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THE MEASUREMENT OF PRODUCTION MOVEMENTS: LESSONS FROM THE GENERAL ENGINEERING INDUSTRY IN ITALY, 1861-1913

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ABSTRACT

In the literature the (Italian) engineering industry is seen as one that transformed metal into machines; its time path is inferred from that of its consumption of metal. Newly recovered evidence indicates that far more metal was turned into (traditional) hardware than into (modern) machines. Machine production grew rapidly from a very small base: metal consumption fails to capture this change in the product mix, and understates the growth of new production at constant prices. Moreover, maintenance activity was in general as significant as new production. Maintenance was labor-intensive rather than metal-intensive, trend-dominated rather than cyclical, and relatively larger, next to new production, in 1861 than in 1913: metal consumption overstates the growth rate of the industry's total product at constant prices, and much overstates its cyclical volatility. Technical progress was negligible in maintenance, but rapid in new production: constant-price-weighted physical measures fail to capture productivity growth, and even late-weighted series overstate the growth of the industry's real product. These results are not tied to conditions peculiar to pre-War Italy: the new estimates presented here pave the way for emending, or at least reevaluating, the engineering-industry product series reconstructed for other times or places.

THE MEASUREMENT OF PRODUCTION MOVEMENTS: LESSONS FROM THE GENERAL ENGINEERING INDUSTRY IN ITALY, 1861-1913

1. Introduction

1 The measurement of the past performance of Italy's industry (and, derivatively, of its entire economy) is proceeding. The first-generation estimates were produced by Italy's Bureau of statistics just over fifty years ago: compiled in haste for Italy's centenary by the Bureau's own (in these matters, inexpert) staff, to international standards of dubious merit, they seemed grossly to misrepresent the path of the economy (Istituto centrale di statistica, 1957; Fenoaltea, 1969, 1972, 2010).

2 The author's second-generation effort is directed primarily at the construction of physical-quantity measures of production, of interest both in their own right and as the basic building blocks for higher-level aggregates. These series are based on a careful critique of the sources, extensively disaggregated to minimize heterogeneity, and designed explicitly to cover all production (avoiding the common, absurd assumption that the documented industries represent the undocumented ones "of the same [arbitrarily defined] sector"); some hundreds now cover all non-manufacturing industries, and a number of manufacturing industries as well (Fenoaltea, 2011a, pp. 60-63). The second-generation aggregates combine the physical-product series with estimates of unit value added in 1911 (a year for which the documentation is particularly rich), and are accordingly comparable to their counterparts in the international literature. As explained in more detail elsewhere (Fenoaltea, 1976, 2010), to the author's mind these are only interim estimates. The desired "real value added" series combine annual estimates of physical product with similarly annual estimates of unit value added at current prices, and deflate the lot with a common price index; one day the "third-generation" estimates will do exactly that.[1]

3 The rising second-generation tide has now covered the engineering industry.[2] In post-Unification Italy it was one of the largest, and most volatile: few others match, and none exceed, its influence on our sense of how, and even more why, the economy then developed as it did (Gerschenkron, 1955, and, on the subsequent literature, Fenoaltea, 2011a, pp. 26, 147-152, 173-176). Unfortunately, with limited exceptions, it is very poorly documented in the sources, and its time path had previously been established only to a first approximation.

4 The exceptionally well-documented parts of industry are of course those with which the State was heavily involved, as a regulator and often as a direct customer. The signal cases

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[1] The calculation of unit value added from current prices and technical coefficients is comparatively straightforward, and far less challenging than the teasing out of physical-product series from limited, imperfect sources: the present author is saving the latter project for his dotage, and one can in fact look forward to the third generation even should he not outlive the second.

[2] On the industry's contours and components see the Appendix below.

are here the railway-rolling-stock industry, and the shipbuilding industry: the various components of new production and maintenance can be reconstructed in fair detail, and their growth is now tracked by a couple of dozen annual series (Ciccarelli & Fenoaltea, 2009, 2012).[3] This paper concerns the rest of the (ordinary) metal-bashing industry, here labeled, for convenience, "general engineering." This residual is now covered by a further (baker's) dozen annual series from 1861 to 1913 that track new output in physical units and maintenance with conceptually analogous physical indices, plus of course the 1911-price value added series for the lot.

5 These new, disaggregated estimates allow the first-ever evaluation of the evolution of the composition of production over time. This greater detail matters for the specifically Italian literature, for as argued elsewhere it destroys the empirical premise shared by all the extant, competing interpretations of Italy's post-Unification industrial growth (Fenoaltea, 2014a). It matters more broadly for the international literature, for it documents the distortions entailed by the simpler indices used so far in the case at hand, and in other empirical contexts as well. These general points, of method, are developed here.

2. The new estimates

1 The first index of the engineering industry's aggregate product, Gerschenkron's, was simply the consumption of (wrought) iron and steel, net of rails (Gerschenkron, 1962 [1955]). The most recent, a very preliminary effort by the present author, combined just four series: one for gold- and silversmithing, a mere interpolation of census benchmarks; one for the maintenance of hand tools, by blacksmiths, similarly constructed; one for the maintenance of machinery, indexed by energy consumption net of firewood; and one for ordinary (non-precious-metal) new production, indexed, much like Gerschenkron's aggregate, by the consumption of (all) iron and steel excluding rails (Fenoaltea, 2003a, p. 729).[4]

2 The reconstruction of the engineering industry's time path has now been brought up to standard. The estimates for the well-documented (shipbuilding and railway-rolling-stock) industries have as noted been presented elsewhere; the new series presented here for the (residual) "general engineering" industry separately track the new production and maintenance by the fabricated-metal, general-equipment, and precision-equipment industries.[5] Table 1 collects the new physical-product series; Table 2, the 1911-price maintenance series; Table 3, the 1911-price subaggregates and aggregates and, for reference, the general-engineering industry's metal consumption. To save space the disaggregated new-production constant-

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[3] As part of a parallel project to document Italy's geographically unbalanced growth, sponsored by the Bank of Italy, the national time series presented there are disaggregated to the regional level.

[4] The metal-consumption series used there includes cast iron, the consumption of which grew much less rapidly than that of wrought iron and steel. The estimates for 1911 extrapolated by the time series were by then census-based, and allowed for the new production of hardware as well as for maintenance; the use of a single new-production (metal consumption) series implicitly assumed an invariant product mix. The precious-metal products industry is here left aside.

[5] The general-equipment industry is doubly a residual, as from the engineering industry excluding the shipbuilding and railway-rolling-stock (and precious-metal-products) industries it further excludes the fabricated-metal (hardware) industry and the precision-equipment industry (producing and maintaining optical, scientific, and musical instruments, and clocks and watches). "General equipment" thus includes all (residual) heavy engineering, and light engineering excluding only its upper tail.

price value added series are not presented; they are simply the physical-product series in Table 1, each multiplied by value added per unit at 1911 prices (415 lire per ton of fabricated metal; 300 lire per ton of machinery assembled from imported parts, 350 lire per ton of truss-structure components, and 900 lire per ton of other general equipment; 16,500 lire per ton of precision instruments, 8,000 lire per ton of clocks and watches assembled from imported parts, and 15,000 lire per ton of clocks and watches from metal).

3 A summary account of the derivation of the present estimates is provided in the Appendix; only enough will be said here to provide the reader with a sense of what they are based on, what they actually are, of what they therefore can and cannot document. The available evidence is quickly recalled: it includes the relevant parts of such general sources as the censuses (Ministero di Agricoltura, industria e commercio, 1876, 1884, 1904, 1913-16, 1915), and the data on international trade (Direzione generale delle dogane e delle imposte indirette, annual), the evidence of metal consumption (calculated from estimated production and reported net imports), and rare surveys that list broad samples of the metalworking firms in Italy and provide, where they could, brief descriptions that include figures on their workers, horsepower, products – and, in a minority of cases, on actual output (Giordano, 1864; Bozzoni, 1885, 1889; Grioni, 1914).

4 The construction of the present general-engineering production series starts by estimating value added (in new production and maintenance together) in the different components of the industry group in 1911, using the data on workers, and power in use, contained in that year's demographic and industrial censuses; both need to be used, as that first industrial census was poorly designed, and the published figures are grossly incomplete (Fenoaltea, 1992, pp. 109-110, 2003b, p. 1059).[6] The evidence on the size distribution of shops, on aggregate metal consumption, and unit metal consumption in new production then dictates the allocation of each component industry's value added to new production on the one hand and to maintenance on the other, essentially as the solution to a system of equations.[7]

5 These same equations are then solved (through a different algorithm) for the earlier benchmarks, the other three years for which the censuses provide evidence of each industry's aggregate work force.[8] These solutions involve independently extrapolating to 1861-1913 a number of the specific new-production, maintenance, metal-consumption, and employment estimates obtained for 1911. The series for the mere assembly (from imported parts) of machines and of clocks and watches, and for the manufacture of truss-structure components, are constructed using product-specific evidence and indices. The series for the maintenance of fabricated metal and of general machinery in turn extrapolate the estimates for 1911 using specific indices of the stocks to be maintained.[9] In the case of precision instruments and of

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[6] The point bears notice, as the literature devoted to estimating industrial employment in 1911 is dishearteningly marred by the consistent failure to grasp what the industrial census actually contains (Fenoaltea, 2014b).

[7] The construction of estimates where direct historical evidence is lacking turns on the identification of the technical and behavioral contraints placed on the desired estimates by the available indirect evidence; the equations at hand specify the here relevant constraints. In point of fact, as noted in the Appendix, the solution derived for 1911 is not independent of the evidence from the earlier benchmarks.

[8] Because of the sharp cyclical downturn in 1901, which no doubt reduced employment, the early-1901 labor-force data are taken to document the actual work force in 1900.

