

German Submarine Blockade, Overseas Imports, and British Military Production in World War II

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At first glance, the struggle between German U-boats and Allied shipping during World War II seems far removed from current threats to Canadian security. In an era of nuclear arms and terrorist attacks, the Battle of the Atlantic, involving hundreds of conventional submarines and thousands of ships, is unlikely to be repeated. In essence, however, the Atlantic blockade is related to modern forms of warfare. Like German U-boats, the purpose of nuclear weapons and terrorist attacks is to undermine the enemy country's will to resist, to destabilize its political structures, and to disrupt its economy. The fundamental parallel between Germany's submarine blockade and the modes of warfare that seem likely to dominate the twenty-first century is that all are means of waging total war by attacking a state's home front, rather than by directly engaging its armed forces in battle. This paper sheds light on this type of conflict by assessing the economic effectiveness of Germany's submarine campaign during World War II.

The Battle of the Atlantic is particularly relevant to Canadian security for four other reasons. First, Canada's military played a prominent role in this campaign by protecting Allied convoys along a large part of the route between North America and Britain.¹ A familiarity with this heritage is essential to the integrity, cohesion, and morale of today's Canadian forces. Second, because of its geographic position, Canada is unlikely to be invaded by the ground forces of a foreign power. It is relatively more vulnerable to attacks on its shipping, and such threats must be understood in historical perspective. Third, submarines are better able than other weapons systems to assert Canadian sovereignty over the Arctic. Fourth, the Battle of the Atlantic is pertinent to Canada's international defence obligations since anti-submarine warfare

¹ Throughout this paper, "Britain" refers to all of the United Kingdom.

is a major function performed by Canadian naval forces in NATO.

In the decades since World War II, scholars have not only accepted that the Battle of the Atlantic was critically important, but have claimed that Germany almost won it. Dan van der Vat's *The Atlantic Campaign* describes it as “a prolonged and desperate struggle that came closer than any other to deciding the war in Germany’s favor.”² V. E. Tarrant, author of a history of Germany’s submarine campaigns during the two World Wars, argues that “the U-Boats . . . came close to being the single decisive factor in both wars.”³ *The Oxford Companion to World War II* states, “U-Boats nearly brought the UK to its knees,”⁴ and renowned military historian Basil Liddell-Hart agrees that “it is evident that Britain had herself narrowly escaped defeat.”⁵ These quotes are from widely-cited and, with the exception of Liddell-Hart, recent academic books, and reflect the tone of most other scholarly and popular works on the subject.

Yet it is not clear on what these sweeping claims are based. For obvious reason, German submarines could not have defeated the Royal Navy in battle or taken control of the Atlantic. This weakness prevented them from ever approaching victory in exclusively military terms.⁶ Although these authors do focus mainly on the military aspects of this campaign, their claims for

² Dan van der Vat, *The Atlantic Campaign: World War II's Great Struggle at Sea* (New York: Harper & Row, 1988), front inside cover jacket.

³ V. E. Tarrant, *The U-Boat Offensive, 1914-1945* (Annapolis, Maryland: Naval Institute Press, 1989), preface on 6.

⁴ Richard Compton-Hall, “Submarines,” in I. C. B. Dear and M. R. D. Foot, eds., *The Oxford Companion to World War II* (Oxford: Oxford University Press, 1995), 845.

⁵ Basil Liddell-Hart, *History of the Second World War* (London: Pan Books, 1973), 405.

⁶ David Syrett, *The Defeat of the German U-Boats: The Battle of the Atlantic* (Columbia: University of South Carolina Press, 1994).

Germany's submarines implicitly refer to their role as agents of economic warfare. In other words, the U-Boats came close to inflicting enough material damage on Britain to knock it out of the war without an outright German military victory.

