

# A short summary of Price Theory\*

as commissioned by the *Journal of Economic Literature*

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## Abstract

I propose an alternative to the conventional definition of “price theory” as price-taking in partial equilibrium. Instead I define it as a methodological approach that derives a small collection of “prices” sufficient to characterize low-dimensional allocative problems in rich aggregate economies. A classic example is optimal income taxation formulas based on summary elasticities of taxable income and measures of inequality. This definition derives from a tight analogy to thermodynamics in physics and contrasts both with “reductionism” (e.g. game theory) that seek more complete characterizations of lower-dimensional economies and reduced-form “empiricism” that builds off of available empirical evidence. I use recent research from fields ranging from market design to international trade to highlight this definition and both the contrasts and complementarities of such price theory with empiricism and reductionism. I then argue that this schema helps make sense of the historical evolution of price theory during the 19th and 20th centuries, especially its interaction with the other traditions during the last half century, when price theory was closely identified with the University of Chicago. I conclude by expediting the analytic tools of price theory.

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This project is dedicated to the memory of Gary S. Becker, who first inspired my interest in price theory.

This is a short summary, prepared for the purpose of soliciting comments and suggestions, of a piece I am preparing at the request of the *Journal of Economic Literature*. Such feedback is therefore extremely welcome. The eventual paper will be about five times longer than this summary, covering approximately 45-50 pages of text and will probably include about 2-3 times the references in this summary.

## I Introduction

Price theory is typically defined (Hammond et al., 2013) as the analysis of price-taking behavior in partial equilibrium. I was therefore surprised when most of the price theory course I took from Gary Becker and Kevin Murphy was concerned with general equilibrium or imperfect competition. Furthermore, much of the research in recent years most closely identified with price theory, including my own, has focused on “simple” models of these supposedly non-price theoretic topics. This paper therefore aims to provide an alternative definition that more accurately matches the way the phrase is used in practice, especially by those who self-identify with the tradition. In particular I respond to the repeated objections Becker expressed to me regarding the traditional definition and his emphasis on identifying the most important “simple” features of markets that aggregate individual behavior.

This emphasis on simplification through aggregation is familiar from other sciences, particularly thermodynamics in physics. While the “reductionist” classical mechanics developed by Newton (1687) are widely acknowledged to have revealed the mechanisms exploited productively during the industrial revolution, his techniques were only capable of analyzing the behavior of one- or two-body systems. To optimize the extraction of power from bodies with many interacting particles, like the steam engines discovered through “empiricist” experimentation in the 18th century by James Watt, Carnot (1824) devised thermodynamics. This field summarized many the detailed “micro-states” of such systems into a small number of “macro-states” sufficient for determining the energy that could be extracted by such a heat engine. Price theory originates in the work of Jules Dupuit, a schoolmate of Carnot’s (Ekelund and Hébert, 1999). Dupuit (1844) defined similarly parsimonious summaries (such as consumer surplus and deadweight loss) sufficient to determine the maximum social value that could be achieved by placing the bridges over which railroads powered by Carnot’s engines would travel.

In fact, Mill (1843), the other founding figure in price theory, identified Carnot’s work as the leading exemplar of the general scientific strategy of “emergentism”, in contrast to

the better-known approaches of empiricism and reductionism. Translating his definition into economic terms, I define price theory as an approach to economic analysis that derives a small set of “prices” sufficient to characterize low-dimensional equilibrium and optimization problems in high-dimensional aggregate economic systems. von Mises (1920) and Hayek (1945) famously argued that such prices dramatically reduce the informational requirements of organizing the allocation of resources in market economies. However, as Marschak (1953) pointed out, low-dimensional statistics can be used to summarize the information needed to allocate resources well beyond currency-denominated markets for private goods, regardless, or even because, of how rich the underlying economy is, so long as the allocation problem itself is low-dimensional. I will argue that contemporary price theory is concerned with deriving such tractable representations in increasingly rich environments (e.g. with richer temporal structures, heterogeneity or less typically “economic” features) and for allocative questions of contemporary interest (e.g. capturing notions of equality of opportunity or regulation of wasteful speculation).

A classic example of the price theoretic approach, which I plan to exposit formally in the introduction, is Dixit and Sandmo (1977)’s characterization of optimal linear income taxes in terms of two prices: the elasticity of taxable income with respect to the tax rate and an endogenous measure of post-tax-and-transfer income inequality. Their work was inspired by and drew on both the extensive empirical literature measuring inequality and a theoretical literature epitomized by Mirrlees (1971) that derived optimal income taxes from primitives of utility functions. However, it took a clearly distinctive approach, because Mirrlees sought to fully characterize optimal non-linear taxes given a model with a single dimension of heterogeneity (in ability). By contrast, Dixit and Sandmo considered a much richer model while focusing on the optimal level of a linear tax, rebated lump sum back to all members of the population. Their work also clearly contrasted with the empirical literature, as the measure of inequality they derive was motivated by the policy question they considered and thus does not line up cleanly with standard empirically-motivated measures of inequality, such as the Gini coefficient.