[9] The hardware stock estimates are based on the housing stock, and the agricultural labor force; the

clocks and watches produced from metal, finally, the maintenance (stock) and new-production (flow) series are estimated together, to obtain figures consistent with the international trade data, tariff movements, and the census-year aggregate work force data. With these estimates in place, the census data allow the calculation at the benchmark years of the work force, metal consumption, and physical output of the residual industries, in fact the two largest, the fabricated-metal (hardware) industry on the one hand and the residual general-equipment (machinery and more) industry on the other.

6 Finally, the time-series estimates for the new production of fabricated metal and residual general equipment are obtained together, interpolating and extrapolating the four benchmark estimates; their joint metal consumption serves as a joint constraint, and differential production movements are inferred from differential movements in the corresponding net imports, allowing for changes in relative net protection.[10]

6 Figure 1 illustrates the path of the industry's metal consumption (Table 3, col. 9). The new second-generation estimates are summarized in Figure 2. The upper graphs illustrate the 1911-price general-engineering-industry value added by the fabricated-metal, general-equipment, and precision-equipment industries in new production and in maintenance (Table 3, cols. 1 - 3 and 5 - 7). These graphs are divided, for clarity, into separate panels; but each pair has a common vertical (as well as horizontal, chronological) scale, and each pair of graphs can be reduced to one by direct superimposition. Moreover, the vertical scale of the upper graphs in Figure 2 matches that of Figure 1, up to a multiplicative constant; these time paths too can therefore be meaningfully superimposed.

3. New production

1 The engineering-industry new-production estimates available to date were aggregate figures based directly on metal consumption. When we think of the engineering industry we naturally think of the production of machines; but our imagination is shaped by the world we live in, and the world we have gotten rid of was very different. From Antiquity until comparatively recently the typical metal-worker was Hephaestus, a smith, who dealt not with machines but with simple hardware. The new, disaggregated estimates bring to light the extent to which post-Unification Italy was in this sense traditional. Even at the end of the period at hand the fabricated-metal industry consumed more metal than the rest of the engineering industry, including ships and railway rolling stock, combined; half a century earlier this traditional sector naturally loomed even larger, with a metal consumption over nine-tenths the engineering total. To a first approximation, one hundred and fifty years ago Italy's engineering industry was not a machinery industry but a hardware industry.[11]

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maintenance of machinery is again based on energy consumption, but the estimates are refined to allow for other uses of energy on the one hand, and for the maintenance of user-powered machines (bicycles, sewing machines) on the other.

[10] The algorithm effectively attributes to each of the two industries the pattern evident in their joint metal consumption and their joint imports: in essence, that in the short run world supply curves were more elastic than domestic ones, and that tariffs altered imports' equilibrium share of the domestic market.

[11] The author's earliest estimates appeared in Fenoaltea (1967). These measured engineering production directly from the metal-consumption side; and, on the natural but erroneous presumptions just noted, calculated value added in 1911 as if all that metal had in fact been turned into relatively complex machines. Maintenance was altogether overlooked, and correspondingly underestimated; but

2 As is clear from the lower left-hand graph of Figure 2, those initial conditions held practically unchanged for the better part of three decades. The share of the precision-equipment industry remained comparatively insignificant throughout the half-century at hand, but that of the general-equipment industry – the production of industrial and agricultural machinery, and more – surged after 1887, matched that of the fabricated-metal industry by 1895, and exceeded it, by varying but often significant margins, over the early years of the twentieth century.[12]

3 As is clear from Figure 1 and the upper left-hand graph of Figure 2, the characteristic long cycle in metal consumption and aggregate general-engineering new production was essentially a hardware-production cycle: not a precision-instruments production cycle, because that production was too small to shape the aggregate, and not a general-equipment production cycle, because the time path of the latter was very different. The long cycle in aggregate and hardware production is shaped by the upswing from the late 1870s through most of the 1880s, the subsequent collapse over the late 1880s and early 1890s, enduring depression through the turn of the century, and a renewed upswing over the halcyon years of the *belle époque*. The production of general equipment shared the initial upswing and the final one, but only those: where the new production of hardware took some twenty years to recover and then exceed its output at the 1888 peak, after 1888 that of general equipment apparently reached a new high in four years out of five, failing the mark only in 1891-93 and 1901-03, as it would again in 1913.[13]

4 The time path of aggregate metal consumption, once attributed to the engineering industry as a whole, was essentially as that of the fabricated-metal industry. But the output of that industry is essentially hardware, the hand tools of artisans and farm workers, the metal pieces consumed in construction work; and of the two, the latter component seems much the more cyclically volatile. Contemporaries attributed the cycle of the engineering industry after 1880 to that in public works and residential construction (Direzione generale della statistica, 1896, p. 398). In the light of what we thought we knew, that assertion was perplexing; in the light of what we now know, it makes perfectly good sense.

5 As is clear from both left-hand graphs in Figure 2, the new production of the fabricated-metal industry and that of the general-equipment industry displayed not only different cyclical paths, but different long-term growth rates. The latter industry grew significantly faster than the former: the composition of the aggregate accordingly changed, in favor of the more highly fabricated goods, those involving a greater value added per ton of metal. This is equivalent, on average, to an improvement in quality, the sort of improvement inevitably missed by ordinary, aggregate physical-product measures.[14] The metal-

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so was hardware, the fact that much metal was used to produce simple, low-value-added goods. The latter error was much the greater of the two, and the value added then attributed to the engineering industry in 1911 exceeds the new, census-based estimate by a full 50%.

[12] The timing of the general-equipment industry’s relative surge overturns the standard evaluation of Italy’s tariff policy (Fenoaltea, 2014a); but the issue cannot be pursued here.

[13] All the extant interpretations of post-Unification Italy’s industrial growth, my own not excluded, are based on the presumption that investment in industrial equipment followed the cycle in aggregate metal consumption; on that at least we all agreed, and we were grieviously in error (Fenoaltea, 2014a).

[14] Unless, of course, they are properly designed. The cotton textile industry is a case in point: the first time series that picked up quality change (and thereby the effects of tariff increases) were the “second-generation” estimates that measured yarn and cloth output not in units of weight, as had so

consumption indices of the engineering industry's aggregate physical product are in this sense ordinary, and grow less rapidly than a proper measure that captures composition effects.

6. The bias of the metal-consumption indices stems of course from the implicit assumption that average constant-price value added per ton of metal (also) remained constant over time, whereas in fact it grew (below, Figure 3, left graph of panel 2). The distortion is not overwhelming; and as it happens it actually compensates the opposite bias those indices introduce by calculating metal consumption simply as the total net of rails, and failing to allow for the growing use of semi-finished metal in construction (as rebars, pipes, I-beams and the like: below, Appendix). The lesson here is of course that offsetting errors are the quantitative historian's best friend: but that lesson, at least, is one we learned long ago.

4. Maintenance

1 As just noted, the structure of the general-engineering industry evolved over time, as the new production of more complex (heavy and light) equipment grew faster than that of simple hardware. That the path of metal consumption understates the actual rise in the (weighted) volume of new production is, however, only the minor part of the relevant story.

2 When we think of the engineering industry we naturally think of the production of machines; but our imagination is shaped by the world we live in, and it leads us doubly astray. From Antiquity until comparatively recently our friend Hephaestus was not only involved with hardware rather than with machines: he was involved at least as much in maintaining the existing stock as in producing gross additions to it. The quantitative proof is in the evidence for 1911, when even with metal consumption at its pre-War peak the industry's aggregate value added far exceeded what could have been absorbed by the transformation of that metal into new products.[15]

3 In Figure 3, the left-hand graph in panel 1 illustrates the maintenance and new-production totals in Table 3, cols. 4 and 8: they are at 1911 prices, because these are the only (sub)aggregate time series we have, pending, as noted, significant, if not particularly challenging, further work. The two series in this graph are volume indices; both are sensitive to the choice of base year, but not much, as rates of productivity growth *within* the new-production group on the one hand and the maintenance group on the other appear to have been relatively uniform. This graph can thus be taken to show that the quantity of new goods produced grew much faster, and varied cyclically far more, than the quantity of extant goods maintained; and that, averaging over the business cycle, during the run-up to the Great War value added in maintenance was comparable to that in new production.

4 To a first approximation, obviously, metal consumption tracks the physical volume of new production, for metal consumption in maintenance is altogether minor; by the same token, value added per ton of metal consumed is far higher in maintenance than in new production. Since as noted the volume of new production grows relatively rapidly, and varies strongly over the cycle, the logical consequence is that the sum of maintenance and new production at constant prices grows more slowly, and varies less over the cycle, than metal consumption (and new production alone); or, to put the same point another way, that industry-average constant-price value added per ton of metal consumed declines over time, and varies

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far been done, but by the length of the yarn spun and woven (Fenoaltea, 2001).

[15] Given, of course, the composition of the work force indicated by the census: had all the engineering-industry workers been watchmakers, the imbalance would have been reversed, and a large share of the metal consumed would not be accounted for.

contracyclically.