The millions of tons of Allied shipping sunk by U-Boats and other German forces would seem to validate this assertion. However, Britain's military production increased dramatically during the war in spite of these losses.⁷ Does this not suggest that the U-Boats may have been ineffective? The fact that German munitions output rose during the conflict is frequently cited to prove the failure of Allied economic warfare against the Reich, whether strategic bombing or maritime blockade.⁸ Even writers who argue that Allied economic warfare was effective inevitably temper their case in acknowledging the growth of German arms production.⁹ This same logic has never been applied to Germany's submarine blockade of Britain. The U-Boats did inflict much damage upon the Allies, but, in the words of Marc Milner, "It remains to be demonstrated, however, whether war losses of shipping materially affected the course of the war."¹⁰

Although the Battle of the Atlantic could have influenced the war in several ways, the central issue is the impact of German submarine blockade upon British war production. To fully evaluate this topic, one would have to assess how far reductions in imports decreased British military output and how much of this reduction is attributable to the submarine blockade, rather than to other constraints. This paper addresses the former question. It begins by asking, in

⁷ Central Statistical Office, *The Statistical Digest of the War* (London: HMSO, 1951), 139 (Table 117).

⁸ For example, see J. K. Galbraith, *A Life in Our Times: Memoirs* (Boston: Houghton Mifflin, 1981).

⁹ For example, see Overy, *Why the Allies Won*.

¹⁰ Marc Milner, "Atlantic, battle of the," in Dear and Foot, *Oxford Companion*, 54.

general terms, how a decline in imports could have affected British national output. After establishing this theoretical framework, it asks how far Britain's wartime loss of imports reduced its war production. The paper argues that reduced imports decreased British military output by a relatively small amount. It concludes by outlining other issues that would have to be addressed in order to fully assess the effectiveness of Germany's submarine blockade.

Since imported materials were a major input to production in Britain, the country's supply of imports was a constraint on its output. However, Britain's national product was also limited by the supply of other factors. Austin Robinson, a Cambridge economist and wartime planner, identified "four main limits: materials, manpower, shipping, and capacity."¹¹ "Shipping" more accurately refers to materials imported by ship, while "materials" refers to domestically produced resources. Likewise, "labour" and "(physical) capital" might be substituted for "manpower" and "capacity."

Britain needed imported materials, but did it need them more than domestic materials, labour, or capital? Which of these factors was the operative constraint on output. Robinson argues,¹²

these various limits were effective in different degrees at different stages of the war. In 1940 and 1941 it was capacity that was the chief limiting factor. At important moments throughout the war . . . it was shipping . . . From the end of 1942 onwards the problems of manpower supply became paramount.

In other words, imported materials were sometimes the operative constraint, but not for a sustained period of time. Labour was the effective limit for most of the war, although capital was more important early on. The literature on Britain's war economy generally supports this

¹¹ Austin Robinson, "The Overall Allocation of Resources," in D. N. Chester, ed., *Lessons of the British War Economy* (Cambridge: Cambridge University Press, 1951), 37.

¹² *Ibid.*

view.¹³

Of course, even if imported materials were not the main constraint, lost imports were of economic consequence. In effect, all factors of production were scarce to the extent that they could be substituted for each other. For example, an industrial procedure to conserve imported materials might be labour-intensive, while a production process to economize labour might waste these materials. Even if labour were more scarce than imported materials, an increase in imported materials (without an increase in labour) would raise output because the imports could be substituted for labour to some extent. Likewise, a decrease in imports would reduce output.

The possibility of substitution implies that imported materials were scarce and that further limiting their supply would reduce output somewhat. However, this implication does not change the fact that they were generally not the scarcest factor. A loss of imports would reduce British output, but not by as much as an equivalent loss of a scarcer factor. During the second half of the war, the marginal cost to Britain's economy of losing a unit of imports would have been less than that of losing a unit of labour.

In addition, one is tempted to argue that whatever economic cost lost imports entailed was borne by the civilian sector, rather than by the military sector, and therefore did not imply a loss of war production. However, to suggest that the civilian sector bore the full cost, without affecting the military sector, implies that there was "surplus" output in the civilian sector that would not otherwise have been transferred into the military sector.¹⁴ In reality, Britain mobilized

¹³ For example, Stephen Broadberry and Peter Howlett, eds., "The United Kingdom: 'Victory at All Costs,'" in Mark Harrison, ed., *The Economics of World War II: Six Great Powers in International Comparison* (Cambridge: Cambridge University Press, 1998), W. K. Hancock and M. M. Gowing, *British War Economy* (London: HMSO and Kraus Reprint, 1975), and Alan Milward, *War, Economy and Society, 1939-1945* (Berkeley: University of California Press, 1977).

