The Classical Theory of Supply and Demand  
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Abstract. This paper introduces and formalizes the classical view on supply and demand,  
which, we argue, has an integrity independent and distinct from the neoclassical theory.  
Demand and supply, before the marginal revolution, are defined not by an unobservable  
criterion such as a utility function, but by an observable monetary variable, the reserva-  
tion price: the buyer’s (maximum) willingness to pay (WTP) value (a potential price) and  
the seller’s (minimum) willingness to accept (WTA) value (a potential price) at the mar-  
ketplace. Market demand and supply are the cumulative distribution of the buyers’ and  
sellers’ reservation prices, respectively. This WTP-WTA classical view of supply and de-  
mand formed the means whereby market participants were motivated in experimental  
economics although experimentalists (trained in neoclassical economics) were not cog-  
nizant of their link to the past. On this foundation was erected a vast literature on the  
rules of trading for a host of institutions, modern and ancient. This paper documents  
textually this reappraisal of classical economics and then formalizes it mathematically.  
A follow-up paper will articulate a theory of market price formation rooted in this clas-  
sical view on supply and demand and in experimental findings on market behavior.  
1 Introduction  
This paper introduces and formalizes the classical view on supply and demand, which,  
we argue, has an integrity independent and distinct from the neoclassical theory. The  
new school, as is well-known, replaced the old in the 1870s through a widespread ac-  
ceptance of constrained utility maximization as a core principle of economics.1 Yet a  
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2  
century later, utility maximization is proven to have no interesting implication for aggre-  
gate (market) demand behavior, not even the law of demand except under artificial,  
restrictive conditions. While this major aggregation problem of standard price theory  
(the ‘anything goes’ or SMD theorem2) is often simply if unintentionally evaded in most  
applied models through the representative-consumer simplification (Hildenbrand, 1983;  
Grandmont, 1987), or by falling back on some additive utility structure or other forms  
of cardinality (Arrow, 1986; A. Kirman, 1989; A. P. Kirman, 1992), a few mathematical  
economists explored a pathway out of it, which consists of investigating the law of mar-  
ket demand as a collective regularity holding by integration over the distribution of con-  
sumers’ preferences or incomes, thus turning aggregation into the solution, rather than  
the problem, of the law of market demand: for example, income or wealth effects, which  
are the main issue in the arbitrariness of neoclassical market demand, can be shown to  
be well-behaved by aggregation over a diverse population of consumers (essentially by  
the law of large numbers).3 Ironically, this is the way the law of demand was understood  
in classical economics; Marshall, for example, who—as further emphasized below (Sec-  
tion 2.1)—tried to revive the classical view on supply and demand, makes it clear that  
his clause of constant marginal-utility of wealth (oft-discussed but oft-misunderstood in  
modern commentaries) is inconsequential on the aggregate of many consumers, poor  
and rich combined (Marshall, [1890] 1920, pp. 15-16, 83). More important for our ob-  
jective here, the old school articulated a price discovery process which found unex-  
pected new meaning in experimental markets establishing their remarkable decentral-  
ized convergence properties; these properties were not and could not be predicted by  
neoclassical modelling (Chamberlin, 1948; V. L. Smith, 1962). The goal of this paper is to  
rehabilitate mathematically the classical view on supply and demand. The classical view  
3  
is easy to understand by opposition to the neoclassical one that replaced it, but which  
introduced into economics a series of mischievous innovations. For example, it used to  
be taken for granted in economics that economic reality is discontinuous at the micro  
level: not only is economic decision (both demand and supply behavior) binary (to buy  
or not to buy, to sell or not to sell is the problem), but goods come in discrete units and  
their relations are binary; for example, a consumer choses between two substitutes, ra-  
ther than substituting infinitesimal amounts of goods, which strictly speaking are empty  
concepts. (For example: is an infinitesimal amount of a diamond still a diamond? Or even  
water?) While many of the marginalists were well aware of this point through Cournot  
([1838] 1897, p. 50), they nonetheless assume that economic variables are smooth so as  
to use the tools of differential calculus.  
Moreover, individual demand and supply, before the marginal revolution, are defined  
not by an unobservable criterion such as a utility function, but by an observable mone-  
tary variable, the reservation price: the buyer’s (maximum) willingness to pay (WTP)  
value (a potential price) and the seller’s (minimum) willingness to accept (WTA) value (a  
potential price) at the marketplace. The underlying concept in value theory, in other  
words, used to be, not pleasure or satisfaction in consuming a good (which is experi-  
enced, or not, after the fact of purchase), but the consumer’s valuation of a good, the  
maximum the consumer would be willing to pay for the good given his expectation of  
the good’s usefulness. Market demand and supply are simply the cumulative distribu-  
tion of the buyers’ and sellers’ reservation prices, respectively. This WTP-WTA classical  
view of supply and demand formed the means whereby market participants were moti-  
vated in experimental economics although experimentalists (trained in neoclassical eco-  
nomics) were not cognizant of their link to the past. On this foundation was erected a  
4  
vast literature on the rules of trading for a host of institutions, modern and ancient.  
(Holt, in Kagel &Roth, 1995, pp. 360-377.)  
