}(c_i)$. The level of social welfare is higher in the market economy than in SP since with $\mu^M > \mu^{SP}$, every allocation that can be attained in SP can be attained in a market economy with even fewer resources. For the same reason, it follows from the proof of Proposition 2 that the range of different goods produced in a market economy is larger than the range of goods produced in SP . In the case of full information (i.e. $\mu \rightarrow \infty$), it holds naturally that $l_i^M = l_i^{SP}$ and $q^M(c_i) = q^{SP}(c_i)$. This completes the proof of Proposition 3.

Gaussian signals with non-quadratic objective

The social planning problem under rational inattention described in the third subsection of Section II restricts information processing to Gaussian signals. In general, such a signal structure is optimal only if the prior uncertainty about the fundamental is Gaussian and the objective is quadratic (Sims 2006). Whether the latter holds in the model depends on the specification of $v(\cdot)$ and $w(\cdot)$. If these are such that the utility function (11) is not quadratic, then the results derived under Gaussian signals provide only an approximation of the behaviour that would arise under an optimal signal structure. In particular, Mackowiak and Wiederholt (2009, p. 794) argue that even with a non-quadratic objective, Gaussian

signals provide a good approximation when the marginal value of information flow is low. In addition, in the model studied here, the bias arising from a suboptimal signal structure works in a particular direction, which implies that the resulting solution can be interpreted as providing a bound to the quantitative role that costly information processing plays in the model.

To see this, notice that a suboptimal signal structure has the same impact in the model as a smaller value of the cost parameter μ . Specifically, both a suboptimal signal structure and a smaller value of μ imply that more resources $\bar{\kappa}(c_i^*)$ are required to achieve a given reduction in uncertainty (measured by entropy) about the realization of c_i^* . (Also recall that preferences are idiosyncratic, i.e. c_i^* is drawn independently for each i , so there is no scope for alternative signals to improve upon Gaussian signals other than through a lower total amount of resources needed to reduce uncertainty about each c_i^* .) The impact of a suboptimal signal structure on the planner's allocation thus works in the same direction as the impact of a smaller value of μ . Given the results in Proposition 1, this implies that a suboptimal signal structure leads to lower values of l_i and $q(c_i)$ than those that would be chosen by a planner with access to an *optimal* signal structure (i.e. access to a less costly information processing technology). Put differently, the value of $q(c_i)$ arising under Gaussian signals represents a lower bound to the value of $q(c_i)$ that would prevail under costly information processing (with the same value of μ) and an *optimal* signal structure.

Simplified model

This subsection sketches a highly simplified version of the model in Section II that abstracts from the mechanism by which the central planner can reduce uncertainty about households' preferences. Instead of specifying a particular information technology (such as the entropy-based technology used above), the stylized model simply assumes that the utility derived from consuming $q(c_i)$ is higher, the more time κ_i is devoted to learning about the preferences of household i . In this simplified model, the utility function is given by

$$(A26) \quad u(\kappa_i, q(c_i), R_i) = x(\kappa_i) v(q(c_i)) + w(R_i),$$

where $x(\kappa_i)$ is a real-valued function that is increasing and concave in κ_i , and bounded by the finite values $\bar{x} > \underline{x} \geq 0$. When $\kappa_i = 0$, $x(\kappa_i) = \underline{x}$. As κ_i increases from zero, $x(\kappa_i)$ goes to the maximum value \bar{x} . The functions $v(\cdot)$ and $w(\cdot)$ have the same properties as specified in the first subsection of Section II.

The social planning problem consists in choosing the allocation of resources (κ_i, l_i, R_i) for each household so as to maximize the sum of households' utility defined by equation (A26) subject to the constraints (7), (8) and (10). Notice that this corresponds to a deterministic time allocation problem, that is, there is no uncertainty in this problem, nor any theoretical structure that would allow me to study the roles of information-related aspects of the economy in determining optimal production decisions (e.g. the role of correlation in consumers' preferences discussed in the final subsection of Section II).