5 In Figure 3, the left-hand graph in panel 2 illustrates the distortion generated if one uses metal consumption as an index of new production (as in the author's preliminary estimates of a decade ago): the former understates the long-term growth rate of the latter, measured at constant prices but allowing for its changing composition. As noted, however, in the larger scheme of things this is a minor effect, and if one uses metal consumption as an index of the industry's total product, the net bias is quite the opposite. As illustrated in the left-hand graph in panel 3, total engineering-industry constant-price value added per ton of metal declines sharply over time in general, and over the cyclical upswings in particular: metal consumption understates the growth of new production, but much overstates the growth rate, and cyclical volatility, of the industry's total product at constant prices.[16]

6 These regularities emerge from the Italian evidence for the pre-War years, but the more rapid growth of new production than of maintenance seems typical of economies in the early stages of industrialization, and the greater variability of (stock-adjusting) new production than of (stock-related) maintenance seems typical of all economies: once again, therefore, the innovative features of the second-generation Italian estimates can serve to improve the estimates, extant or in progress, related to other times or places (e.g., Prados de la Escosura, 2003, p. 68) – or, failing that, to improve at least our understanding of their implications. In a closely related empirical context, for example, Felice and Carreras (2012) have recently reconstructed the estimates of industrial production in inter-war Italy, and point out that "the 1929 crisis now looks more profound than before" (ibid., p. 458). They treat the present author's work with such consistent generosity that it seems churlish to turn it against them, but if, as it seems, they indexed engineering production by metal consumption (ibid., online Appendix Table 1), the presumption must be that their estimates overstate the industry's cyclical volatility, and are biased in favor of their conclusion.

5. Total real product: the deficiencies of the second-generation estimates

1 As can be seen in the left-hand graph in Figure 3, panel 1, in (and around) 1911, at then current prices, the boom-bloated new-products component of the general engineering industry was larger, but not very much larger, than the maintenance component.

2 What the volume indices in that graph do not show is the relative growth rate, and size over time, of the new-production and maintenance components of that industry, because rates of productivity growth differed sharply *between* them. Since the second-generation aggregates calculate 1911-price value added in proportion to output, as one goes back in time measured value added per worker declines, the more so, the greater productivity growth; measured value added per worker thus remains constant in maintenance (and assembly work), which continued to be done by hand, but declines, more or less precipitously, in (other) new production. The constant-price series suggest that over the nineteenth century maintenance always exceeded new production; but that suggestion is entirely misleading.

3 In the case at hand, the present estimates for 1911 suggest that maintenance work represented 50% of employment but just 40% of value added, reflecting the greater capital-intensity of new production. But in 1911 new production was at a remarkable peak, and the

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[16] From 1861 to 1913 the industry's aggregate product at constant (1911) prices grows from 169 million lire to 606 million lire (Table 3, cols. 4 + 8), or well under four-fold, metal consumption from 102,000 tons to 817,000 tons (ibid., col. 9), or almost exactly eight-fold; the coefficient of variation of the former equals .43, that of the latter exceeds .75.

maintenance share of employment was historically low; as estimated, it equals 54% in 1900, 58% in 1881, and again 58% in 1871. The share of value added at 1911 prices attributed to maintenance also grows as one goes back in time, to 59% in 1900, 74% in 1881, and 81% in 1871, drifting up ever further above the maintenance share of employment. At current prices, as one goes back in time, one would expect to see the very opposite: the maintenance share of value added should approach the maintenance share of employment ever more closely, as (going back in time) new production is ever more artisanal, ever more a hand process rather than a machine process, in short ever more like maintenance.

4 To capture the relative growth not of physical output but of industry, of "real value added," we need the third-generation estimates; these have not yet been compiled, but their logic was presented in detail some time ago (Fenoaltea, 1976; Fuà, 1993). In our discipline the distinction between "real" and "nominal" emerged in the context of inflation: to us "real" means not generally "like things," as it does in common speech, but specifically "like things when the currency loses its value in exchange, and things do not." "Like things" only in those particular circumstances: our discipline cut its baby teeth on the water-diamonds paradox, we know full well that "real value" depends on relative scarcity as well as physical characteristics, that it can change with the former even with no change in the latter. "Real" in its technical sense is a *metaphor,* a figure of speech: an industry's "real product" is not literally its own physical output, but that output (*rectius* value added) converted into goods in general.[17] The third-generation estimates (will) do exactly that: by deflating the (not yet available) product-specific current-price value added series by a *common* price index, they (will) recognize the changes in *relative* value added per unit caused by relative shifts in supply, notably those due to differential rates of technical progress, and, in the presence of specialized resources, by relative shifts in demand.

5 The series illustrated in the left-hand graph of Figure 3, panel A are second-generation estimates, at constant prices, "real" in the literal sense; for present purposes, to eliminate here irrelevant considerations, we can imagine that they track a homogeneous stock of goods maintained, and a homogeneous flow of goods produced.[18] Of the two, the maintenance series can be taken as (approximately) real in the proper metaphorical sense as well; the new-production series cannot, as new production, unlike maintenance, was characterized by rapid technical progress.[19]

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[17] If we grant the identity of income and product, and therefore of real income and real product, and further grant that real income is properly measured in "goods in general," it follows that "real product" is to be measured in the same way. Counterfactual *intellectual* history is not a popular sport, but it bears notice that if the profession had settled on a less toxic metaphor, and referred not to "real" but simply to "deflated" value added, Arrow and Sims might never have argued that "it" exists only if the production function is suitably separable; Fabricant and Geary might not have proposed to measure it as a difference between weighted physical series, with its notorious tendency to generate negative figures; and David might not have reacted by suggesting own-output-price deflation, which avoids negative results at the cost of violating the first condition required of any measure of value added, that it be invariant to (here, vertical) disaggregation. See Fabricant (1940), Geary (1944), David (1966), Sims (1969), Arrow (1974), Fenoaltea (1976).

[18] As such, they share the conceptual deficiencies of the extant "real" measures; but as approximations to the proper ones they are no worse, and often better, than the alternatives in the literature (see the numerical comparison to the Fabricant-Geary and David indices in Fenoaltea (1976).

[19] Since the maintenance relevant here remained essentially a hand process unaffected by technical progress, the implicit standard of "real value" is here simply labor time; a basket of goods is as noted

6 In sum, the only measure of production ("real value added") that allows us to do what we want it to do – to make meaningful comparisons across industries and across years – is one not at constant prices, but at a constant *price level*: and for that we need to construct the third-generation estimates, that is, to take the second-generation physical series, weight them one by one and year by year by unit value added at current prices, and then deflate the resulting industry-specific current-price value added estimates with a common deflator.[20]

6. Total real product: ersatz third-generation estimates

1 Pending such estimates, however, we can construct a crude first approximation: ersatz-third-generation value added series that maintain a constant (1911) price level, but reflect current relative prices, are illustrated in the right-hand graph in Figure 3, panel 1.[21] With respect to the left-hand graph the maintenance series is unchanged; the new-production series has instead been subjected to a simple trend-growth correction to force it through two points, the 1911 estimate on the one hand, and a revised benchmark for 1871 that assigns new production 45% of the total (marginally above its 42% labor share, to allow for a slightly greater capital intensity, even then). In (properly understood) real terms, maintenance and new production grew at very similar long-term rates, albeit of course with very different variability.[22] Maintenance exceeded new production only about half the time; similarly, cumulating over the full period at hand, maintenance represented approximately half the industry's product.[23]

2 As already noted, the use of metal consumption as an index of the engineering industry's aggregate production of new goods understates (weighted) volume growth, because it ignores the growing complexity, on average, of those goods; this is brought out by the left-hand graph in Figure 3, panel 2, which shows a steady rise in new-production value added, at 1911 prices, per ton of metal consumed. But in the presence of technical progress the growth

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the obvious alternative, but with diffuse technical progress it would here inject complications that are again irrelevant to the fundamental point at hand. The discussion accordingly proceeds as if the current-price equivalency of labor-time and goods-in-general (the real wage) remained constant over time.

[20] To revive a useful metaphor, the standard aggregates of things are like time-pieces that keep time badly. Repeated changes in the base year contain the error by resetting the watch; an annual chain resets the watch every day, but to construct it one needs the full set of current-price value added estimates that provide the continuously-varying weights, and once one has those one may as well go *totus porcus*, to the third-generation estimates, here the marine chronometer.

[21] For a precedent and further discussion see Fenoaltea (2011b).

[22] The reason for the relative stability of maintenance is of course that it is tied directly to the extant stocks, while new production is tied to the desired *adjustments* to those stocks. Maintenance per stock unit may also vary over the cycle, but it is not clear whether with it (as when times are hard maintenance too can be postponed) or against it (as when times are hard older assets may be maintained and kept in use rather than scrapped and replaced); in any case, these appear to be second-order considerations, and the present estimates ignore them.

[23] The importance of maintenance was similarly noted for the shipbuilding and railway-rolling-stock industries (with the signal exception of naval vessels, which once built are little used). It may be pointed out that in those two industries maintenance and new production use very similar processes and facilities, and the calculations at hand can be performed directly with the second-generation figures.

in the products' complexity must be set against the growing efficiency of production; and in the case at hand the latter far outweighed the former. This is brought out by the right-hand graph in Figure 3, panel 2. The new products became more complex, but the real cost of turning metal into finished products fell dramatically: new-production real value added per ton of metal fell over time, and the growth of metal consumption *overstates* the real growth even of new production alone, and very badly at that.

3 This distortion carries over if metal consumption is used as an index of the engineering industry's aggregate product. Using the ersatz 1911-price-level (third generation) estimates illustrated by the right-hand graphs in Figure 3, maintenance and new production show much more similar trend growth rates (panel 1), and the growth of metal consumption overstates the growth of total product (panel 3) about as much as it already, badly, overstates that of new production alone (panel 2).[24] In both perspectives, clearly, maintenance rendered total product less cyclically variable than its metal-intensive new-product component. As metal consumption varies over the cycle, value added per ton of metal consumed also varies, but contracyclically: the path of metal consumption much overstates the cyclical variability of the engineering industry, in terms both of weighted volumes (panel 3, left-hand graph) and of real value added (panel 3, right-hand graph).