¹⁴ In this case, "surplus" output refers to civilian output appreciably above that required to maintain Britain's population, both physically and morally, and to sustain production in the military sector.

its economy intensively for World War II and no such surplus existed.¹⁵ Although it is possible and necessary to identify which imports were qualitatively important to the military sector and which served mainly civilian purposes, it is dubious to suggest, on the aggregate level, that the output lost through lower imports would otherwise have been used to increase civilian production instead of war production.

In any case, Britain could adjust for some loss of imports at little or no cost to either its civilian or military sector. One such example hinges on the distinction between retained and re-exported imports. In 1938, the last full year of peace, Britain imported £920 million of goods, retained £858 million of them, and re-exported the remaining £62 million (or 7% of total imports). In 1939, the year the war began, Britain imported £886 million, retained £840 million, and re-exported £46 million (or 5%). Britain could easily cut the value of its imports by at least 5% of pre-war levels simply by eliminating imports for re-export, without reducing the supply of imported materials available to its economy. This adjustment was made and British re-exports fell to a negligible fraction of total imports during World War II.¹⁶

While re-exports are a special case, the relationship between imports and exports is of much broader significance. The wartime loss of British imports implied, and was partly caused by, a reduced level of British exports during the war. Since, with the exception of re-exports, Britain exported different products than it imported, lower exports would not completely cancel out lower imports. However, they could partially offset the economic impact. To the extent that British imports were inputs to the production of British exports, lower exports would naturally

¹⁵ This is the picture presented by the literature on Britain's war economy. See the sources in note 16 above.

¹⁶ Central Statistical Office, *Digest of the War*, 162 (Table 142).

compensate for lower imports. This tendency could be strengthened by deliberate efforts to restrict the quantity of imported material used in producing goods for export.¹⁷

A final point about the general impact of imports on output is that the possibilities for substitution mean that factors of production can be productively combined in a variety of different ratios, rather than in a rigidly fixed proportion. Because of this, the loss of one factor of production implies a proportionally smaller, rather than a proportionally equal, loss of output. For example, if all factors were equally scarce in Britain, a 10% drop in the supply of imported materials would imply less than a 10% drop in overall output. Indirect substitution between different factors of production naturally lessens the extent to which lost imports reduce output.¹⁸ In Britain's case, the fact that imported materials were less scarce than other factors further reduced this cost. The relatively easy adjustments allowed by the relationship between British imports and exports constitute further deductions from this cost.

These theoretical statements help to explain how British output increased despite falling imports. They also suggest that the loss of imports did not restrain this growth very much. However, theory alone does not resolve either of these issues concretely. Only more detailed examination of actual British wartime imports can provide tangible answers to these questions. It is also needed to respond to those who claim, using empirical evidence rather than economic theory, that the U-Boats were nearly successful.

¹⁷ J. Hurstfield emphasizes the achievements of this policy in *The Control of Raw Materials* (London: HMSO, 1953).

¹⁸ This point is stressed by Mancur Olson in *The Economics of Wartime Shortage: A History of British Food Supplies in the Napoleonic War and in World Wars I and II* (Durham, North Carolina: Duke University Press, 1963).

The following figures on the wartime decline of British imports have been widely reproduced in works on the Battle of the Atlantic:¹⁹

Table I: Britain’s Dry-Cargo Imports, 1940-1944 (in millions of tons)

	Total	Ministry of Supply	Ministry of Food
1940	41.9	22.1	19.3
1941	30.5	15.0	14.7
1942	22.9	11.5	10.6
1943	26.4	12.8	11.5
1944	25.1	11.8	11.0

The years 1939 and 1945 are excluded from these comparisons because Britain was at war only for parts of them. These figures show a shocking 40% drop in dry-cargo imports between 1940 and 1944, or a 37% drop between 1940 and 1943.²⁰ Those imports used for industrial production, and administered by the Ministry of Supply, declined even more sharply, falling by 47% from 1940 to 1944 and by 42% from 1940 to 1943, the year of peak British war production.²¹ Even if each unit of lost imports implies only a small loss of output, a decline of 37 to 47% still suggests a substantial loss of output.