Using the same arguments of symmetry as in the fourth subsection of the Appendix, let the solution to the social planning problem feature $z_j = l_i$ for $j = i$, and $q(c_i) = f(l_i)$. The first-order conditions are then given by

$$(A27) \quad \{\kappa_i\} : x_{\kappa}(\kappa_i) v(f(l_i)) = \eta,$$

$$(A28) \quad \{l_i\} : x(\kappa_i) v_l(f(l_i)) = \eta,$$

$$(A29) \quad \{R_i\} : w_R(R_i) = \eta,$$

where η is the Lagrange multiplier of the time budget constraint (10). Together, these three conditions imply that, in optimum, the central planner must be indifferent between devoting an additional unit of time to processing information, devoting additional time to producing consumption goods, and using additional time as leisure. (If this were not the case, then the central planner could achieve higher social welfare by reallocating time from one of these three activities to another one.)

Combining equations (A28) and (A29) leads to the optimality condition

$$(A30) \quad \frac{w_R(R_i)}{v_l(f(l_i))} = x(\kappa_i).$$

Let us compare equation (A30) to the corresponding optimality condition that would arise if $x(\kappa_i)$ was fixed to \bar{x} , that is, if there was no need for the central planner to allocate resources to κ_i . In this case (which can be thought of as representing the case of full information), combining the first-order conditions with respect to l_i and R_i leads to an expression equivalent to equation (A30), but where the right-hand side of the equation is given by \bar{x} instead of $x(\kappa_i)$.

We can now use the fact that $x(\kappa_i) < \bar{x}$ to show that the value of l_i must be smaller in the first case (where resources κ_i are needed to achieve higher values of $x(\kappa_i)$) than in the second case (where $x(\kappa_i)$ is fixed to \bar{x}). For ease of exposition, let the variables corresponding to the first case be denoted with a tilde, so that it holds that

$$(A31) \quad \frac{w_R(\tilde{R}_i)}{v_l(f(\tilde{l}_i))} < \frac{w_R(R_i)}{v_l(f(l_i))}.$$

In addition, it must hold that

$$(A32) \quad \tilde{l}_i + \tilde{R}_i \leq l_i + R_i,$$

since the first case features $\tilde{\kappa}_i \geq 0$, the second case features $\kappa_i = 0$, and in both cases resources must add up to T . Now notice that there are three possible ways in which inequality (A31) might be fulfilled in general:

- (i) $w_R(R_i) > w_R(\tilde{R}_i)$ and $v_l(f(l_i)) < v_l(f(\tilde{l}_i))$;
- (ii) $w_R(R_i) < w_R(\tilde{R}_i)$ and $v_l(f(l_i)) < v_l(f(\tilde{l}_i))$;
- (iii) $w_R(R_i) > w_R(\tilde{R}_i)$ and $v_l(f(l_i)) > v_l(f(\tilde{l}_i))$.

Given that $v(\cdot)$ and $w(\cdot)$ are strictly increasing and strictly concave, the inequality $w_R(R_i) > w_R(\tilde{R}_i)$ implies that $R_i < \tilde{R}_i$. In the same way, $v_l(f(l_i)) > v_l(f(\tilde{l}_i))$ implies $l_i < \tilde{l}_i$. Thus case (iii) would lead to the result that $\tilde{l}_i + \tilde{R}_i > l_i + R_i$, which is contradictory to restriction (A32). Therefore the optimal allocations must be characterized by either (i) or (ii). In each case, it holds that $\tilde{l}_i < l_i$ and thus also $\tilde{q}(c_i) < q(c_i)$.

This result mirrors the results in Propositions 1 and 3, in the sense that it implies that economic systems that require more resources to guarantee that produced goods are valued highly by consumers will feature lower levels of production and less labour input going into production than economies without a need to spend resources to guarantee that the produced goods are valued highly.