Classical economics is not commonly viewed in these terms; rather it is often reduced  
to a simplistic supply-side, cost or labor theory of value, that fails to explain even the  
basic water-diamond value paradox because it was thought to be lacking the concept of  
marginal utility (a misunderstanding and distraction; Inoua & Smith, 2020a). Therefore,  
we must briefly revisit the old literature to document our interpretation and to frame  
the analysis in Section 2, which derives the classical conception of supply and demand  
progressively and heuristically from the classical literature. The second part of this paper  
(Section 3-4) is a formal restatement of classical supply and demand. Section 3 formu-  
lates mathematically the supply side of classical economics and derives key propositions  
of classical value theory.4 Section 4 derives the less known demand side, with special  
attention to the foundation of classical demand theory, as it is made explicit in the  
French classical literature following Adam Smith.  
2 The classical methodology  
Overall, the classical economists adopted a methodology that can be summarized in  
three principles:  
Principle 1: It is a realistic portrayal of a market economy based on astute observation  
of individual behaviors and interaction in the marketplace.  
5  
Principle 2: It derives from the acute observations and facts about the economy’s deep  
emergent properties that are the collective unintended consequences of these latter, the  
results of human actions but not of human design.5  
Principle 3: Supply and demand are classically given by an observable, operational, mon-  
etary value: the reservation price—the buyer’s maximum willingness to pay (WTP) and  
the seller’s minimum willingness to accept (WTA).  
This paper, which is part of a general rehabilitation of classical economics, deals more  
specifically with Principle 3, the classical conception of supply and demand.6 It is thus  
situated within the authors’ overall rehabilitation project: it emphasizes how supply and  
demand were viewed before the marginal revolution. Alfred Marshall attempted to rec-  
oncile this old view of supply and demand with the new-born marginalist school.  
2.1 Marshall’s revival of a key principle  
Alfred Marshall’s ‘pairs of scissors’ image is often invoked in an oversimplification of the  
history of modern economics divided into three phases: from the classical, supply-cen-  
tered, cost or labor theory of value to the early neoclassical demand-centered, marginal-  
utility theory of value, and to Marshall’s synthesis of these two one-sided views into a  
unified price theory, which, allegedly, became the foundation of contemporary econom-  
ics. Yet Marshall actually holds a more subtle view of the history of economics: his ‘pairs  
of scissors’ metaphor was merely intended to put an end to an old, essentially meta-  
physical, controversy over the ultimate cause of value—a problem which consisted of  
deciding which one of the two, unanimously recognized,7 basic causes of value, utility or  
cost, is the most primitive cause. Marshall’s reading of the history of economics, at the  
time, is unique, in that he most clearly recognized what was really at stake during the  
6  
marginal revolution. Though he accepted diminishing marginal utility (DMU) as central  
to value theory (making him a marginalist of course), yet he saw in Jevons’s program a  
major setback from a core methodological principle of classical economics, which is of-  
ten overlooked in modern commentaries. This principle consists of dealing, as regards  
individual economic decisions, not with the ultimate psychological forces driving them,  
but operationally with the monetary sacrifices that people make in order to satisfy them.  
Thus, the relevant concepts for demand theory, for example, are, not the ultimate psy-  
chological motivations behind demand decisions (desire, want, pleasure), which had de-  
fied any precise quantitative modeling, but the money prices consumers are willing to  
pay in order to acquire the desired goods. This most fundamental principle, is applied  
equally to the supply side, and to market price theory more generally. Investigated from  
the standpoint of people’s feelings, the value attached to an object reflects ultimately  
the desire of possessing it and the effort in producing it (an object, in this sense, is valu-  
able, the more it is desired, and the more difficult it is to produce, in terms of toil and  
trouble)8. But investigated from the standpoint of the monetary values (or prices) trad-  
ers in a market are willing to pay in order to produce or consume a good, the market  
price simply balances the ordered set of higher values that buyers are willing to pay to  
possess the good, with the ordered set of lower values that sellers are willing to accept  
in order to produce it. This, as textually documented below (Section 2.2), was precisely  
how supply and demand were understood long before the marginal revolution.  
Alfred Marshall, perceptively recognizing this classical methodology, credited its discov-  
ery to Adam Smith, whom he viewed as having launched an epoch in the history of eco-  
nomics when he built from this principle a value theory that unifies all of economics “by  
a clearer insight into the balancing and weighing, by means of money, of the desire for  
7  
the possession of a thing on the one hand, and on the other of all the various efforts and  
self-denials which directly and indirectly contribute towards making it. Important as had  
been the steps that others had taken in this direction, the advance made by him was so  
great that he really opened out this new point of view, and by so doing made an epoch.”  
([1890] 1920, Appendix B, p. 759). It is in fact this principle for measuring motives that  
confers upon economics a special quantitative nature among the social sciences ([1890]  
1920, Book I, Ch. II, p. 12). Thus, in reaction to the hedonistic marginal utilitarianism of  
Jevons and Walras, who make pleasure the fundamental motivating category of eco-  
nomics, Marshall reformulates it operationally—as did the classicists (and, as it was ap-  
plied, unknowingly, in the first market experiments)—entirely in terms of WTP and WTA  
(or demand-price and supply-price, as Marshall calls them, because he wanted to relate  
that difference to the incentive for seller entry)9. This WTP-WTA approach to supply and  
demand frames value theory throughout the classical literature; we first emphasize the  
demand side, since it is the less known.  
2.2 Classical demand and French contributions  
The demand side of classical price theory is sketched in Adam Smith’s Lectures on Juris-  
prudence ([1763] 1869), under ‘Cheapness and Plenty’, which prefigures the Wealth of  
Nations ([1776] 1904). In the magnum opus, he simply grants that the purpose and foun-  
dation of consumer demand is to satisfy need, and he expresses demand in terms of  
WTP. He then directly explains price formation from the competition (higgling and bar-  
gaining) among the sellers and buyers in a market (Ch. VII of Book I).  