While Dixit and Sandmo’s approach was largely ignored during the following two decades, it has recently been revived (Saez, 2001; Chetty, 2009) through its connection to empirical measurements in intervening years and has become the basis of much recent work in public finance. This is true in many other fields of economics as well. With the rise of game theory, the identification revolution in econometrics and computational techniques that expanded the range of feasible structural modeling, price theory declined, and became increasingly narrowly associated with the University of Chicago, during the quarter century following 1980. However, in the past decade the crucial role of price theory in complementing the

other approaches has increasingly been appreciated and even celebrated: five of the last six winners of the John Bates Clark Medal were in part recognized for contributions that fit comfortably into my definition of price theory. Thus, despite the passing of one of its leading figures, it appears price theory is experiencing a renaissance.

## II An Illustrated Definition

This section, to which I plan to devote approximately 10 pages, will use work from this renaissance in a wide range of fields to clarify the definition to economists working in these disparate areas. I will use these to explain and illustrate my objections to the standard definition of price theory, the aspects of my definition and both the contrasts and complementarity of price theory with reductionism and empiricism. I will begin by discussing two recent contributions that strongly and clearly identify with price theory, but that simultaneously are explicitly focused on general equilibrium effects (Goulder and Williams III, 2003) and imperfect competition (Farrell and Shapiro, 2010).

I will then use three recent price theoretic papers (Gentzkow and Shapiro, 2010; Einav et al., 2012; Azevedo and Leshno, 2013) from different fields of economics (political economy, industrial organization and market design, respectively) to highlight the key elements of my definition. Namely I will illustrate how each paper considers a *low-dimensional allocative problem* in a *formally rich economic environment* where far higher-dimensional questions *could have been asked* and are thereby able to characterize these problems in terms of a small set of *prices*. I will relate each to the idea that, like thermodynamics, price theory focuses on “high entropy” systems where only relatively few features of an environment are of interest to the analyst.

To further clarify the distinctiveness of this approach, I will use examples to contrast classic price theoretic studies with closely related studies of similar or even the same issues using the other approaches. First, I will highlight a contrast with reductionism, in particular game theory and Revelation Principle-based mechanism design, through the classic work of Bulow and Roberts (1989) who analyze the same issues as Myerson (1981), but using a very different methodological perspective. As a result, each led to a different literature, pursuing emergentist (Bulow and Klemperer, 1996; Bulow et al., 1999; Klemperer, 2002; Bulow and Klemperer, 2009) and reductionist (Cr mer and McLean, 1988; Dasgupta and Maskin, 2000; Bergemann and Morris, 2005) questions respectively, in recent years. Second, I will contrast two papers on the same topic, in the same year with two overlapping authors, but where one takes a reductionist structural approach and the other takes a price theoretic approach. Einav et al. (2010b) and Einav et al. (2010a) both consider insurance, but while Einav et al.

(2010b) build a fully-specified, and thus necessarily restrictive, low entropy structural model that allows them to consider a wide range of discriminating policy interventions, Einav et al. (2010a) allow a richer high entropy environment at the cost of only being able to consider uniform subsidies and mandates. Finally, I will consider a contrast with empiricism, again sharing an author. Chetty and Saez (2005) study the empirical impact of the 2003 dividend tax cut on dividend payments, plausibly motivated by optimal tax considerations but with no explicit normative model or welfare concern, taking a classically empiricist approach. By contrast, Chetty (2008) tightly links the measurements of worker liquidity and moral hazard to his model (Baily, 1978; Chetty, 2006) of optimal unemployment insurance.

By using these overlapping authors, I hope to highlight the value that leading price theorists clearly attribute to and gain from the other approaches. Despite this, an emphasis on the contrasts between the approaches still risks obscuring the powerful complementarity between the approaches that has been at the core of much progress in recent years. I will therefore discuss three cases that illustrate how price theory is often most powerful in communication and collaboration with the other traditions.