ACKNOWLEDGMENTS

I thank Mirko Wiederholt, seminar participants at University College Dublin and Beijing University of Technology, and several anonymous referees for helpful comments and suggestions. Open Access funding enabled and organized by Projekt DEAL.

NOTES

1. The conjecture of the first welfare theorem can, of course, be traced back to Adam Smith's *The Wealth of Nations*; in 1776, Smith did not have access to the mathematical tools needed to state and prove the theorem rigorously.
2. Factors commonly studied in this context include imperfect competition, information asymmetries, transaction costs, and externalities.
3. I use the terms 'planned economy', 'centrally planned economy' and 'centralized economy' interchangeably when referring to an economic system where production decisions are determined by a central authority (e.g. the government) rather than by interactions in free markets.
4. See Stiglitz (1996) and the literature on 'market socialism' summarized by Persky (1991) and Rothbard (1991), as well as Hayek (1945), who highlighted the role of prices as a mechanism for reducing information needs.

5. There may be several reasons for this. With the collapse of the Soviet Union in 1991, much of the political relevance of analysing the role of information frictions in centralized economies became obsolete, but many important contributions to the economics of information were made only more recently, including fundamental insights on the endogeneity of beliefs, information asymmetries, and the structure of information processing (see Stiglitz 2017; Handel and Schwartzstein 2018). In the absence of a meaningful real-world application, the purpose of the concept of a social planner in economics is reduced to serving as a hypothetical benchmark in theoretical work, which by definition does not need to be made 'more realistic'. The recent development successes of some East Asian economies involving strong elements of government intervention in markets (see Wade 1990) might be seen as providing a new motivation to revisit the role of costly information processing in centralized economic systems.
6. For a detailed overview of the different approaches to information processing used in economics, including a comprehensive discussion of the assumptions, limitations and benefits of the rational inattention approach, I refer to the surveys provided in Handel and Schwartzstein (2018), Maćkowiak *et al.* (2018) and Kőszegi and Matějka (2020).
7. Specifically, for this case I assume that part of households' time endowment has to be spent on communicating the consumption preferences to firms. This reduces the time available to work at a firm producing goods or to enjoy leisure.
8. The categories are: *statist*, *mixed statist*, *mixed capitalist–statist*, *capitalist–statist*, *mixed capitalist*, and *capitalist*.
9. This aggregation also makes sense because some of the six original categories comprise only two or three countries in some years.
10. Available at <https://datacatalog.worldbank.org/dataset/worldwide-bureaucracy-indicators> (accessed 4 August 2022).
11. For example, in 2010, greater economic freedom was positively correlated with log GDP per capita (0.666) and with product variety (0.510), but negatively correlated with hours worked (−0.390).
12. While the coefficient of *Capitalist* does not differ from that of mixed economies at standard significance levels, it is statistically different from the estimate for *Statist* at the 1% significance level.
13. Similar to column (1) of Table 1, the coefficient of *Capitalist* does not differ from that of mixed economies, but it is statistically different from the estimate for *Statist* at the 1% significance level.
14. Throughout the paper, I focus on a utilitarian objective function with equal weights for each household. The robustness of the main results to alternative weightings is discussed in the third subsection of Section II.
15. As shown in the second subsection of the Appendix, it does not matter which households are assigned to process information about any particular household's consumption preferences.
16. This condition applies, in general, as long as c_i^* is independent across households (the final subsection of Section II discusses what happens if this assumption is relaxed). Notice also that condition (5) corresponds to a standard choice problem under uncertainty. In the rational inattention literature, this is sometimes referred to as the second-stage problem, while choosing the allocation of attention is called the first-stage problem (Matějka and McKay 2015; Naeher 2022).
17. This second trade-off is similar to the trade-off between consumption and leisure in standard models without uncertainty about households' preferences. However, the difference here is that consumption is defined not just in terms of the quantity of a single good but in terms of preferences over a variety of goods.
18. At the same time, the stylized model in the final subsection of the Appendix does not allow us to derive any insights on the role of the structure of uncertainty (e.g. the results on uncertainty reduction in the presence of correlated preferences discussed in the final subsection of Section II).
19. Gaussian signals are, in general, optimal only if the prior uncertainty about the fundamental is Gaussian and the objective is quadratic (Sims 2006). If $v(\cdot)$ and $w(\cdot)$ are such that the utility function (11) is not quadratic, then the results can be interpreted as providing a bound to the quantitative role that costly information processing plays in the model (see the discussion in the Appendix).
20. The entropy of a Gaussian random variable with variance σ^2 is given by $\frac{1}{2} \log(2\pi e\sigma^2)$.
21. For example, μ may capture the quality of the information infrastructure available in a country, where higher values of μ indicate better infrastructure (e.g. higher mobile phone and internet penetration rates).
22. Note that the first inequality, $\mu > (v_l/v) ((e/\sigma_c^2) - \frac{1}{2})$, will always be fulfilled in the model if the parameter T takes a sufficiently large value for given values of μ and σ_c^2 . This holds, because higher values of T eventually lead to higher values of l , so that the ratio of v_l and v is decreasing in T for any strictly concave function $v(l)$. The second inequality, $\mu > -v_l^3/(2v^2v_{ll})$, is less straightforward since the expression on the right-hand side may, in general, not be monotonic in l . However, using the derivations in the second subsection of the Appendix, it is easy to verify that this condition holds for commonly used utility functions, e.g. when v is a logarithmic or square-root-shaped function and $\mu \geq 1$.
23. In addition, a change in μ may affect the optimal value of κ_i . The direction of this effect is ambiguous and depends on the value of μ as well as the specifications of the utility and production function. At low levels of μ , an increase in μ can initially make it more attractive to allocate additional resources to κ_i . At higher levels of μ , this effect vanishes because the term $[A - (c_i - c_i^*)^2]$, which is increasing in κ_i (see the second subsection of the Appendix) is bounded from above by A . In principle, an increase in μ that leads to an increase in κ_i may thus work towards reducing l_i . However, the proof of Proposition 1 shows that under the assumptions made (including the parameter restrictions discussed in note 22), any such effect is dominated by the two effects