¹⁹ These figures appear in tabular form in Olson, *Wartime Shortage*, 129 and Kevin Smith, *Conflict Over Convoys: Anglo-American Logistics Diplomacy in the Second World War* (Cambridge: Cambridge University Press, 1996), 249-250 (Tables I, II, and III). They are referred to in the text of many other works. “Total” includes munitions imports and some other miscellaneous imports not included in the departmental programs.

²⁰ In Britain’s official history of merchant shipping during the war, C. B. A. Behrens presents the same data, compiled on a slightly different basis. It shows that dry-cargo imports declined by 43% between the first year of war (1939/40) and the calendar year 1944. However, changes in the country’s stocks of imported goods imply that the decline in national import consumption between these two periods was 38%. Between 1939/40 and 1943, there was a 40% decline in imports and a 46% decline in import consumption. *Merchant Shipping and the Demands of War* (London: HMSO, 1955), 201.

²¹ 1943 was the year in which military outlays occupied the highest proportion of British national income and the year in which production of many types of armaments peaked. Mark Harrison, “The Economics of World War II: An Overview,” in Harrison, *Economics of World War II*, 21 (Table 1.8) and 15 (Table 1.6). During 1944, Britain moved its economy off of a war footing. Robinson, “Overall Allocation.”

More detailed figures provide a better picture of the relationship between British imports and military output. Appendix I divides all of Britain's imports into more specific categories. It shows that overall British imports remained about constant (by weight) between 1941 and 1944 because an increase in tanker imports offset a decrease in dry-cargo imports. However, since munitions and tanker imports (i.e. oil) sustained existing military forces, rather than being used to produce new arms, it is reasonable to focus on the departmental programs, the dry-cargo imports of the Ministries of Supply and Food, in assessing the relationship between imported materials and military output. These departmental imports declined by 18% from 1941 to 1943 and 23% from 1941 to 1944. The more interesting results, however, are produced by grouping the imports within the departmental programs. In the Ministry of Supply program, imports of ferrous metals declined 30% to 1943 and 41% to 1944. However, imports of non-ferrous metals increased 14% to 1943 and 1% to 1944, while non-metallic materials decreased only 3% and 4%. In the Ministry of Food program, imports of staple crops declined 38% by 1943 and 45% by 1944, while other foods increased 7% and 10%.

The decline in departmental imports was not evenly spread between different goods. While imports of ferrous metals and staple crops fell substantially, imports of non-ferrous metals and other foods rose somewhat and imports of non-metallic materials declined marginally. An assessment of the changes in these different types of imports, rather than a simple appraisal of the overall drop in departmental imports, is needed to properly analyze the pressures endured by Britain's war economy. For this reason, the paper provides a detailed examination of the five categories used in Appendix I: ferrous metals, non-ferrous metals, non-metallic materials, staple crops, and other foods.

At first glance, the great drop in ferrous metals (iron, allied materials, and steel) is the most troubling feature of Britain's wartime import statistics since steel is the principal material used to manufacture most armaments. Robinson supports this impression by mentioning "the scarcity . . . of steel which was all-pervasive in its effects."²² But how costly was this loss of imports?

To some extent, reduced imports could be replaced by increased home production. The following table presents data on Britain's iron ore supplies.²³

Table II: Britain's Iron Ore Supplies, 1939-1945 (in thousands of tons)

	Imports	Home Production	Change in Stock Reduction (Addition)	Quantity Available	Actual Consumption
1939	5,200	14,486	?	19,686	?
1940	4,508	17,702	(459)	21,751	20,718
1941	2,241	18,974	(39)	21,176	19,911
1942	1,935	19,906	154	21,995	20,753
1943	1,924	18,494	(261)	20,157	19,001
1944	2,148	15,472	733	18,353	17,341
1945	4,191	14,175	(44)	18,322	17,691

These figures show that Britain was able to replace lost ore imports with increased home production through 1943 and, in 1944, to partially compensate for reduced home production by drawing down stocks accumulated in previous years. As a result, iron ore consumption was relatively stable during the conflict.