Adam Smith did not articulate demand theory in a systematic, explicit, and formal way;  
but this articulation, which will be made explicit later by his disciples, can be sketched  
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simply. Utility, or the capacity of a good to satisfy a consumer’s need, is classically  
treated, not in the abstract, but in the specific sense of use-value: the value that a person  
attaches to an object by virtue of this object’s usefulness and measured by what the  
person is willing to pay to get the object. Demand being thus founded on use-value, and  
use-value being operationally WTP, Adam Smith, throughout Wealth of Nations, equates  
demand directly to ‘those who are willing to pay’ a price. Elaborating on his work, the  
other classical economists also recognized explicitly WTP as the relevant concept in clas-  
sical demand theory. Malthus, for example, announced early in his Principles that ‘de-  
mand will be represented and measured by the sacrifice in money which the demanders  
are willing and able to make in order to satisfy their wants.’ (Malthus, [1820] 1836, p 62)  
The systematic and formal presentation of this classical demand theory appears in the  
important yet often overlooked French contribution to classical value theory, notably  
the works of Germain Garnier, Jean-Baptiste Say, Augustin Cournot, and Jules Dupuit,  
but also the Italian Pellegrino Rossi, who succeeded J.-B. Say at College de France’s eco-  
nomics chair.10 We see and interpret the French classical literature as a substantive ra-  
ther than a mere echo, or popularization, of British classical economics; nor do we see  
it as detached from the classical school and interpreted as an anticipation of marginal-  
utility theory. Cournot, firmly in the classical stream, can be said to have charted new  
directions, notably on supply theory, which prepared the ground for the transition to  
neoclassical economics (though Cournot’s views are more nuanced than its interpreta-  
tions)11. Jules Dupuit, refining an intuition of J.-B. Say, clarified that use-value corre-  
sponds more precisely, not to any WTP, but to maximum WTP reservation price. J.S. Mill  
reached the same conclusion, putting it more technically: ‘Value in use […] is the ex-  
9  
treme limit of value in exchange.’ Or: ‘the utility of a thing in the estimation of the pur-  
chaser, is the extreme limit of its exchange value [the maximum price the purchaser  
would be willing to pay].’ (Mill [1848] 1909, bk. 3: chap. 1, sec. 2; chap. 2, sec. 1.) Alt-  
hough no classical economist stated it explicitly, a consumer’s demand follows by defi-  
nition of the consumer’s valuation: willingness to buy any unit whose value is greater  
than the price. This basic inequality, as formally emphasized in Section 4, defines entirely  
the market demand function, which is simply the total number of units that are valued  
more than the price offered: namely the complementary distribution function of con-  
sumers’ values.  
As to the foundation of classical demand, namely the determinants of WTP itself, it is  
not utility in the absolute, but a mix of utility and wealth. Need, unlike wealth, is a prim-  
itive demand concept.12 Consumers buy goods to satisfy a list of needs: to each need is  
associated a certain good (or collection of goods) that satisfies it. A consumer’s demand  
decision is shaped by a pyramid or hierarchy of needs, a ranking of needs from the most  
urgent to the least urgent: broadly speaking, from necessities, conveniences, to luxuries  
and fancies.13  
This hierarchy of needs is the fundamental principle of classical demand theory, as  
shown with great clarity by J.-B. Say ([1828] 2010, p. 368) and as recognized by Dupuit  
(1849, p. 15), quoting Rossi’s exposition ([1840] 1865, Lesson 5, pp. 87-88). The hierar-  
chy of needs is partly objective, even universal. Thus, no good is valued higher than wa-  
ter, which serves a vital biological need; a diamond, serving an ornamental need, is val-  
ued lower, since one would be willing to give all diamonds at hand to survive. Yet the  
market prices for a cup of water and a diamond (or their objective exchange values) are  
inversely related to their subjective valuations—a paradox which is long-known to be  
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solved by the concept of scarcity, and which no classical economist regarded as an un-  
solved mystery (Inoua & Smith, 2020a). But the hierarchy of needs is in part subjective  
as well. At any rate, the economist takes a consumer’s needs as given.  
In summary, the classical value literature from Adam Smith to Jules Dupuit offers a con-  
sistent picture of demand, which Marshall attempted to reconcile with the newborn  
marginal school.14  
2.3 Classical cost and supply decision  
Cournot, who beautifully expounds the old view on demand in one fascinating para-  
graph ([1838] 1897, p. 50), goes on, however, to introduce an abstract theory of atom-  
istic profit-maximizing firms—which will become the standard view on supply in the  
hands of the marginalists. Like utility maximization, profit maximization thus conceived  
raises decision problems that actual firms hardly face; for example, it leads to an ill-de-  
fined supply function when marginal cost is nonincreasing (most manufactured prod-  
ucts?)15 or zero (information products such as software programs). The basic problem  
lies in the definition of the firm’s production possibility set as an unbounded set: thus, a  
firm facing a constant unit cost, for example, would be willing to supply an infinite  
amount of output when facing a price greater than the unit cost. Consider in contrast an  
actual firm under the same cost condition: granted that the firm’s maximum production  
capacity is finite, its supply decision is obvious: willing to supply every producible unit at  
any price greater than the unit cost.  