described above, so that the overall effect of an increase in μ on l_i is unambiguously positive. In contrast, the direction of the overall effect of an increase in μ on R_i is, in general, ambiguous, and depends on the specifications of the utility and production function.

24. Notice that in the central planner's problem, κ_i denotes the time that household i spends on collecting and processing information about the preferences of any households (and $\bar{\kappa}(c_i^*)$ denotes the total amount of time that is allocated to processing information about a particular c_i^*). In the case of a market economy, κ_i denotes the time that household i spends on communicating its own preferences to a firm. Thus in the market economy, κ_i represents the time that household i needs to spend to provide a firm with a signal that reduces the firm's uncertainty about c_i^* by the amount of entropy specified in equation (13).
25. For example, Stiglitz (1996, p. 153) argues that: 'Market economies are decentralized: production decisions occur in millions of firms, and consumption decisions occur in millions of households. No one has to know the preferences of all consumers. No one has to know the production capabilities of all firms. This is one of the great advantages of market economies.'
26. The analysis does not attempt to justify or derive endogenously $\mu^{\tilde{M}} > \mu^{\tilde{P}}$.
27. In fact, one may argue that the special case of a market economy considered here abstracts from the information value of prices altogether, by focusing on a symmetric setup where all prices can be normalized to 1.
28. The model presented in the final subsection of the Appendix shows furthermore that most of these results can be generalized in a framework that does not rely on a particular type of information technology.
29. Correlation here refers to dependence in an information-theoretic sense, i.e. including all forms of stochastic dependence (not just linear dependence as captured, for example, by the Pearson correlation coefficient).
30. For example, in the extreme case where preferences are perfectly correlated, the social planner has to process information only about a single household to learn equally about the preferences of all households.
31. In principle, the prediction that the degree of correlation in consumer preferences will be positively related to households' welfare in planned economies but not in market economies could be tested by regressing a measure of consumer welfare on an interaction term of two variables capturing the degree of correlation in consumer preferences and the type of economic system. Unfortunately, I do not have access to adequate data for performing such a test.
32. Such efforts range from promoting uniform dress styles to idealizing asceticism and opposing individualism in consumerism, claiming to protect traditional values and styles (Betts 2014), and to guard against the 'winds of extravagance and habits of luxury' (Stearns 2009, p. 66).
33. Note that while the model shows that there can be economic motives for planners to align consumer preferences, it does not provide any insights on whether it is actually possible for governments to influence preferences or not. For a discussion of the determinants of individuals' preferences, I refer to the literature on endogenous preferences and tastes (e.g. Bowles 1998; Alesina and Fuchs-Schündeln 2007; Fehr and Hoff 2011).
34. Notice that this applies to all forms of planning, including centralized, decentralized and participatory forms of economic planning. The degree to which it applies, however, might differ across different forms of planning (e.g. relying on the participation of firms and households might help to mitigate the misalignment in information and decision-making that exists under fully centralized planning).
35. Notice that households are indifferent between working to produce consumption goods and working an equal amount of time to process information. Thus it is not a necessary feature of a solution that each household spends the same amount of time on each of these two activities. However, assuming that they do does not lead to a loss of generality regarding the results for any other variables in the model.