Table II also shows that iron-ore imports fell more sharply than overall ferrous-metal imports. This discrepancy was caused by shifts within this category of British imports.

Appendix II illustrates Britain's trade in iron and steel between 1938 and 1945. In criticizing the British steel industry's wartime performance, Correlli Barnett emphasizes its relative decline

²² Robinson, "Overall Allocation," 37.

²³ For notes and references for this and subsequent tables, see "Notes on Tables" at the end of the paper.

prior to the conflict.²⁴ Despite this, Britain was a major producer and exporter of steel immediately before World War II. It imported a large amount of iron ore, a significant amount of steel components (pig iron, scrap, and ferro-alloys) and a small amount of semi-finished steel, and exported a substantial quantity of finished steel. In other words, Britain profited by buying raw or partly processed material, manufacturing it, and then selling the finished steel.

Britain's healthy iron and steel trade gave it much room to adjust for a decline in its imports of ferrous metals. It could increase the "net imports" derived from a given volume of imports simply by cutting exports. It could increase the value (in terms of finished steel) of a given tonnage of imports by importing lighter finished materials, rather than bulky raw materials. In 1939 and 1940, Britain reduced imports of ore, increased those of steel components and of semi-finished steel, and reduced its exports of finished steel. In 1941, Britain continued the shift from ore to steel components and semi-finished steel, and became a net importer of finished steel. It began to shift from steel components to semi-finished steel in 1942 and drove up its finished steel imports in 1943. It started to return to its peacetime position in 1944 and became a major iron-ore importer and finished-steel exporter in 1945. Through these shifts Britain maintained (or even increased) the amount of finished steel provided to the British economy, even though it imported fewer tons of ferrous metal.

²⁴ Correlli Barnett, *The Audit of War: The Illusion & Reality of Britain as a Great Nation* (London: Macmillan, 1986), 90-93.

The following figures on allied materials further illustrate British policy:

**Table III: Britain's Imports and Consumption of Allied Materials, 1938-1945
(in thousands of tons)**

	<u>Chrome Ore</u>		<u>Tungsten</u>		<u>Molybdenum</u>		<u>Vanadium</u>	
	Imp.	Con.	Imp.	Con.	Imp.	Con.	Imp.	Con.
1938	37.6	?	10.9	?	1.9	?	?	?
1939	50.6	?	9.9	?	4.9	?	?	?
1940	87.6	?	13.4	?	2.4	?	?	?
1941	56.0	64.4	12.6	3.5	4.1	2.1	?	0.5
1942	99.6	70	7.6	2.0	7.2	3.9	2.6	0.5
1943	36.6	72.1	6.6	1.9	6.5	3.0	2.6	0.5
1944	93.8	73.3	6.2	2.5	0.5	1.8	0.6	0.3
1945	50.4	74.1	3.7	2.5	1.1	1.1	1.3	0.2

Britain's importation and consumption of allied materials reflect these trends. Chrome, tungsten, molybdenum, and vanadium are components alloyed with iron to make steel. Chrome and molybdenum imports increased up to 1942 and declined afterward. Tungsten imports peaked earlier (which may reflect an increase in home-produced tungsten ore), but this trend generally fits a shift from iron ore to components until 1942, followed by the subsequent shift from components to semi-finished and finished steel. Although consumption figures are not available until 1941, the post-1941 decline in consumption was less pronounced than the decline in imports. In the case of chrome ore, consumption increased significantly despite a large decrease in imports. Since Britain did not produce these materials (except tungsten),²⁵ this trend reflects the drawing down of previously accumulated stocks.