Prior to Cournot’s innovation, the discussion on supply decision seems to presume none  
other than the basic principle, taken for granted, of willingness to supply whenever it is  
11  
profitable to do so, that is, at any price beyond a minimum acceptable price (the mini-  
mum WTA). Like classical demand, classical supply is not explicitly and formally defined;  
yet it goes without saying, by definition of the concept of minimum price, which corre-  
sponds to the cost of production, or more precisely the cost of supplying the commodity  
to the market. Classical cost is the monetary evaluation of all the sacrifices the producer  
makes in order to supply the commodity, including the expectation of a minimum profit  
compensation (without which none would engage in the toil and trouble of producing).  
Regarding this monetary cost valuation, Adam Smith, and this is crucial, assumes none  
other than the actual practice of firms in their cost accounting: not only the obvious part,  
wages and the cost of raw materials (determined by market rates), but also the mone-  
tary estimate of the use of fixed capital (allowance for depreciation), and the producer’s  
minimum compensation, which is a subjective evaluation in general; but would expect  
at least the ‘ordinary profit’ in the industry. Adam Smith, who particularly emphasizes  
this actual practice of firms on many occasions, faces none of the technical complica-  
tions of later authors who will treat capital as a physical agent of production (the aggre-  
gation problem as it applies to fixed capital).16 Granted the cost valuation (a monetary  
evaluation of all expenses of production), which is the producer’s minimum WTA, the  
producer is willing to supply any unit at a price that covers at least the money cost: will-  
ingness to sell any unit whose cost is lower than the price. This inequality, as emphasized  
below, defines entirely the supply function: since market supply is the number of units  
that can be supplied profitably, it is given by the cumulative distribution function of the  
unit costs.  
2.4 Limitations of Marshall’s synthesis  
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Marshall’s insightful attempt to revive the classical method does not pay full justice to  
the old paradigm, due to his desire to integrate neoclassical utility theory into his treat-  
ment. For example, he defines the demand function as the surplus-maximizing quantity  
of a representative consumer that hypothetically buy by infinitesimal increments of the  
commodity, and he founded the law of demand on diminishing marginal WTP (or ‘de-  
mand price’); he defines supply similarly. This and other neoclassical imports play no  
essential role in the classical formulation, and none when Marshall is brought to a de-  
scription of price formation in a local country market. [Marshall ([1890] 1920, Book V,  
Chap. II) simply reverts to a WTP/WTA description of “higgling and bargaining” as we  
find it in A. Smith ([1776] 1904, Book I, Ch. VII).]  
Marshall ([1890] 1920, p. 64) acknowledges that economic reality is discontinuous in  
regard not only to the quantity of goods but also of individual behavior, but demand is  
smoothed, “in so far as the motives of that action are measurable by a money price;  
and in these broad results the variety and the fickleness of individual action are  
merged in the comparatively regular aggregate of the action of many”; a form of the  
law of large numbers. The motivation for this theoretical procedure is this other  
equally important principle of classical methodology noted in the introduction, which  
Cournot expressed in a most fascinating way ([1838] 1897, p. 50), and which consists  
more generally of investigating economic regularities as collective regularities emerg-  
ing by aggregation over agents. For the classical economists, this meant aggregation  
over the distribution of agents’ characteristics, and not just a hypothetical average  
agent, as Marshall did.  
Finally, we have Marshall’s deviation from the old school in regards to his dealing with  
wealth effects through his oft-discussed clause of constant marginal utility of wealth,  
13  
which may be erroneously interpreted to mean that thinking in terms of reservation  
price is a narrow case of the utility-function view; though Marshall in fact goes on to  
argue that variations in marginal utility of wealth, like the discontinuities of demand with  
respect to price variations, are of no significance on the aggregate of many consumers,  
with poor and rich, young and old combined (Marshall, [1890] 1920, pp. 15-16, 83).  
Space forbids to elaborate further on Marshall’s synthesis. Rather this paper concerns  
the restoration of the old school, on its own merits, bereft of Marshall’s attempted syn-  
thesis.  
3 Supply  
3.1 The market supply function  
Consider a market economy in which goods and services (including labor services) are  
traded at market prices A producer in any market is willing to sell any  
unit that can be produced profitably. Consider a given commodity, which we single out  
by not indexing it. In terms of cost, each unit of a commodity produced is characterized  
by the number of inputs from other commodities its production required, which we de-  
note generically as a vector17 and the input prices. Thus, the cost of a unit  
of a commodity is  
(1)  
Different units clearly may cost differently to produce since they may involve a different  
mix The producer would be willing to sell any unit at a price The function  
that associates to any price vector the total number of units of that commodity that  
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14  
would be supplied, at this price vector, by all the producers in the market is, by defini-  
tion, the market supply function. It is by construction the cumulative distribution func-  
tion of unit costs, which is a non-decreasing step function of the market price, ceteris  
paribus:  
S(a,p) SF(a,p), (2)  
where by definition and is the total (maximum) supply  
capacity in the market (the total number of units that can be supplied, which would be  
fully supplied were the market price infinite); for a particular market, the distribution in  
question refers to the collection of all units of the same commodity.  
Figure 1: Market supply is the cumulative distribution of unit costs.  
The prices of inputs assumed fixed here: their changes corresponding  
to shifts of the supply curve.  
The relevant unit of analysis in supply theory is the supply for a unit of a commodity:  
if and S (p) 0,otherwise. The supply of a firm is simply is a list of  
j  
such elementary supplies: it is entirely specified by the number of units the firm can  
produce and the corresponding list of costs for each unit.  