4 Figure 4 presents alternative indices of the general-engineering industry's aggregate product, all rescaled to set them equal to 1.00 in 1861. The top-most (dotted) line, with eight-fold growth from end to end, is the index of the industry's metal consumption (the same line as in Figure 1, merely rescaled). The second (hyphenated) line from the top is the index of the aggregate product at 1871 prices, calculated with the 1871 weights estimated above (45% to new production, 55% to maintenance): from 1861 to 1913 it grows six-fold. The third (dashed) line from the top is the index of the (present, second-generation) aggregate product at 1911 prices (the sum of the two series in the left-hand graph in Figure 3, panel 1, suitably rescaled): from 1861 to 1913 it grows less than four-fold, much less than its counterpart at 1871 prices.

4. The fourth (continuous) line from the top is the (ersatz third-generation) aggregate product properly calculated at a constant price *level* (the sum of the two series in the right-hand graph in Figure 3, panel 1, suitably rescaled): and it suggests that from end to end the general-engineering industry's aggregate product merely doubled. At *any* year's price level: a calculation with the price level of a different year would yield a different lire aggregate parallel (on a semi-logarithmic scale) to the present series at the price level of 1911, and once rescaled to a common index base (such as 1861 = 1.00) the series simply coincide.

5 Figure 4 sheds an interesting light on the "Gerschenkron effect," which seems widely misunderstood.[25] That in the presence of differential technical progress the volume index with early weights grows faster than its counterpart with late weights is an arithmetic necessity, and duly reappears in the case at hand. But the common opinion that the two are respectively "biased upward" and "biased downward" is simply wrong. That the 1911-price-weighted second-generation series understate growth is a recurring criticism (echoed most recently in Baffigi, 2011, p. 169); in fact, next to a proper measure of real value added they are biased *upward*, and a parallel calculation with "early" weights only compounds that bias.[26]

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[24] In both cases, over the half century at hand constant-price-level value added per ton of metal drops by more than two thirds (from the right-hand graphs in panels 2 and 3, noting their different scales).

[25] See Fenoaltea (2014c). This topic too cannot be pursued here.

[26] This statement must be qualified in the light of the complications introduced by rising real wages,

6 But the most severe upward bias is that of the metal consumption index, which in the case at hand registers from end to end an eightfold increase in lieu of the actual twofold one.[27] Gerschenkron's pioneering use of metal consumption to track the growth of the poorly documented engineering industry was a marked step forward (Gerschenkron, 1962 [1955]), and as noted he has been widely imitated; but the biases of that measure are now apparent, and the broad corpus of estimates that follow that precedent is now to be reconsidered.

7. Conclusion

1 The general engineering industry in post-Unification Italy was very poorly documented by contemporary sources, and the quantitative historiography has traced its progress by tracking its consumption of metal. The industry is seen, through the prism of our own experience, as in essence a producer of machines; but that prism appears grossly to distort it.

2 The new, disaggregated "second-generation" measures exploit the periodic census evidence on the industry's composition, and use the consumption of metal only as an overall constraint on production. The burden of the evidence that has thus been brought to bear is that in the period at hand, and especially in its early decades, the general engineering industry was overwhelmingly a hardware industry rather than a machinery industry, and devoted to maintenance as much as to new production. In Italy at the time of Unification the typical metal-basher was simply the local smith, the maker and repairer of the hand tools of agricultural laborers and industrial artisans, the supplier of the metalware used in construction and by households: the Italian case seems typical of traditional, agricultural societies. In Italy the production of machinery, of complex heavy and light equipment, grew significantly, even in relative terms, over the succeeding decades: the Italian case seems typical of the early stages of industrial growth.

3 The new estimates have broad methodological implications. Metal consumption is a widely used index of the engineering industry's real product. The growing complexity of physical output means that metal consumption underestimates its growth, in quality-corrected physical terms. But in the presence of technical progress physical goods are no more "real" than paper money in the presence of inflation. Productivity growth reduces the real value added embodied in the product, per ton of product, per ton of metal; a metal-consumption index vastly overstates the growth rate of new production, calculated at a constant price *level*. Moreover,

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so far assumed away (footnote 18). Labor-time is *a* proper measure of real value, but goods-in-general are another, and with rising real wages the two yield different results. If we take goods-in-general as our standard, with rising real wages labor-tine itself increases in real value, and the bottom-most line in Figure 4 would be rotated upward. From 1861 to 1913 real wages may have doubled (Fenoaltea, 2011a, pp. 123-131): the late-weighted series overstate the end-to-end increase in "real-product" by a factor of about 2 if the standard is labor-time, but get it approximately right if the standard is goods-in-general (this of course by happenstance, as by the "goods" standard the understatement of the growth of maintenance, due to its below-average productivity growth, roughly offsets the overstatement of the growth of new production, due symmetrically to its above-average productivity growth). Intuitively, the most reasonable standard is somewhere between goods-in-general and labor time (Fenoaltea, 1976, 2014c), and on that basis the present late-weighted aggregates retain an upward bias.

[27] This is with a metal consumption series that allows as noted for the growing use of metal outside the engineering industry. If only rails are excluded, as in Gerschenkron's own calculations, the bias of the metal consumption index is even greater, as it grows ninefold (using the figures reported below, in the Appendix).

maintenance was a large part of the industry's work. The stocks maintained grew far less rapidly than the physical output of new goods; but the critical point is that maintenance was cyclically stable, and used little metal. A metal-consumption index thus much overstates the cyclical variability, as well as the average level, of the industry's growth rate.

5 The distortions of the metal-consumption index are documented by the new estimates for post-Unification Italy, but are *in ipsis rebus*; we are now better equipped to evaluate the similar indices used in other empirical contexts.

Appendix: Sources and methods

1 A full account of the derivation of the present estimates is available on request; it is provided in some 130 pages of single-spaced text, and 100 of accompanying tables (Fenoaltea, in progress, section F). What follows is only a summary designed to convey a sense of the issues that were faced, and the means by which they were resolved.[28]

2 The engineering industry is here defined as the contents of categories 4.3, 4.4, and 4.5 in the Italian 1911 census. This industry is substantially that covered by ISIC category 38 (manufacture of fabricated metal products, machinery, and equipment); the principal differences are that the present industry excludes the manufacture of wood carts, carriages, and sleighs (part of 3849), and wood boats not built in yards (part of 3841), but includes the manufacture of jewelry and related articles (3901) and metal musical instruments (part of 3902) and the repair of electrical appliances (9512), motor vehicles (9513), watches, clocks, and jewelry (9154), and other equipment (9519). The general repair services of blacksmiths and the like, and the specialized services of shipyards and railway repair shops are included in the present engineering industry and also in ISIC category 38 (3811, 3841, 3842); the typically low-level maintenance carried out within households, or within firms that lacked a separate maintenance shop (and therefore employed no professional machinists, to judge from the similarity of the demographic- and industrial-census figures for category 4.4), are excluded from the present industry and also from ISIC category 38.[29]

3 The present paper considers the engineering industry net of the shipbuilding and railway-rolling-stock industries, already documented and discussed, and of the production of precious-metal goods, which is a horse of a different, shiny color; it is accordingly limited to the residual base-metal-working industry, referred to for convenience as the "general engineering industry." Its major components are what are here called the hardware industry, the precision-equipment industry, and the "general equipment industry" (again a residual, covering heavy engineering net of the shipbuilding and railway-rolling-stock industries, and light engineering net of the upper, "precision" tail).

4 The general-engineering industry's product is constrained, year by year, by its total consumption of metal. The annual estimates of that consumption are here refined, with respect to earlier work, by allowing both for the consumption of non-ferrous metals, and for the metalmaking industry's other products that were absorbed, like rails, without further fabrication. The latter correction is the one that matters: the reductions to allow for railway chairs, rebars, I-beams, pipes, wire, and the like grow from 11% of ferrous-metals consumption net of rails in 1861 to 23% in 1913, while the net consumption of other metals

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[28] For further details on the construction of the estimates for 1911 see Fenoaltea (2014d).

[29] See the above-cited censuses of 1911 and United Nations (1971).

adds back just 3 to 5%, without much altering the resulting time path.[30] The metal consumption relevant here is of course the engineering-industry aggregate, reduced to exclude the metal consumed in the production and maintenance of ships and railway rolling stock, considered elsewhere.

5 The construction of the new production series for the general engineering industry starts from the labor-force data in the demographic census of 1911, and the employment and power-in-use data of the contemporaneous industrial census, presented with a common industrial classification. The industrial census, which didn't come off as planned, counts only the workers (and horsepower in use) in shops with at least two workers, and separate from the owner's residence.[31] In the case at hand, full (or over-full) employment is suggested by the doubling of metal consumption in the half-dozen years to 1911; the demographic-census labor-force figures are accordingly taken as direct measures of actual employment, and simply grouped into here useful subtotals for the fabricated (ordinary) metal industries, the "general equipment" industries (to be understood here and henceforth as net of the shipbuilding and railway-rolling-stock industries), and precision-equipment industries.

6 The next step is to estimate the corresponding figures for horsepower in use. The industrial census provides separate figures for the large shops (with more than 10 subordinate workers), and small shops, which it covered; not surprisingly, the horsepower/labor ratio was far lower in small shops than in large shops. The horsepower in the omitted shops are extrapolated from the numbers of omitted workers, allowing for the apparent average size of the omitted shops suggested by the ratio of omitted (subordinate) blue-collar workers to omitted owner/managers. Typically, the omitted shops appear to be even smaller, on average, than the industrial-census small shops (suggesting an even lower ratio of horsepower to labor), but the opposite occurs, interestingly, in the case of the largest fabricated-metal categories.

7 Value added is then estimated, for each of these industries, as the sum of labor and capital costs. Labor costs are estimated on the basis of standard wages by age and sex, plus an allowance for salaries for workers in large shops; the procedure yields industry-specific averages per worker that reflect the distribution of the labor force by age, sex, and shop size.