Barnett cites Britain's "dependence on America for" finished steel and ferro-alloys as evidence of the industry's poor wartime performance.²⁶ However, this supposed dependence was the result of a deliberate and appropriate shift from imports of raw materials to imports of

²⁵ John Ellis, *World War II: A Statistical Survey* (New York: Facts On File, 1993), 273 (Table 76).

²⁶ Barnett, *Audit of War*, 88.

processed materials to sustain British war production from a reduced overall volume of ferrous-metal imports. While this move from importing raw resources and processing them domestically to importing materials processed elsewhere undoubtedly weakened Britain's post-war economic prospects, it was a sound wartime decision.

Another successful wartime policy was the recovery of scrap steel from Britain's domestic economy. "A National Survey of scrap resources was carried through the midst of the bombing, and it covered everything that could be converted into scrap - derelict railways, disused bridges, redundant plant of all kinds."²⁷ In addition, many tramlines were ripped up and steel was recovered from bombed buildings.²⁸ The program effectively supplemented ferrous-metal imports with domestic material. While the main substitution of home production for imports occurred in the realm of iron ore, this initiative yielded some four million tons of scrap steel.²⁹

The following table presents data on British steel supplies:

Table IV: Britain's Steel Supplies, 1939-1945 (millions of tons)

	Domestic Production	Imports	Exports	Net Imports	Total Available
1939	13.2	0.5	1.1	(0.6)	12.6
1940	13.0	0.8	0.8	0.0	13.0
1941	12.3	0.8	0.3	0.5	12.8
1942	12.9 or 12.8	0.5	0.2	0.3	13.2 or 13.1
1943	13.0 or 13.3	0.8	0.1	0.7	13.7 or 14.0
1944	12.1	0.4	0.2	0.2	12.3
1945	11.8	0.0	0.5	(0.5)	11.3

Domestic production is steel produced in Britain from home-produced and imported ore,

²⁷ The Times, *British War Production, 1939-1945: A Record* (London: The Times, 1945), 116.

²⁸ Ibid., 114 and 116.

²⁹ Ibid.

components, and semi-finished steel, and from recovered scrap. Imports, exports, and net imports refer only to finished steel, rather than to iron ore, components, and semi-finished steel used to produce it. These figures show that, while domestic production was relatively stable through 1943, rising net imports of finished steel increased the amount of finished steel available to the British economy. The progressive depletion of steel stocks after 1941 increased consumption over the current total available, although these additions were not significant in aggregate terms.³⁰

Was there really a steel shortage? *The Times's* survey of British war production states,³¹

During this period the statistics covering the relationship of demand against supply show that in 1941 deliveries met 92.6 per cent. of allocations, in 1942 96.1 per cent., and in 1943, the highest consuming year, 100.8 per cent., while in 1944 the figure was 98.1 per cent. This is a record of which any industry might be proud.

These figures demonstrate either that there was no real shortage, or that the planners who made the allocations were able to handle it. While Robinson and Barnett may be correct that there was a shortage, it was a small and manageable one, rather than a large and unmanageable one. More significantly for this paper's purposes, whatever shortage of finished steel did exist occurred because of the industry's domestic shortcomings,³² not due to lost ferrous-metal imports. As Appendix II shows, Britain's import program maintained (or even increased) the amount of finished steel available despite a falling volume of ferrous-metal imports.

The next category of imports is non-ferrous metal. Generally, this category consists of metals used for purposes other than steel production. However, the British classified some steel alloys (i.e. those in Table III above) as allied materials in the "ferrous metal" category and others

³⁰ Central Statistical Office, *Digest of the War*, 107 (Table 93).

³¹ *The Times*, *British War Production*, 114.

³² Barnett, *Audit of War*, chapter 5.

as “non-ferrous metal.”³³ To keep the analysis of particular imports consistent with the framework of Appendix I, the paper follows the British classification and treats some alloy metals as being non-ferrous metals.