First, I will discuss two advances (Chetty et al., 2009; Dávila, 2013) in “behavioral” price theory that were stimulated, respectively, by reductionist work in psychology and economics (Gabaix and Laibson, 2006) and decision theory (Weyl, 2007; Brunnermeier et al., 2014). It seems unlikely that price theorists would have thought of the important welfare effects and policy tools highlighted by these reductionist analyses, but the price theoretic analysis has played an important role in quantifying the implications of these impacts for optimal sales and financial transaction tax policy. Second, I will consider an interaction between price theory and reductionist structural measurement in international trade. In particular I will discuss how the reductionist work on heterogeneous firms and/or economies of scale of Krugman (1980), Eaton and Kortum (2002), Anderson and van Wincoop (2003) and Melitz (2003) stimulated Arkolakis et al. (2012) to derive a general price theoretic, elasticity-based formula for the welfare gains from international trade. Finally, I will discuss how Saez (2001)’s demonstration that the optimal rate of taxation on the wealthiest individuals could be derived from features of inequality and labor supply elasticities that had been estimated in the empiricist literature was crucial to reviving Dixit and Sandmo (1977)’s price theoretic approach to optimal income taxation. Furthermore, I will discuss how this analysis then stimulated further empirical work by Saez, his co-authors and others to refine estimates of parameters he showed were crucial to optimal income taxes.

### III Application to the History of Economics

I plan for the longest section of the piece, about 15 pages, to apply this definition to making sense of the history of price theory and its interactions with the other approaches. I will begin by spending 4 pages on the history of price theory prior to the period when it was most closely identified with the University of Chicago:

1. Origins: Price theory originates with a group of French engineers led by Jules Dupuit who studied how optimally to build and price public works. This led Dupuit (1844) to propose many basic concepts of price theory, such as consumer surplus, monopoly optimization, price discrimination, cost-benefit analysis and formulae for excess burden. While the French engineers were ahead of their time and thus were largely ignored until the advent of the marginal revolution, Dupuit's focus on the measurement of economic aggregates for optimization was taken up by Mill (1848). In this period I will emphasize both the close connection of each of these thinkers' thought to emergentism in other sciences.
2. Marginal Revolution: Dupuit's work was more fully incorporated into mainstream political economy through the early marginal revolution work of Jenkin (1870, 1871–1872) and Jevons (1871). Building on these contributions, Marshall (1890) systematized, applied and expanded the scope of price theory to address a wide range of social phenomena. He introduced, in the appendices of his book, many of the formulas and graphical representations that became central to the teaching of price theory, as well as many canonical applications of the theory. In this period I will highlight how the essence of these graphical representations was to demonstrate a low-dimensional “prices” summarizing the solution of high-dimensional economic systems, making sense of the widespread association between price theory and graphical analysis. In particular, the graphical representations are almost always of the *solution* of the model, rather than its primitive components which are typically too high-dimensional to be represented graphically.
3. Neo-Classical Synthesis Period: The 1930's-1950's were a period of rapid transformation of economics into an empirical and mathematical science. Within price theory the central figures in this transformation were Harold Hotelling and Paul Samuelson. Hotelling developed a range of mathematical tools to extend Marshall's approach to richer multidimensional and non-concave settings. Building off of a similar attempt by Hicks (1939), Samuelson (1947) codified and systematized these and other developments into the most successful comprehensive and fully mathematical statement of

Marshall's theory. In this period I will highlight how these tools functioned to allow the sort of dimension reduction that is central to my definition.

I then plan to devote approximately 3 pages to tracing the histories of the other two traditions to highlight the contrast between their approaches and price theory.

1. Reductionism: Reductionism originates with Walras (1874) and Edgeworth (1881)'s vision of a fully-describable mechanical economic system (Mirowski, 1989), building on the earlier mathematical work of Cournot (1838) and built on hydraulic computational machines. This computational-mathematical approach gained great currency in the aftermath of the WWII as computer technology developed (Weintraub, 2002), culminating in its four great and closely-connect achievements, decision theory, game theory, social choice theory and general equilibrium theory. I will highlight the close connection between these advances and the development of computers by many of the leading proponents of reductionism. I will also highlight how low-dimensional, especially graphical, representations in this tradition were used to portray the primitive inputs (e.g. a game form or preference structure) of a system, in contrast to price theory's focus on using them to represent model solutions. I will then discuss how these approaches were adopted at first gradually and then increasingly rapidly during the 1970's and 1980's. With the advent of another dominant reductionist paradigm, information economics and mechanism design, and the acceleration of computational power, they largely eclipsed price theory.
2. Empiricism: While empiricisms has its roots in the German Historical School, its influence on mainstream Anglo-American political economy came primarily through the American Institutional school, especially the work of Thorstein Veblen and J. R. Commons. Empiricism, in its modern quantitative form, began to take shape in the work of Wesley Clair Mitchell and the National Bureau of Economic Research (Fogel et al., 2013). It was crystalized by the "measurement without theory" approach of Burns and Mitchell (1946), which was most fully expressed in the research program of Simon Kuznets. Koopmans (1947) and other structural econometricians critiqued this extreme empiricism leading to the dominance of price theoretically-guided empirical research exemplified by the work of participants in the Cowles Commission. However, concerns about the plausibility of identifying assumptions, especially exclusion restrictions (Leamer, 1983), in these theoretically-guided models helped trigger a reaction during the 1980's that led to a resurgence of empiricism around the measurement of causal "treatment effects" during the 1990's and early 2000's. I will use this discus-