REFERENCES

- ALESINA, A. and FUCHS-SCHÜNDELN, N. (2007). Goodbye Lenin (or not?): the effect of communism on people's preferences. *American Economic Review*, **97**(4), 1507–28.
- ANGELETOS, G.-M. and SASTRY, K. (2019). Inattentive economies. NBER Working Paper no. 26413.
- ARROW, K. J. (1951). An extension of the basic theorems of classical welfare economics. In J. Neyman (ed.), *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*. Oakland, CA: University of California Press, pp. 507–32.
- BARRO, R. J. (1991). Economic growth in a cross section of countries. *Quarterly Journal of Economics*, **106**(2), 407–43.
- BETTS, P. (2014). The politics of plenty: consumerism in communist societies. In S. A. Smith (ed.), *Oxford Handbook of the History of Communism*. Oxford: Oxford University Press, pp. 424–37.
- BICK, A., FUCHS-SCHÜNDELN, N. and LAGAKOS, D. (2018). How do hours worked vary with income? Cross-country evidence and implications. *American Economic Review*, **108**(1), 170–99.
- BLANCHARD, O. and KREMER, M. (1997). Disorganization. *Quarterly Journal of Economics*, **112**(4), 1091–126.
- BOWLES, S. (1998). Endogenous preferences: the cultural consequences of markets and other economic institutions. *Journal of Economic Literature*, **36**(1), 75–111.
- CADOT, O., CARRÈRE, C. and STRAUSS-KAHN, V. (2011). Export diversification: what's behind the hump? *Review of Economics and Statistics*, **93**(2), 590–605.