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p ,  
F ( a , p ) ( c p ) S S ( a , )  
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3.2 The labor theory of value  
Unlike Ricardo (and his followers), Adam Smith mentioned only passingly the labor the-  
ory of value which applies only in rude societies:  
“In that early and rude state of society which precedes both the  
accumulation of stock and the appropriation of land, the proportion  
between the quantities of labour necessary for acquiring different  
objects seems to be the only circumstance which can afford any rule for ex-  
changing them for one another. If among a nation of hunters…it usually costs  
twice the labour to kill a beaver which it does to kill a deer, one beaver should  
naturally exchange for or be worth two deer…the produce of two days or two  
hours labour, should be worth double…the produce of one day's or one hour's  
labour.18 (Smith, [1976] 1904, p. 49)  
Ricardo himself makes it clear that the labor theory of value applies only when goods  
can be produced with homogenous labor, in abundant amounts, and at proportional  
costs (which excludes the complications of the diversity of fixed capital that Ricardo  
would later deal with); Ricardo later concedes that quantity of labor is the dominant (not  
the sole determinant) of price, at least in the long run. Both J.-B. Say and Malthus oppose  
Ricardo even regarding long-run value, which, as they point out, is determined by both  
supply and demand. Although historically Ricardo is perhaps the most influential of the  
classical economists, it is a mistake to view Ricardo’s formulation as a culmination of this  
school of thought; it is not true upon scrutiny that Ricardo was resolving inconsistencies  
in Adam Smith’s view; Ricardo was dealing with technical complications (the diversity of  
labor and fixed capital) that are precisely the reason why Adam Smith mentions only  
16  
passingly labor theory of value and goes on to develop (Book I, Ch. VII) the general the-  
ory of market price formation. For example, Ricardo deals with the diversity of labor  
following Adam Smith’s view that wage differentials are determined by the ‘higgling and  
bargaining’ of the market; but this is precisely why the relevant price theory in general  
is a theory of supply and demand. While this point is now commonplace in economics,  
yet Adam Smith in most commentaries on classicalism is overshadowed by Ricardo; and  
the classical school is still commonly reduced to the labor theory of value, although  
much of the controversies that opposed Ricardo to both Say and Malthus pertains pre-  
cisely to Ricardo’s reduction of this school of thought and his downplaying the role of  
demand in price theory. Let it be reminded that the labor theory of value is equivalent  
to assuming a Leontief price system, as known since the influential revival of Ricardo’s  
theory by Sraffa (1960); see Inoua and Smith (2020a).  
4 Demand  
4.1 The market demand function  
For a given commodity, let if a consumer considers commodity is more urgent  
than the commodity under consideration, and otherwise; let .  
Consumers differ in terms of hierarchy of needs h and wealthw.Let the distribution of  
these consumers’ attributes be referred to as . A unit of a commodity will be de-  
manded by a consumer if the money left out of his wealth, once more urgent needs are  
considered, can afford the unit: that is, if (w h p ) p.Thus the consumer’s valu-  
k k k  
ation of the commodity, as given by his maximum WTP for it (reservation price) is  
v w h p w hp. (3)  
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17  
The consumer would be willing to buy every unit whose v p. The market demand  
function at any price is therefore the number of units of the good to which consumers  
attach a greater value than the price: it is by construction the complementary distribu-  
tion function of the consumers’ reservation prices, which is a non-increasing step func-  
tion of price, ceteris paribus, which we write generically:  
(4)  
where G(h,w,p) (v p)andD D(h,w,0) is the total (maximum) number of units  
of the good that consumers need (their overall demand were the market price zero).  
Figure 2: Market demand is the complementary distribution  
function of consumers’ valuations (or reservation prices).  
4.2 Remarks on a few conceptual distinctions  
Quantity: needed versus demanded versus bought  
The focus on the elementary demand for a unit of a good irrespective of the identity of  
the demander, is on purpose, as unit demand is the relevant unit of analysis. The total  
demand of a consumer is merely a list of unit demands: it is entirely specified by the  
D ( h , w , p ) D G ( h , w , p ) ,  
18  
number of units the consumer needs and their reservation prices. Let  
be the consumer’s demand function for commodity The demand (resp. supply) func-  
tion, be it reminded, indicates the quantity the consumer would demand were the con-  
sumer facing any arbitrary price p. The total quantity needed is 19 It is  
a different concept from the quantity the consumer succeeded to actually buy, which  
depends on the extent of competition in the market. The distinction more generally be-  
tween quantity demanded or supplied (willingness to trade) and the quantity actually  
traded is of utmost importance: serious paradoxes and conceptual obstacles in the ne-  
oclassical theory of price formation can be shown to be due to failure to acknowledge  
explicitly actual trades as a conceptually district notion from a supply and demand func-  
tion, which summarize all willingness to buy and sell at any possible price; since Walras,  
for example, it is common to treat supply and demand as if always fulfilled into actual  
trades, which would be the case only in equilibrium.  
Complements and substitutes  
Realistically, the relationship among commodities are binary. Consider two commodities  
and k viewed from the consumer’s viewpoint. By definition, the two goods are com-  
plementary if they jointly serve the same need, and hence are jointly demanded:  
implies and vice versa. They are substitutes if they serve the same need, but in-  
terchangeably, so that demand for one excludes demand for the other: implies  
d 0, and vice versa. In both cases, demand for one good derives logically from de-  
k  
mand for the other: theoretically, therefore, all substitutes, on the one hand, and all  
complements, on the other, can be treated mathematically as forming one class of  
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goods, of which knowledge of one element is like knowledge of the whole. Thus, we are  
left with the hierarchical relation among goods as the essential notion in demand deci-  
sion: good is more urgent than good if implies  
4.3 The pyramidal model of market demand  
The law of demand and the law of supply, as we saw (Figure 1 and Figure 2), hold by  
construction, in the sense that market demand and market supply are, respectively,  
nonincreasing and nondecreasing (step) functions of price, ceteris paribus. This weak  
version of the two laws is all that the theory of price formation requires in general (Inoua  
& Smith, 2020b). But stronger versions can also be derived under minimum assump-  
tions, as the French classical20 economists emphasize; we derive them formally now.  