8 Capital costs are estimated as the sum of two components; the first is labor-related ("circulating capital"), and set equal to a uniform 12.5% of labor costs. The second is horsepower-related ("fixed capital"); distinct estimates for the various industry groups are derived as follows. An initial benchmark is obtained for the shipbuilding and railway-rolling-stock industries: deducting their wage bill and labor-related capital costs, calculated as above, from their independently estimated value added, one obtains residuals that, divided by

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[30] Aggregate ferrous-metal consumption excluding only rails clearly overstates the long-term growth rate of actual engineering-industry metal consumption; and since the share of cast iron in metal consumption also declined over time, from perhaps one quarter in 1861 to nearer one seventh by 1913, the overstatement is compounded if one deducts rails, as Gerschenkron did, from *wrought* iron and steel consumption alone.

[31] This separation seems to have been interpreted as a separation of street addresses, as the demographic census form was supposed to document whatever industry took place at the residential address (or even elsewhere, if the member of the household who worked there worked alone). It failed to do so; the published industrial census warns that it tabulates only the data collected on one of the two forms on which it was to be based. It apparently omits, therefore, all one-man shops; most (other) artisanal shops, as artisans often lived above their shop; and, apparently, whatever factories were located next to their owner's residence in a single compound with a single street address. The demographic census counted 4.3 million industrial workers (including of course the unemployed), the industrial census just 2.3 million.

horsepower, are, serendipitously, virtually identical. The 1938 census data are then used to calculate relative power-related capital costs across industries; and these relatives are applied to the 1911 shipbuilding/railway-rolling-stock benchmark to estimate industry-specific capital costs per horsepower and, derivatively, power-related capital costs, total capital costs, and value added.

9 The estimates of aggregate value added and employment are then broken down to separate maintenance and new production. This allocation by activity can only be estimated; but the logical problem is straightforward. Ignoring its internal subdivisions, the industry is divided into a new-production sector, and a maintenance sector; aggregate value added, metal consumption, and employment are given, in 1911, as are value added and metal consumption per unit of output. The lower the share of aggregate (employment and) value added attributed to maintenance in 1911, the higher value added, and therefore metal consumption, in new production, and the lower, therefore, the residual metal consumption available for maintenance, overall and per maintenance worker, in 1911; since the latter consumption must be positive, the share of maintenance in aggregate value added in 1911 has a lower bound. The higher the share of aggregate value added (and employment) attributed to maintenance in 1911, conversely, the higher the residual metal consumption available for maintenance, overall and per maintenance worker, again in 1911. But as one goes back in time, aggregate maintenance is indexed directly by independent evidence, and 1911-price value added, employment, and metal consumption in maintenance are correspondingly determined. At the earlier benchmarks, these estimates yield as residuals the labor force and metal consumption in new production, and the corresponding metal consumption per worker (including unemployed workers, but the time-series evidence suggests that the share of the latter was plausibly small in 1871, and negligible, as in 1911, in 1881). At the early benchmarks, average metal consumption per worker is relatively low; the average in maintenance varies directly with that calculated for 1911 (as the two are linked by the maintenance index), and the higher it is, the lower is the implied average in new production. But metal consumption per worker must always have been many times higher in new production than in maintenance: a reasonable ratio between the two at the 1871 benchmark requires that estimated metal consumption per worker be sufficiently low in 1911, that is, on the logic outlined above, that the share of (employment and) value added attributed to maintenance in 1911 also be sufficiently low. In short, the share of maintenance in 1911 is bounded from below by the implied metal consumption in maintenance in 1911 itself, and from above by the implied ratio of metal production per worker in new production to that in maintenance decades earlier; and the margin between these two bounds turns out to be pleasingly narrow.

10 In practice, of course, the internal subdivisions of the industry cannot be ignored. In practice, the share of each industry's value added and employment attributable to maintenance is obtained in two steps. First, value added per worker in maintenance is estimated directly; since maintenance was essentially a hand process, value added is calculated as the (small-shop) average wage, augmented by the standard allowance (12.5%) for labor-related circulating capital costs, and a further small allowance (2.5%) to allow for hand tools and the like. Second, aggregate small-shop value added and employment are allocated to maintenance on the one hand and new production on the other on the assumption that the small shops' average value added per worker was a weighted average of the (directly estimated) maintenance figure and a new-production figure equivalent to that observed for the industry's large shops (assumed specialized in new production).[32] Estimates of value added and metal

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[32] The actual calculation allows where necessary for mere assembly, for example of clocks and watches from imported parts.

consumption per ton of output are then combined with the estimates of value added in new production to estimate each industry's physical output and metal consumption; the residual metal consumption is attributed to maintenance activity, and allocated among industries in proportion to (suitably weighted) maintenance employment.

11 The estimates of these same variables at the earlier benchmarks are obtained by solving the same system of equations, but with a different algorithm. Aggregate metal consumption is estimated independently, as noted, and each industry's aggregate work force is obtained from the census data; the other unknowns are pinned down in succession, in part by directly extrapolating the estimates for 1911 already obtained.

12 Five of the seven new-production series in Table 1 are thus obtained independently, because they are idiosyncratic and/or directly documented. Two series refer to the assembly of machines, and of clocks and watches, from imported parts. These are separated out because domestic value added per unit of final output is obviously far lower than in the production of those same goods from metal; because such production is not caught at all by the metal-consumption figures; and not least because part imports are documented by the international-trade data. The import series display sharp cyclical movements, suggesting that those parts were indeed assembled into new machines, and not used, as one might have thought, as replacement parts in (stock-related) maintenance activity.[33]

13 A third series is prompted by the surviving anecdotal evidence that the manufacture of iron bridges and canopies was a, if not the most, significant component of the heavy engineering industry ca. 1880, and a point estimate, by the major manufacturer, of its metal consumption in 1884. Since this industry was protected, and apparently enjoyed a comparative advantage at free-trade prices (as evidenced by its leadership in demanding, and obtaining, drawbacks on export work), that point estimate is here extrapolated to 1861-1913 with an index of (weighted) domestic construction, and inflated by recorded exports (those separately identified because they offset duty-free imports of metal). Also included here are estimates of the production of other truss structures (power-line towers, estimated from the growth of hydroelectric capacity). With these items separated out, the general-equipment (from metal) industry is covered by two separate series, one for relatively simple (truss-structure) goods with low value added per ton, and the other for the residual, with a much higher value added per ton. Over the early decades, this residual is relatively homogeneous, as it consists essentially of ordinary (industrial, agricultural) machines; in the early twentieth century it becomes increasingly heterogeneous, as it includes growing quantities of products characterized by a value added per ton that was very high (automobiles) or very low (pressure pipelines), but the data in the census and in the late directory sample suggest that these largely offset each other.[34]

14 The other two new-production series refer to precision equipment (precision instruments, including musical instruments; clocks and watches). Since these consumed only trivial quantities of metal, they are estimated directly, in conjunction with the corresponding stocks maintained, with an eye to obtaining estimates of the stocks consistent with the flows,

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[33] On reflection, the thought would be a poor one. In an age before cheap air freight, firms simply did not have the now low-cost option of obtaining parts from the manufacturer as they happen to be needed. Had replacement parts been ordered as needed from the original manufacturer the machines' down-time would have been long and costly, had original spare parts been held in stock inventories would have been large and costly; the least-cost solution was no doubt simply to mend or remanufacture parts as needed, incurring high direct production costs but saving the even greater costs of waiting, or of keeping large inventories.

[34] Not by happenstance: power-line towers were separately estimated, and added to bridges and canopies, to obtain this very result.

of the flows consistent with the corresponding import data (allowing for changes in tariffs), and of the lot consistent with the census work-force data.

15 The other maintenance value added and metal-consumption series are also obtained by direct extrapolation of the estimates obtained for 1911. The maintenance of fabricated metal is divided into three components, to allow for differences in metal consumption per worker, or in the series' time paths. Blacksmiths are taken to have maintained, in the main, agricultural implements; that maintenance is extrapolated at the long-term growth rate of the agricultural population.[35] Other smiths and other (ferrous-metal) hardware workers can instead be presumed to have maintained the copper- and ironware either directly incorporated in buildings (copper drainpipes, iron hinges, and the like) or broadly complementary in particular to residential structures (kitchenware); that maintenance is accordingly extrapolated in proportion to the estimated maintenance of private buildings, with its growth rate marginally augmented to allow for the progressive diffusion of metal..

16 The maintenance of general equipment appears in Table 2 as a single aggregate (col. 4); since the maintenance of structures, including metal structures, is the province of the construction industry, this aggregate represents in essence the maintenance of machinery. The estimates for 1911 are extrapolated with an index that combines two components: a major one, related to power-driven machinery, and a minor one, related to (modern, metal) user-driven machinery. The maintenance of power-driven machinery is here taken to have varied with its level of activity, itself indexed by its apparent consumption of energy. The latter is estimated from the net imports of coal (and coke), augmented by the coal-equivalent consumption of liquid and gaseous fuels. These figures are then reduced by specific estimates of the here irrelevant uses of coal (and other mineral fuels): the coal consumed by the railways (documented in the sources); the coal (or coke) used to heat materials rather than to raise steam by various industries, including the kiln-products industries, the chemical industries, the metalmaking industries, the engineering industry itself (estimated from its consumption of metal), the sugar industry, the gas utilities; the coal used by the electric utilities to generate light rather than power. These fuel-consumption series are estimated from the physical product series and the relevant technical coefficients, allowing where relevant for the progressive substitution of coal for wood or charcoal. The net estimates of the coal actually used to generate steam for motive power are further adjusted to allow for the reduction of transmission losses as electricity replaced gears, belting, and the like. The resulting series is finally augmented to allow for the use of water power, both directly, and to generate electricity (excluding allowances for the water power absorbed on the one hand by traditional wooden machinery, and on the other by electric lighting). Overall, the profile of this index of the maintenance of power-driven machinery is much as one would have predicted, with relatively steady growth save for a marked slow-down over the 1890s. The maintenance of (modern, metal) user-powered machinery is in turn a weighted sum of two stock estimates, one for sewing machines (built up from the import data), and another for bicycles (documented by the annual sales of license plates). The indices for power- and user-driven machinery are then combined with weights equal to .90 and .10, respectively, in 1911, estimated using the detailed census data.[36]

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[35] That growth rate is calculated from the early censuses, excluding that of 1911. This last was taken in summer (rather than, like the others, in mid-winter), and the recorded agricultural population appears sharply reduced by the absence of temporary migrants.