- COVER, T. M. and THOMAS, J. A. (1991). *Elements of Information Theory*. New York: John Wiley and Sons.
- FEENSTRA, R., INKLAAR, R. and TIMMER, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, **105**(10), 3150–82.
- and KEE, H. L. (2004). On the measurement of product variety in trade. *American Economic Review*, **94**(2), 145–9.
- FEHR, E. and HOFF, K. (2011). Tastes, castes and culture: the influence of society on preferences. *Economic Journal*, **121**(556), F396–F412.
- FELDMAN, A. M. and SERRANO, R. (2006). *Welfare Economics and Social Choice Theory*. New York: Springer Science & Business Media.
- FREEDOM HOUSE (2003). *Freedom in the World 2003: The Annual Survey of Political Rights and Civil Liberties*. Lanham, MD: Rowman & Littlefield Publishers.
- FUCHS-SCHÜNDELN, N. and SCHÜNDELN, M. (2020). The long-term effects of communism in Eastern Europe. *Journal of Economic Perspectives*, **34**(2), 172–91.
- FUNKE, M. and RUHWEDDEL, R. (2001). Product variety and economic growth: empirical evidence for the OECD countries. *IMF Staff Papers*, **48**(2), 225–42.
- GROSSMAN, S. J. and STIGLITZ, J. E. (1980). On the impossibility of informationally efficient markets. *American Economic Review*, **70**(3), 393–408.
- HALL, R. E. and JONES, C. I. (1996). The productivity of nations. NBER Working Paper no. 5812.
- HANDEL, B. and SCHWARTZSTEIN, J. (2018). Frictions or mental gaps: what's behind the information we (don't) use and when do we care? *Journal of Economic Perspectives*, **32**(1), 155–78.
- HAYEK, F. A. (1945). The use of knowledge in society. *American Economic Review*, **35**(4), 519–30.
- HERITAGE FOUNDATION (2019). *2019 Index of Economic Freedom: 25th Anniversary Edition*. Washington, DC: Heritage Foundation.
- IMBS, J. and WACZIARG, R. (2003). Stages of diversification. *American Economic Review*, **93**(1), 63–86.
- KORNAI, J. (1998). The place of the soft budget constraint syndrome in economic theory. *Journal of Comparative Economics*, **26**(1), 11–17.
- KŐSZEGI, B. and MATĚJKA, F. (2020). Choice simplification: a theory of mental budgeting and naive diversification. *Quarterly Journal of Economics*, **135**(2), 1153–207.
- LANGE, O. (1942). The foundations of welfare economics. *Econometrica*, **10**(3), 215–28.
- LERNER, A. (1934). The concept of monopoly and the measurement of monopoly power. *Review of Economic Studies*, **1**(3), 157–75.
- LIPNOWSKI, E., MATHEVET, L. and WEI, D. (2020). Attention management. *American Economic Review: Insights*, **2**(1), 17–32.
- MAĆKOWIAK, B., MATĚJKA, F. and WIEDERHOLT, M. (2018). Survey: rational inattention, a disciplined behavioral model. *Working Paper*.
- and WIEDERHOLT, M. (2009). Optimal sticky prices under rational inattention. *American Economic Review*, **99**(3), 769–803.
- MATĚJKA, F. and MCKAY, A. (2015). Rational inattention to discrete choices: a new foundation for the multinomial logit model. *American Economic Review*, **105**(1), 272–98.
- NAEHER, D. (2022). Technology adoption under costly information processing. *International Economic Review*, **63**(2), 699–753.
- PERSKY, J. (1991). Retrospectives: Lange and von Mises, large-scale enterprises, and the economic case for socialism. *Journal of Economic Perspectives*, **5**(4), 229–36.
- ROLAND, G. (2000). *Transition and Economics: Politics, Markets, and Firms*. Cambridge, MA: MIT Press.
- ROTHBARD, M. N. (1991). The end of socialism and the calculation debate revisited. *Review of Austrian Economics*, **5**(2), 51–76.
- SALA-I MARTIN, X. X. (1997). I just ran four million regressions. NBER Working Paper no. 6252.
- SIMS, C. A. (2003). Implications of rational inattention. *Journal of Monetary Economics*, **50**(3), 665–90.
- (2006). Rational inattention: beyond the linear-quadratic case. *American Economic Review*, **96**(2), 158–63.
- STEARNS, P. N. (2009). Consumerism. In J. Peil and I. van Staveren (eds), *Handbook of Economics and Ethics*. Cheltenham: Edward Elgar, pp. 62–76.
- STIGLITZ, J. E. (1996). *Whither Socialism?* Cambridge, MA: MIT Press.
- (2017). The revolution of information economics: the past and the future. NBER Working Paper no. 23780.
- WADE, R. (1990). *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization*. Princeton, NJ: Princeton University Press.
- WEIL, D. (2013). *Economic Growth*. London: Pearson.