For partial-equilibrium purposes, let wealth distribution and the prices of related goods  
be given. In a sufficiently large market, as Cournot beautifully emphasized ([1838] 1897,  
p. 50), market demand (resp. market supply) can be assumed to be a smoothly decreas-  
ing (increasing) function of price. A large market can be formally defined as an idealized  
version of a market that involves a sufficiently large number of distinct values and costs  
modeled by continuous density functions supported on continuums. Formally, a large  
market is therefore one for which the distribution of costs and values are modeled by  
the continuous density functions and supported on the intervals and  
respectively, over which the density functions are strictly positive by defini-  
tion. It then follows by construction SF'(p) 0 and  
on the respective supports.  
Now, consider a market in isolation, setting hp 0 in (3), so that v w and  
G(h,w,p) G(p) (w p),so that market demand is given by the distribution of  
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wealth across consumers, which Garnier, Say, and Dupuit represented as a pyramid (Fig-  
ure 3), whose top represents the wealthy minority and whose base represents the poor  
majority: more generally, the pyramid represents the distribution, not of wealth per se,  
but of the portion of wealth each consumer would be willing to pay for the commodity  
(Garnier, [1796] 1846, pp. 195-196; Say, [1828] 2010, p. 370, footnote 1). The pyramidal  
assumption in formal and general terms simply means a decreasing probability density  
of wealth or WTP more generally, so that market demand is a convex function  
of price, as Dupuit insightfully observed (1844, pp. 367-368). Unlike the law of demand  
proper, however, this convexity property, sometimes referred to as Dupuit’s second  
‘law’ of demand (Ekelund Jr & Thornton, 1991; Humphrey, 1992 )21, is true only to the  
extent that the pyramidal assumption is true: it is not essential to price theory.  
Figure 3: Pyramidal model of market demand (Garnier, Say, Dupuit). The pyra-  
mid (left) represents the distribution in society of wealth (top=the wealthiest,  
bottom=the poorest), or more precisely the distribution of consumers’ WTP.  
Market demand, at each price, is measured by the cross-sectional area of the  
pyramid corresponding to the price. If price is zero, all consumers can afford the  
good; as price increases, a lower and lower fraction of society can afford the  
good; and beyond some maximum value (125), none can afford the good.  
G '' 0 ,  
21  
Figure 4: Triangular market demand model (2-dimensional version the pyram-  
idal model): market demand is the length of the segment XY: it is a linear func-  
tion (as can be proven from elementary geometry). The pyramidal market de-  
mand (3-dimentiomal) is simply the square of this triangular market demand.  
For illustration, assume (following Garnier, Say, and Dupuit) a square pyramid (Figure 3):  
then market demand is simply the square of its two-dimensional image (Figure 4), ob-  
tained by reducing the pyramid to a triangle, and the cross-sectional areas of the pyra-  
mid to segment lengths. It can be shown from elementary geometry [Thales’s (intercept)  
and Pythagoras’s theorems] that  
(5)  
This corresponds to a uniform probability distribution of consumers’ reservation prices  
supported on [The extension to the general case is straightforward:  
G(p) (v p)/(v v ).] The two-dimensional, pyramidal, model yields (as-  
max max min  
suming again a square pyramid)  
(6)  
which is indeed a (strictly) convex demand function. It should be insisted that the law of  
demand, even in its smooth version, holds for any continuous probability distribution of  
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consumer valuations; it is only the secondary, convexity, property that requires the py-  
ramidal assumption 22  
Although this probabilistic view on demand (based on the distribution of consumers, as  
ranked in different orders of society based on WTP, or, as we would say today, in differ-  
ent statistical classes), was first formalized in the French literature, it was in fact implicit  
throughout the classical school: thus Adam Smith was implicitly treating consumers in  
that way when, for example, he observed in his Lectures that ‘everything is dearer or  
cheaper according as it is the purchase of a higher or lower set of people’ (A. Smith,  
[1763] 1869, p. 177).  
5 Conclusion  
The classical economists mostly adopted the same realistic view of the market economy;  
not that they concurred to it by an explicit a priori methodological commitment; but,  
rather, they concurred to it because they were essentially adopting the same mentaliz-  
ing process, which consists, first of all, of carefully observing everyday economic life, and  
then deriving from this acute observation, deep emergent regularities that are unin-  
tended consequences of these ordinary individual behaviors and interactions. J.-B. Say  
explained this classical methodology with great clarity in his Cours complet (and com-  
plained that Ricardo at times deviated from it).23  
But in place of this realistic methodology, the early neoclassical economists substituted  
a-priori axiomatic theorizing, whereby a theorist starts beforehand with a set of axioms  
(for example: pleasure explains every move in human behavior) and from these abstract  
premises, constructs through a chain of formal deductions an imaginary economy (often  
populated by a single player: Robinson Crusoe); and even after the axioms have proved,  
G '' 0 .  
23  
upon more scrutiny, to be empirically empty by the barrenness of their implications, the  
as-if theorist finds further refuge in fiction, and an excuse for holding onto these axioms.  