sion to highlight the inter-temporal parallels in the debate between price theorists and empiricists.

Finally, I plan to devote 7 pages to what I view as the core of the paper, the use of my definition to make sense of the distinctive microeconomic approach of the University of Chicago during the period when it was most closely identified with price theory. After briefly discussing Jacob Viner’s establishment of the “Price Theory” course at Chicago, I will discuss Friedman (1962)’s parallel effort at formalizing Marshall’s ideas, which dissented from many of Samuelson’s substantive implications but adopted many of his formal innovations. I will highlight that two of the classic papers identified with Chicago Price Theory, Harberger (1964) and Stigler (1964), were concerned with general equilibrium and imperfect competition respectively and illustrate how my definition helps make sense of how they were distinctive from parallel work in other traditions in their methodology rather than in their topic.

I will then focus particularly on the life, research and teaching of Gary Becker, including notes from my personal experience with these. I will begin with two well-known examples from his work, his work on fertility (Becker, 1960) and his theory of marriage (Becker, 1973), and show how both simultaneously built closely on empiricist and reductionist insights respectively but took a distinctively price theoretic approach to characterizing the problems in rich settings in terms of low-dimensional statistics. I will then discuss how his professional affinity with sociology, and skepticism of psychology, reflected shared emergentist methodological inclinations. Finally, I will use three examples from his teaching, one reflected in his problem sets, one published in his book of lectures (Becker, 1971) and one buried in his work on crime (Becker, 1968), to illustrate how my definition of price theory helps organize what was distinctive about his perspective on the notion of simplicity and elegance in economic analysis.

I will then conclude with a brief, page-long discussion, tying the parts above together, about how the increasing marginalization of price theory within economic theory (Tirole, 1988), structural modeling (Pakes, 2003) and reduced-form empirical research (Leamer, 1983; Angrist and Pischke, 2010) led to price theory being closely associated with the University of Chicago prior to its recent and broader renaissance through the work of, among others, Emmanuel Saez, Jonathan Levin, Amy Finkelstein and Raj Chetty.

## IV Analytic Tools

Derivation of prices is based on a range of approximation techniques that allow more important effects to be retained while less important effects are discarded. In this section, to



which I plan to devote approximately 10 pages, I will briefly exposit and illustrate through a few examples the role played by seven widely used techniques:

1. Price-Taking: Perhaps the most canonical simplifying technique in price theory is to treat individual actions as negligible in determining aggregate prices and thus that individuals take prices as given. The role of this assumption in competitive equilibrium theory is well-known, but I will discuss how it can be fruitfully applied to many less familiar contexts, where the relevant price is not a money-denominated rate of exchange between private goods, using recent work in market design as a leading example (Azevedo and Budish, 2013).
2. Calculus: The next most common, and closely related, price theoretic technique is to consider locally linear approximations to those systems using calculus. After briefly surveying the most classical applications of calculus in price theory as in Samuelson (1947), I will discuss how calculus methods have been extended to treat richer topics such as general equilibrium with discrete goods (Aumann, 1966; Starr, 1969; Smale, 1976; Novshek and Sonnenschein, 1979; Azevedo et al., 2013), the choice of infinite-dimensional instruments such as non-linear pricing schedules (Wilson, 1993), the analysis of interventions that deform multidimensional sets of participating consumers (Weyl and Veiga, 2014) and work on making econometric identification more transparent (Gentzkow and Shapiro, 2013).
3. The Envelope Theorem and the le Chatelier principle: Another canonical technique based on calculus is the irrelevance to the welfare of an optimizer of changes in control variable in response to a small change in exogenous parameters (the envelope theorem) and the tendency of such responses to be larger when more control variables can be adjusted (the le Chatelier principle). I will particularly highlight recent applications of these results in public finance (Chetty, 2009) and how they have been extended by Milgrom and Segal (2002) and Milgrom and Roberts (1996) to richer environments.
4. Ironing: Calculus-based techniques for optimization yield sensible results only when second-order conditions are satisfied. I will discuss Hotelling (1931)'s "ironing" technique for transforming a problem where such conditions are not globally satisfied into one where they are using a recent application by Einav et al. (Forthcoming) and briefly discuss how this technique has been extended to more general environmental by Guesnerie and Laffont (1984) and Toikka (2011).
5. Quasi-linear Utility: Many of the complications in studying economies can be ignored if individuals have utility that is quasi-linear in a numeraire good. I will review arguments