[36] It may be noted that these shares imply that (engineering-industry) maintenance per ton of user-powered equipment far exceeded that per ton of machine-powered equipment. This suggests that on a day-to-day basis most industries maintained their own machines far more than households did or could, and that the engineering industry as defined by the census (and here) included only the physically

17 Deducting from the appropriate totals the benchmark-year employment and annual metal consumption thus attributed to all maintenance on the one hand, and to the generally minor branches of new production (truss-structure components, precision instruments, clocks and watches, assembly from imported parts) on the other, one obtains benchmark-year estimates of the work force in the new production of fabricated metal on the one hand and of (residual) general equipment on the other, and annual estimates of the corresponding consumption of metal in these two activities together. Since the general-equipment industry appears to have experienced rapid growth from benchmark to benchmark (and in particular boom conditions even in 1900), its metal consumption is estimated directly from its estimated new-production work force, allowing for productivity growth, and metal consumption in the production of fabricated metal is obtained as a residual. The benchmark output and (1911-price) value added estimates for these two industries are then derived from estimated metal consumption, thus completing the set of estimates for the benchmark years.

18 Finally, the benchmark output estimates for the fabricated-metal and (residual) general-equipment industries are extrapolated to 1861-1913 on the assumption that their relative shares of their joint metal consumption varied in response to relative movements in their markets, evidenced by those of the corresponding imports, corrected for changes in relative protection. In the early decades, as noted, even the general-equipment industry was very small; at that time, for all the sanding and filling described above, the path of the fabricated-metal industry's output is in fact tightly constrained by that of the engineering industry's aggregate consumption of metal.

19 In summary, the four sets of benchmark estimates are relatively firmly grounded in the census data. The algorithm that interpolates and extrapolates those estimates is thoroughly heuristic, but the resulting time series are consistent, by construction, with the supply-side constraint imposed by their joint metal consumption, with the demand-side fluctuations suggested by the international trade statistics, and with a good deal of ancillary evidence.

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separate major-maintenance shops of the larger enterprises, and all the independent maintenance shops: those that overhauled (and remanufactured parts for) the equipment of other firms, and those that met the maintenance needs of the owners of consumer durables.

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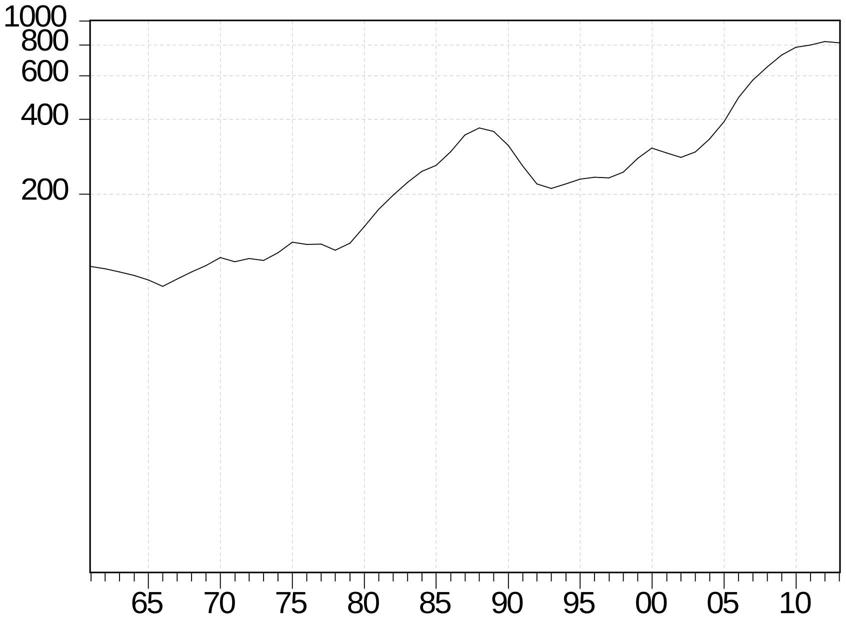
Figure 1. General-engineering metal consumption, 1861-1913
(thousand tons)

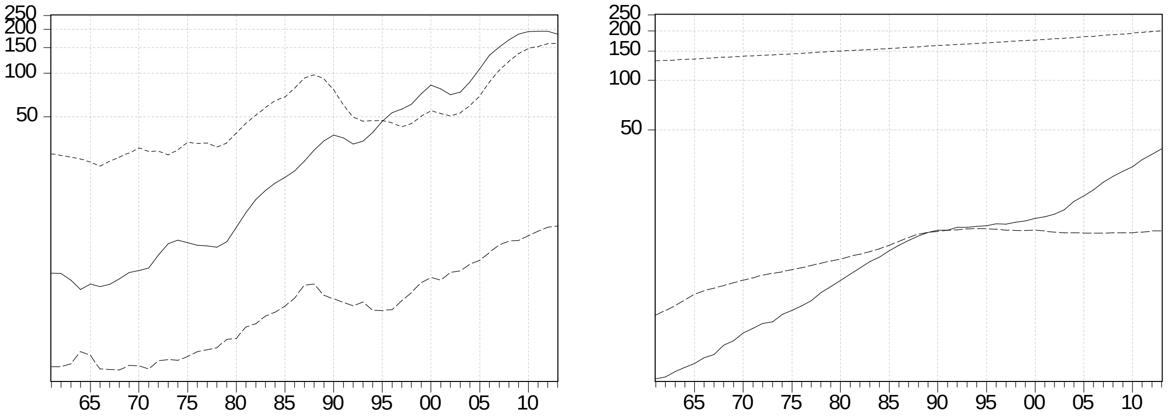


NB: "general engineering" excludes the shipbuilding, railway rolling-stock, and precious-metal-products industries.

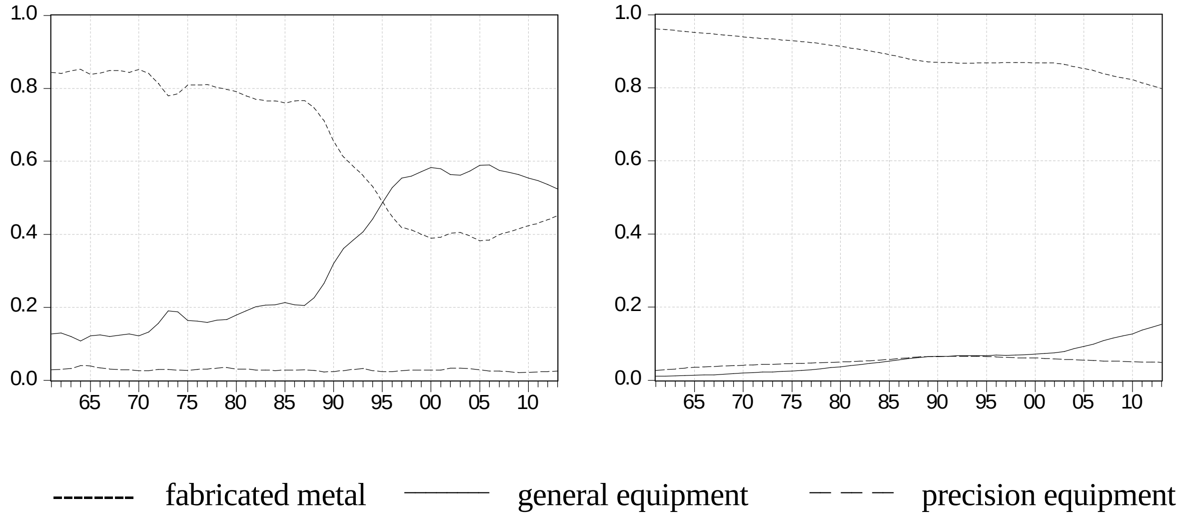
Figure 2. General-engineering new production and maintenance, by industry, 1861-1913

A. New production *B. Maintenance*

1. Value added at 1911 prices (million lire)



2. Shares of aggregate new production and aggregate maintenance, at 1911 prices



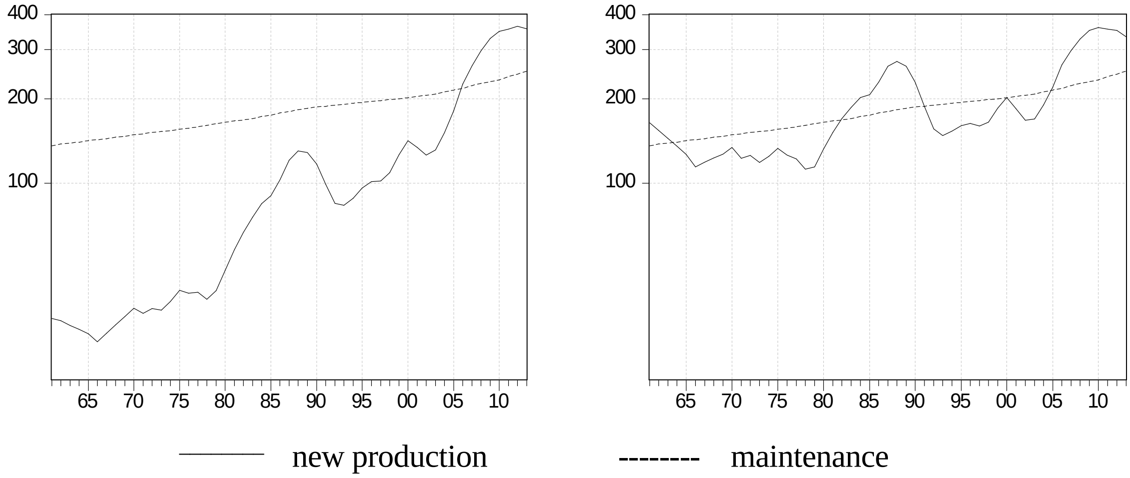
NB: “general engineering” excludes the shipbuilding, railway rolling-stock, and precious-metal-products industries.