Thus, price-taking behavior, for example, was recognized from the very beginning to be  
a dead end as a premise for a theory of competitive market price formation (for if eve-  
ryone in the economy takes price as given, where do these prices come from in the first  
place?) Yet in the face of this dead end, an early evasion simply assumed a perfect mar-  
ket in which supply and demand and the consequent equilibrium price are perfect  
knowledge to every trader beforehand (Jevons, [1871] 1888). A second, now-standard,  
escape consists of simply postulating the existence of a fictional auctioneer who seeks  
all equilibrium prices by trial and error (Walras, [1874] 1954).24 In the same spirit, the  
aggregation problem of neoclassical demand is evaded through the representative-con-  
sumer assumption.  
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1 In the standard undergraduate intermediate theory course the consumer  
chooses units (x1, x2) of goods defined on a continuous commodity space  
to Max U (x1, x2) [increasing and concave in (x1, x2)] subject to I = p1x1 +  
p2x2, given (U, I, p1, p2). Every aspect of this model is contrary to the clas-  
sical economic model, wherein: (1) the consumer chooses only discrete  
units of goods [the primary meaningful application to continuous action  
spaces is in finance]; (2) if income is fixed and constrains choice, wealth is  
stationery, but the classical economists saw as their end and purpose to  
inquire as to the nature and causes of the wealth of nations; (3) prices and  
income were to be determined in the market, and were not given to it; (4)  
U was a hidden variable to the classics, but people in markets revealed that  
28  
they had willingness to pay demand valuations for goods, and for inputs to  
supply goods, and these were central to their analysis.  
2 That is, the Sonnenschein-Mantel-Debreu theorem (Sonnenschein, 1972,  
1973a, 1973b; Debreu, 1974; Mantel, 1974; Shafer & Sonnenschein, 1993;  
Rizvi, 2006).  
3 This abstract revival of the law of demand as an aggregate regularity, sys-  
tematically explored in Hildebrand (1994), can be viewed as part of the gen-  
eral ‘regularity by aggregation’ literature, which seeks to solve the multiple  
indeterminacy of neoclassical theory (e.g. the indeterminacy of demand  
when preferences are non-convex). For an overview of this literature, see  
Trockel (1984).  
The probabilistic view on demand has in fact resurfaced in different other  
forms even before the SMD crisis; for example, Becker’s intuition that even  
impulsive or random consumer choice constrained by a budget would obey  
the law of demand by aggregation, independently of utility maximization  
(Becker, 1962); for a recent revival of this view, see (Shaikh, 2012); for a  
recent experimental exploration in a general-equilibrium context, see  
Crockett, Friedman, and Oprea (2019).  
4 Classical market price theory is not to be confounded with the labor theory  
of value, on which Ricardo insisted, and which is a diversion from the gen-  
eral classical theory of price formation; the precise conditions under which  
the labor value theory applies are restated in 3.2; for a formal derivation  
see Inoua and Smith (2020a).  
5 “[N]ations stumble upon establishments, which are indeed the result of  
human action, but not the execution of any human design” (Ferguson,  
1782, p 205)  
6 A follow-up paper will present a theory of price formation that is rooted  
in the classical view on competition and relates that view to experimental  
findings on market behavior. Other more preliminary papers tackle obsta-  
cles and limitations of the classical literature, which may seriously impede  
or even discourage the modern reader’s assessment of the old literature,  
and explains the articulation of value theory in the classical school: the tech-  
nical jargon of classical economics (natural price, monopoly price, effectual  
29  
demand); the endless classical controversies regarding essentially unsolva-  
ble, metaphysical, issues (the invariable measure of value and the ultimate  
cause of value); these controversies can mislead the modern reader into  
seeing irreconcilable divergences in the classical school (and whose unity  
may thereby be questioned).  
7 None of the protagonists of this old utility-versus-cost controversy denied  
that market price is determined jointly by utility and cost: ‘Almost all writers  
have agreed substantially, and have rightly agreed, in founding exchangea-  
ble value upon two elements, -power in the article valued to meet some  
natural desire or some casual purpose of man [utility], in the first place, and,  
in the second place, upon difficulty of attainment [cost]. These two ele-  
ments must meet, must come into combination, before any value in ex-  
change can be established.’ (De Quincey, 1844, p. 13).  
8 Following the classical terminology, Marshall ([1890] 1920, p. 282) distin-  
guishes between real cost (pain, effort, difficulty of producing a product)  
from money cost (the monetary valuation of the real cost: the expenses of  
production, including a minimum profit requirement). Today we take for  
granted the fact that cost of production (difficulty of production) is meas-  
ured by the monetary sacrifices the producer makes (the expense of pro-  
duction). Yet this principle (which applies to the demand side as well) will  
be adopted in the neoclassical school only as a shortcut or a concession,  
Thus, Jevons’s program, a pure subjectivism, aimed at explaining value en-  
tirely in terms of pleasure (utility, demand) and its negation, pain or effort  
(disutility of labor, supply).  
9 Marshall explains this often-overlooked classical principle in a systematic  
way throughout his famous Principles of Economics ([1890] 1920), particu-  
larly in Book I, Ch. II, and makes it clear that its paternity originates with  
Adam Smith, and his “unsurpassed powers of observation”. Marshall did  
not realize, however, that all the classical economists, as they followed in  
Smith’s footsteps, reached the same conclusion, that value theory should  
be founded on people’s monetary valuations. With hindsight, it was a major  
editorial mistake on the part of Marshall to have moved the section on the  
30  
history of economics—in which he clearly explains the classical paternity of  
this principle—to the Appendix, in response to the public demand for mak-  
ing the first parts of his book less tedious.  