by Friedman (1957), Willig (1976) and Bewley (1977) that this simplifying assumption is a reasonable approximation in many contexts and discuss how this approximation has simplified the analysis of optimal income taxation (Diamond, 1998).

6. **Approximating Functional Forms:** Because the true empirical functional forms of economic primitives like cost and demand forms often given rise to intractable equilibrium systems, price theorists commonly approximate these with tractable forms that are flexible with respect to properties central to certain policy questions. After briefly discussing a range of contexts where this occurs, I will focus on tracing the development of this approach in the context of single-dimensional partial equilibrium models from the constant elasticity demand and cost forms of Dupuit (1844) and Mill (1848) to a recent general theory I have proposed jointly with Michal Fabinger (Fabinger and Weyl, 2014). I will also discuss related recent work by Edmans and Gabaix (2011) and Gabaix (2012) applying a similar approach to financial models.
7. **Symmetry:** Another common technique for reducing the dimensionality of equilibrium systems is assuming that various actors in the market enter symmetrically into the determination of equilibrium in various senses. I will illustrate this approach with recent work on aggregate games (Acemoglu and Jensen, 2013) and symmetric differentiation in competition (White and Weyl, 2012; Mahoney and Weyl, 2014).
8. **Aggregation:** Often some properties of the aggregate systems price theory is concerned with can be derived from assumptions on the individual units that make up the system *if and only if* those individuals are considered in large aggregates. I will discuss a couple of recent examples of insights derived from this approach (Jaffe and Weyl, 2010; Chetty, 2012).

## V Future Directions

Since approximately 1980, the terms “theory” and “structural modeling” in economics have become associated with reductionism, while “applied work” has been increasingly associated with empiricism. Price theory has therefore become a misfit, sitting uncomfortably with field and methodological boundaries. However, this survey will aim to show that, despite occasional resulting derogation, price theory is a distinct, complementary approach with a long, deep history cutting across all fields of microeconomics. Furthermore, this method has been the foundation of many of the field’s most celebrated advances. Whether it should be called “theory”, “structural modeling” or “applied work”, or considered a separate

field/methodology, is largely a matter of semantics and organizational sociology beyond the remit of this project. However, I hope to persuade the reader that it deserves an important place among the priorities of the economics profession.

To show some of the directions I believe such an agenda can take, I will briefly discuss a few examples where reductionism or empiricism have thus far been successfully applied but to which price theory seems likely to have much to contribute. First, Juan Camilo Castillo is working to show how comparative static models of different temporal durations (viz. “long-run” v. “short-run” models) can validly be used to reach inferences about dynamic models. Second, recent work by Eduard Azevedo and Daniel Gottlieb indicates that much of the multiplicity of equilibria in signaling models may be resolved by allowing richer, multidimensional heterogeneity, offering the potential for linking signaling models more clearly to statistical properties of aggregates. Third, with Bruno Strulovici I am working to revive the Samuelsonian “Correspondence Principle”: important comparative statics properties are implied directly by equilibrium stability without requiring the sort of restrictive complementarity conditions imposed in existing game theoretic literature (Milgrom and Shannon, 1994; Echenique, 2002). Finally, work on equality of opportunity has thus far primarily focused on measures such as intergenerational mobility with limited normative foundation. Ananth Seshardi is currently working to derive measures of international mobility directly from philosophical definitions of equality of opportunity.

I then plan to conclude with a brief discussion of how price theory might give back to the field of thermodynamics that has contributed so much to it. In particular I will argue that the difficulty thermodynamics has had in providing a philosophically-satisfying definition of the macro-states necessary to measure entropy can be resolved if the discipline explicitly adopts the optimization perspective of the economics of information (Blackwell, 1951, 1953; Marschak, 1953). Thermodynamics was concerned with macro-states relevant to energy extraction because energy extraction is useful to humans, just as Dixit and Sandmo (1977)’s measures of inequality and taxable income elasticity are relevant because governments often make decisions about raising or lowering tax rates. Just as quantum mechanics showed that external reality cannot be divorced from its observers, emergentism should not be divorced from the goals of those who use it.

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