Figure 3. Aggregate general-engineering new production and maintenance, 1861-1913

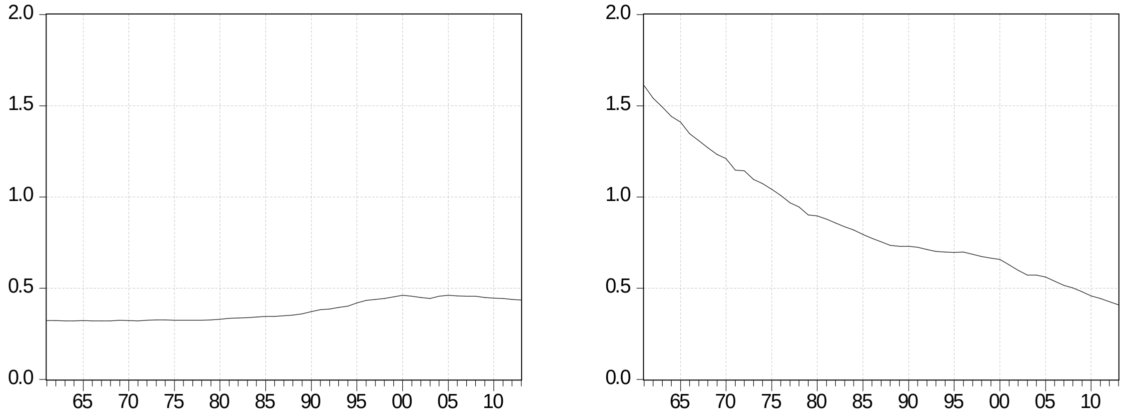
A. Second-generation estimates
(at 1911 prices)

B. Ersatz third-generation estimates
(at the 1911 price level)

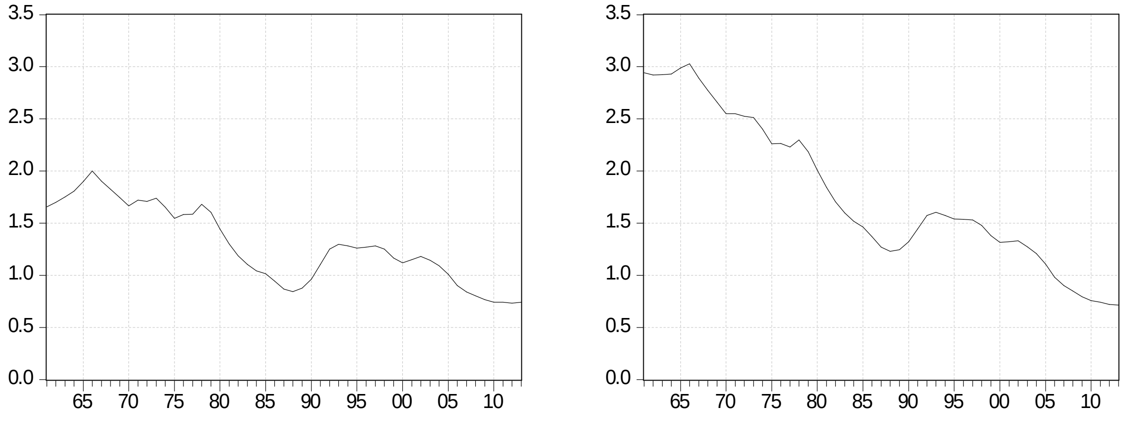
1. value added (million lire)



2. new-production value added per ton of metal consumed (thousand lire)

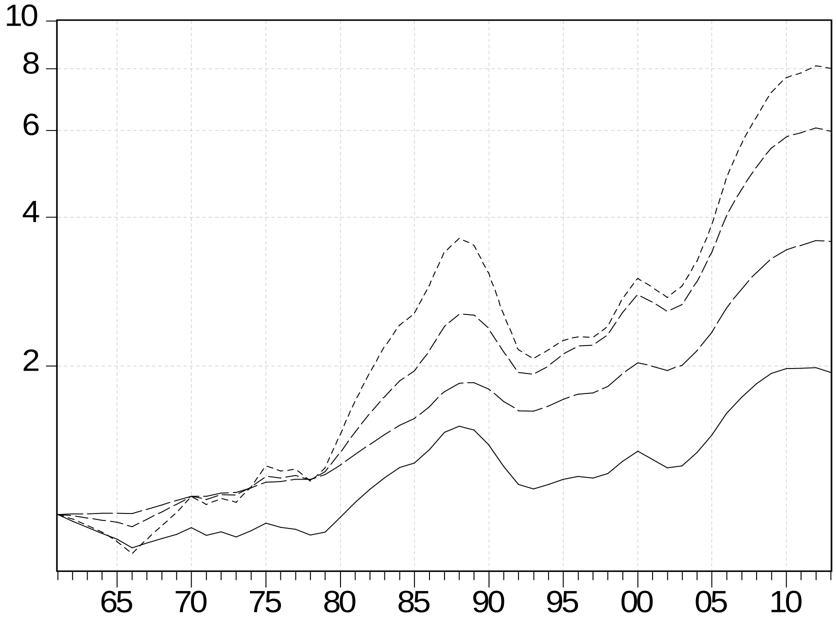


3. total value added per ton of metal consumed (thousand lire)



NB: “general engineering” excludes the shipbuilding, railway rolling-stock, and precious-metal-products industries.

Figure 4. Alternative indices of aggregate general-engineering new production and maintenance, 1861-1913 (1861 = 1.00)



------- metal consumption
— — — aggregate product at constant 1871 prices
— — aggregate product at constant 1911 prices
——— aggregate product at a constant price level

NB: “general engineering” excludes the shipbuilding, railway rolling-stock, and precious-metal-products industries.

Table 1. Estimated new production of general-engineering products, 1861-1913 (thousand tons)

	(1) Fabricated metal	(2) Machines merely assembled	(3) Truss-structure components	(4) Other general equipment	(5) Precision instruments	(6) Clocks and watches	(7)
						merely assembled	from metal
1861	67.07	.40	1.72	3.86	.036	.004	.022
1862	65.46	.40	1.95	3.76	.036	.004	.022
1863	63.56	.32	2.04	3.27	.036	.006	.024
1864	61.85	.27	1.92	2.78	.043	.011	.028
1865	58.66	.62	1.93	2.99	.042	.006	.027
1866	55.24	.39	1.58	3.02	.032	.006	.023
1867	59.75	.57	1.23	3.23	.030	.011	.022
1868	63.80	.54	1.24	3.61	.030	.010	.022
1869	68.02	1.12	1.13	3.91	.031	.015	.023
1870	73.60	.80	1.26	4.11	.030	.016	.023
1871	69.64	.84	2.77	3.70	.028	.016	.022
1872	70.03	1.64	4.58	3.89	.033	.020	.023
1873	66.17	2.23	7.22	3.90	.037	.018	.021
1874	71.45	2.17	7.55	4.22	.037	.017	.021
1875	80.90	1.53	6.59	4.49	.037	.021	.023
1876	78.97	1.63	6.45	4.24	.038	.030	.023
1877	79.85	1.69	6.25	4.22	.038	.031	.025
1878	74.63	1.50	6.35	4.09	.041	.030	.025
1879	79.59	1.30	6.82	4.61	.044	.046	.025
1880	93.04	2.54	7.87	5.78	.049	.037	.026
1881	108.74	3.90	9.37	7.29	.054	.062	.027
1882	123.98	5.68	11.65	8.57	.058	.062	.029
1883	139.71	6.31	13.03	10.15	.061	.083	.031
1884	156.14	7.86	12.53	11.99	.066	.081	.035
1885	165.16	9.12	12.23	13.61	.072	.092	.038
1886	189.45	8.02	12.05	16.22	.080	.113	.041
1887	223.16	9.71	12.09	19.62	.112	.124	.043
1888	234.44	8.90	13.19	24.66	.129	.098	.042
1889	220.70	7.23	12.17	30.83	.110	.072	.038
1890	185.45	5.34	10.99	35.62	.095	.087	.036
1891	146.44	3.64	9.83	34.84	.082	.091	.037
1892	119.98	2.84	9.68	31.52	.073	.092	.037
1893	112.69	2.58	8.07	33.70	.073	.110	.039
1894	113.50	2.95	9.27	38.86	.068	.082	.037
1895	113.74	2.87	7.91	47.86	.065	.088	.036
1896	109.59	2.46	7.77	55.59	.074	.077	.035
1897	102.79	2.19	13.12	56.94	.088	.086	.038
1898	108.31	1.75	11.67	62.66	.108	.084	.043
1899	121.76	2.96	11.13	74.95	.122	.106	.050
1900	132.87	5.41	10.43	85.95	.128	.120	.057
1901	126.94	4.17	11.83	80.50	.134	.085	.058
1902	122.20	4.24	15.73	71.40	.137	.131	.062
1903	127.99	4.05	20.04	72.85	.143	.122	.069
1904	144.25	5.81	16.24	88.27	.152	.143	.080
1905	167.38	5.84	16.98	110.39	.167	.143	.084
1906	208.76	8.59	26.63	134.53	.205	.128	.095
1907	252.49	11.27	30.19	152.33	.239	.139	.102
1908	290.53	16.67	30.77	170.42	.255	.146	.108
1909	328.48	11.06	33.31	189.18	.255	.131	.121
1910	355.74	12.33	40.91	194.58	.259	.160	.137
1911	367.76	14.18	41.77	194.78	.277	.160	.154
1912	385.07	11.65	42.32	196.02	.290	.175	.167
1913	385.93	11.07	42.23	186.83	.299	.160	.178

NB: “general engineering” excludes the shipbuilding, railway rolling stock, and precious-metal-products industries.