10 The references are G. Garnier ([1796] 1846, pp. 195-196); J.-B. Say (1803  
[2006], vol. 2, bk. 2, chap. 1; [1828] 2010, vol. 1, part 3, chap. 4), particularly  
the later book, the Cours complet, which synthetizes and extends the ma-  
terial covered in Say’s earlier books; P. Rossi ([1840] 1865, Vol. I, Lesson 5);  
A. A. Cournot ([1838] 1897, chap. 4), and J. Dupuit (1844, 1849). Many of  
the relevant passages of this French literature on demand and value are  
quoted in (Ekelund Jr & Hébert, 1999).  
11 On more of the methodological innovations of Cournot, see Smith and  
Inoua (2019).  
12 The classical concept of WTP is out of wealth, not income. The idea of  
income as a constraint on commodity choice is conceptually a blatant neo-  
classical error. Modeling choice in the current period only makes static  
sense if one of the goods is variable and constitutes saving—not consum-  
ing—with personal value in the current period; otherwise, the action set is  
not closed and part of the dynamics of wealth accumulation. For Adam  
Smith that value is security, which he saw as protection against downside  
loss: “We suffer more…when we fall from a better to a worse situation, than  
we ever enjoy when we rise from a worse to a better. Security, therefore,  
is the first and the principal object of prudence.” (Smith, 1759, p. 213)  
13 More than a century later, A. Maslow (1943) offers a famous psychologi-  
cal theory of the pyramid of needs.  
14 Marshall perhaps first noticed the classical methodology through his read-  
ing of Cournot and Dupuit, whose influences on him he acknowledged  
([1890] 1920, p. 85, footnote 1). The remarkable thing is his seeing the con-  
nection with the classical school more generally and tracing its origin back  
to Adam Smith.  
15 It was common belief in the classical literature that most (manufactured)  
goods are produced at constant or decreasing unit costs (production on a  
31  
large scale leads to efficiency gains because it promotes a better division of  
labor, for example); only agricultural produce and mined resources were  
believed to command increasing unit costs. See, for example, Mill ([1848]  
1965, p. 464 ff.) Various modern surveys suggests that increasing marginal  
costs are indeed exceptional in practice: it seems, according to one survey  
of the US economy, that ‘only 11 percent of GDP is produced under condi-  
tions of rising marginal cost.’ (Blinder, Canetti, Lebow, & Rudd, 1998) For a  
discussion of these issues with neoclassical supply theory, see Keen (2011,  
Part I, Ch. 5).  
16 This assessment of the producer’s minimum price through a realistic cost  
valuation is clearly stated throughout Wealth of Nations, starting from Ch.  
7 of Book I ([1776] 1904, p. 50). It is repeated countless times in specific  
contexts. For example: ‘When any expensive machine is erected the ex-  
traordinary work to be performed by it before it is worn out, it must be  
expected, will replace the capital laid out upon it, with at least the ordinary  
profits.’ (p. 103) Or elsewhere: ‘The lowest price at which coals can be sold  
for any considerable time, is, like that of all other commodities, the price  
which is barely sufficient to replace, together with its ordinary profits, the  
stock which must be employed in bringing them to market.’ (p. 168) This  
view would appear throughout the classical literature. Marshall ( [1890]  
1920, p. 299) also clarifies this cost valuation of firms.  
17 More precisely a matrix with double entry, in more explicit notation; but  
by fixing the commodity under study, the notation is simplified from dis-  
tracting indices.  
18 A source of confusion, perhaps, is the distinction between the labour the-  
ory of value and the concept of labour as a measure of value, developed by  
Smith. Thus, “The value of any commodity…to the person who possesses it,  
and who means not to use or consume it himself, but to exchange it for  
other commodities, is equal to the quantity of labour which it enables him  
to purchase or command. Labour, therefore, is the real measure of the ex-  
changeable value of all commodities.” (Smith [1776, 1904, p 32)  
32  
19 Adam Smith introduces the distinction ‘absolute demand’ versus ‘effec-  
tual demand’ to reflect the nuance between quantity needed or desired and  
quantity effectively demanded (determined by need, constrained by  
wealth). An explanation of the technical classical jargon (absolute versus  
effectual demand; natural versus monopoly price, etc.) can be found in  
Inoua and Smith (2020a).  
20 By now, there should be no reason for hesitating to refer to all of them  
simply as classical economists.  
21 Dupuit emphasized, besides the standard law of demand proper (as price  
drops, quantity demanded increases), a so-called second ‘law’ (Ekelund Jr  
& Thornton, 1991; Humphrey, 1992 ): the increase in demand due to a price  
drop is the higher, the lower the initial price: that is, the second derivative  
of the demand function is positive, which, as Dupuit justified intuitively, and  
as formally proven in the text, derives from the pyramidal assumption.  
22 This nuance is missing in the original literature, and understandably so,  
since back then even the basic difference between continuity and differen-  
tiability (let alone probability density function versus cumulative probability  
function) have yet to be well-understood, as Cournot’s characterization of  
continuity at one point in his book attests ([1838] 1897, p. 50, phrase  
italicized).  
23 J.-B. Say discusses the methodology underlying classical economics in the  
opening Considerations générales of the Cours complet ([1828] 2010, pp. 3-  
61).  
24 Walras merely set the stage for this fiction: the explicit introduction of  
the imaginary auctioneer in the theory of tatonnement came later.