Sources: see text.

Table 2. Estimated value added in the maintenance of general-engineering products, 1861-1913 (million lire at 1911 prices)

	(1)	(2)	(3)	(4)	(5)	(6)
	Fabricated metal					
	by blacksmiths	by other smiths	other	General equipment	Precision instruments	Clocks, watches
1861	96.44	29.83	4.80	1.54	.23	3.53
1862	97.06	30.05	4.84	1.58	.23	3.77
1863	97.68	30.27	4.87	1.71	.23	4.05
1864	98.31	30.50	4.91	1.81	.23	4.42
1865	98.94	30.72	4.95	1.91	.24	4.78
1866	99.57	31.10	5.01	2.07	.24	5.03
1867	100.21	31.48	5.07	2.17	.24	5.24
1868	100.85	31.85	5.13	2.46	.24	5.44
1869	101.49	32.16	5.18	2.63	.24	5.66
1870	102.14	32.39	5.22	2.92	.24	5.89
1871	102.80	32.62	5.25	3.12	.24	6.09
1872	103.45	32.86	5.29	3.35	.25	6.30
1873	104.12	33.09	5.33	3.42	.25	6.47
1874	104.78	33.25	5.35	3.78	.26	6.62
1875	105.45	33.64	5.42	4.01	.26	6.81
1876	106.13	33.95	5.47	4.27	.27	7.01
1877	106.81	34.42	5.54	4.60	.27	7.24
1878	107.49	34.96	5.63	5.13	.27	7.47
1879	108.18	35.28	5.68	5.59	.28	7.71
1880	108.87	35.68	5.75	6.08	.28	7.95
1881	109.57	36.00	5.80	6.67	.28	8.24
1882	110.27	36.32	5.85	7.23	.28	8.51
1883	110.98	36.57	5.89	7.92	.29	8.81
1884	111.69	36.97	5.95	8.45	.29	9.20
1885	112.40	37.38	6.02	9.23	.30	9.66
1886	113.12	37.86	6.10	9.96	.32	10.18
1887	113.84	38.27	6.16	10.65	.35	10.77
1888	114.57	38.76	6.24	11.34	.38	11.26
1889	115.31	39.33	6.33	11.93	.41	11.53
1890	116.04	39.91	6.43	12.26	.43	11.68
1891	116.79	40.32	6.49	12.29	.44	11.82
1892	117.53	40.58	6.53	12.82	.44	11.94
1893	118.29	40.84	6.58	12.82	.44	12.07
1894	119.04	41.35	6.66	12.98	.45	12.12
1895	119.81	41.85	6.74	13.08	.45	12.08
1896	120.57	42.30	6.81	13.47	.45	11.99
1897	121.34	43.00	6.92	13.41	.46	11.86
1898	122.12	43.62	7.02	13.77	.48	11.77
1899	122.90	44.16	7.11	14.00	.51	11.73
1900	123.69	44.71	7.20	14.49	.54	11.77
1901	124.48	45.34	7.30	14.89	.58	11.55
1902	125.28	45.90	7.39	15.38	.61	11.34
1903	126.08	46.55	7.50	16.43	.65	11.23
1904	126.89	47.20	7.60	18.40	.69	11.18
1905	127.70	47.85	7.71	19.88	.74	11.09
1906	128.51	48.68	7.84	21.59	.81	10.97
1907	129.34	49.61	7.99	24.12	.91	10.89
1908	130.16	50.71	8.16	26.19	1.03	10.84
1909	131.00	51.30	8.26	27.96	1.13	10.74
1910	131.84	52.33	8.43	29.87	1.24	10.64
1911	132.68	53.72	8.65	32.86	1.36	10.63
1912	133.53	55.03	8.86	35.55	1.49	10.63
1913	134.38	56.53	9.10	38.41	1.62	10.60

NB: “general engineering” excludes the shipbuilding, railway rolling stock, and precious-metal-products industries.

Sources: see text.

Table 3. Estimated general-engineering value added, 1861-1913: summary estimates
(million lire at 1911 prices)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	New production				Maintenance				Metal consumed (thousand tons)
	Fabri-cated metal	General equipment	Precision equipment	Total	Fabri-cated metal	General equipment	Precision equipment	Total	
1861	27.83	4.20	.96	33	131.07	1.54	3.76	136	102
1862	27.17	4.19	.96	32	131.95	1.58	4.00	138	100
1863	26.38	3.75	1.00	31	132.82	1.71	4.28	139	97
1864	25.67	3.26	1.22	30	133.72	1.81	4.65	140	94
1865	24.34	3.55	1.15	29	134.61	1.91	5.02	142	90
1866	22.92	3.39	.92	27	135.68	2.07	5.27	143	85
1867	24.80	3.51	.91	29	136.76	2.17	5.48	144	91
1868	26.48	3.85	.91	31	137.83	2.46	5.68	146	97
1869	28.23	4.25	.98	33	138.83	2.63	5.90	147	103
1870	30.54	4.38	.97	36	139.75	2.92	6.13	149	111
1871	28.90	4.55	.92	34	140.67	3.12	6.33	150	107
1872	29.06	5.60	1.05	36	141.60	3.35	6.55	152	110
1873	27.46	6.71	1.07	35	142.54	3.42	6.72	153	108
1874	29.65	7.09	1.06	38	143.38	3.78	6.88	154	116
1875	33.57	6.81	1.12	42	144.51	4.01	7.07	156	128
1876	32.77	6.56	1.21	41	145.55	4.27	7.28	157	125
1877	33.14	6.49	1.25	41	146.77	4.60	7.51	159	126
1878	30.97	6.35	1.29	39	148.08	5.13	7.74	161	119
1879	33.03	6.93	1.47	41	149.14	5.59	7.99	163	127
1880	38.61	8.72	1.49	49	150.30	6.08	8.23	165	148
1881	45.13	11.01	1.79	58	151.37	6.67	8.52	167	173
1882	51.45	13.49	1.89	67	152.44	7.23	8.79	168	198
1883	57.98	15.59	2.14	76	153.44	7.92	9.10	170	223
1884	64.80	17.53	2.26	85	154.61	8.45	9.49	173	247
1885	68.54	19.27	2.49	90	155.80	9.23	9.96	175	261
1886	78.62	21.22	2.84	103	157.08	9.96	10.50	178	297
1887	92.61	24.80	3.49	121	158.27	10.65	11.12	180	347
1888	97.29	29.48	3.54	130	159.57	11.34	11.64	183	370
1889	91.59	34.18	2.96	129	160.97	11.93	11.94	185	358
1890	76.96	37.51	2.80	117	162.38	12.26	12.11	187	315
1891	60.77	35.89	2.64	99	163.60	12.29	12.26	188	260
1892	49.79	32.61	2.50	85	164.64	12.82	12.38	190	220
1893	46.77	33.93	2.67	83	165.71	12.82	12.51	191	211
1894	47.10	39.10	2.33	89	167.05	12.98	12.57	193	220
1895	47.20	46.70	2.32	96	168.40	13.08	12.53	194	230
1896	45.48	53.49	2.36	101	169.68	13.47	12.44	196	234
1897	42.66	56.50	2.71	102	171.26	13.41	12.32	197	233
1898	44.95	61.00	3.10	109	172.76	13.77	12.25	199	246
1899	50.53	72.24	3.61	126	174.17	14.00	12.24	200	279
1900	55.14	82.63	3.93	142	175.60	14.49	12.31	202	307
1901	52.68	77.84	3.76	134	177.12	14.89	12.13	204	294
1902	50.71	71.04	4.24	126	178.57	15.38	11.95	206	281
1903	53.12	73.79	4.37	131	180.13	16.43	11.88	208	296
1904	59.86	86.87	4.85	152	181.69	18.40	11.87	212	333
1905	69.46	107.05	5.16	182	183.26	19.88	11.83	215	393
1906	86.64	132.97	5.83	225	185.03	21.59	11.78	218	491
1907	104.78	151.04	6.59	262	186.94	24.12	11.80	223	577
1908	120.57	169.15	7.00	297	189.03	26.19	11.87	227	652
1909	136.32	185.24	7.07	329	190.56	27.96	11.87	230	730
1910	147.63	193.14	7.61	348	192.60	29.87	11.88	234	783
1911	152.62	194.18	8.16	355	195.05	32.86	11.99	240	801
1912	159.80	194.73	8.69	363	197.42	35.55	12.12	245	827
1913	160.16	186.25	8.88	355	200.01	38.41	12.22	251	817

NB: “general engineering” excludes the shipbuilding, railway rolling stock, and precious-metal-products industries.

Sources: see text.