Aluminium was the most important non-ferrous metal for Britain’s war effort. It was the main material used to build aircraft, which accounted for a large share of British arms output. While different non-ferrous metals could often be substituted for each other to some extent, the only way to replace aluminium in aircraft production was to build airframes out of wood, which could not reasonably be done on a large scale.³⁴

Before the war, Britain imported all of its bauxite,³⁵ the metal from which aluminium is produced, and a small amount of finished aluminium. During the war, some bauxite was produced in Northern Ireland, but not enough to matter at the aggregate level.³⁶

Appendix III shows two main trends in Britain’s bauxite and aluminium supplies between 1939 and 1945. First, imports of finished aluminium displaced imports of raw bauxite. Between 1939 and 1942, bauxite imports fell from 302 to 48 thousand tons, but, due to stockpiling and to increased industry efficiency,³⁷ British aluminium production increased from 25 to 47 thousand tons. More significantly, imports of finished aluminium rose from 58 to 132 thousand tons. As a result, the amount of aluminium available to Britain’s economy increased

³³ In Central Statistical Office, *Digest of the War*, it seems that metals on 108 (Table 94) are included as “Iron and Steel and allied materials” on 187 (Table 163), while metals on 109 (Table 95) are included as “non-ferrous ores and metals” on 187 (Table 163).

³⁴ While Britain did build the famous Mosquito out of wood and used some plywood in other aircraft, wood could not reasonably be substituted for aluminium on a large scale.

³⁵ Ellis, *Statistical Survey*, 273.

³⁶ Central Statistical Office, *Digest of the War*, 109 (Table 95).

³⁷ The Times, *British War Production*, 135-136.

from 83 to 178 thousand tons. The quantity available more than doubled even as the base of imports was cut in half. In 1939, Britain imported more than four tons of bauxite and aluminium for each ton of aluminium made available to its economy. In 1942, this ratio was one to one. In 1943, Britain expanded its bauxite imports, aluminium production from these imports, and aluminium imports, increasing the quantity of aluminium available to 269 thousand tons, more than treble than 1939 figure. In 1944 and 1945, Britain scaled back its bauxite imports, aluminium production, and aluminium imports.

The second trend is a substantial increase in secondary (i.e. reused or recycled) aluminium output. Stocks of material that could be refined were built up before the war and there was a “revolutionary change in the policy of utilization of secondary material” during the war.³⁸ Primary aluminium producers meticulously conserved secondary material produced by their operations, while secondary producers greatly expanded their plant.³⁹ This process was supplemented by the recovery of aluminium from aeroplanes that crashed on British soil.⁴⁰ Secondary aluminium production increased from 38 thousands tons in 1940 to 94 thousand in 1943 and 105 thousand in 1944. While secondary aluminium could not be perfectly substituted for primary aluminium, technical innovations during the war increased Britain’s capacity to do so.⁴¹ Taking secondary production into account, the total amount of aluminium available increased to a peak of 362 thousand tons in 1943, more than four times the 1939 figure.⁴²

³⁸ Ibid., 136.

³⁹ Ibid.

⁴⁰ Central Statistical Office, *Digest of the War*, 111 (note 1 for Table 96).

⁴¹ The Times, *British War Production*, 136.

⁴² This ratio exceeds four-to-one even if one assumes that there was some secondary production in 1939.

The relative value of primary and secondary aluminium is not clear. It would be inaccurate to look only at primary material and ignore secondary material. Yet, a ton of secondary product was not equivalent to a ton of primary product. What can be concluded with certainty is that the quantity of aluminium available to Britain increased vastly during the war.

However, given the greatly increased demand created by the war, it is more difficult to determine whether or not there was a shortage of aluminium. The fact that aluminium prices declined appreciably during the war suggests that there was not.⁴³ This evidence could be challenged on the grounds that wartime prices reflected government controls than market forces. Yet, while state regulations could have restrained a price increase, it is unlikely that they would have depressed prices if the material was actually becoming more scarce. It is fairly safe to conclude that bauxite and aluminium imports were not a significant check on British war production.

A complete analysis of Britain's other non-ferrous metals is difficult simply because there are so many of them. This paper emphasizes copper, magnesium, and zinc for three reasons. First, these metals were imported in far larger quantities than other non-ferrous metals (with the exception of lead).⁴⁴ Second, unlike other non-ferrous metals, they were imported both as ore and as refined metal.⁴⁵ Third, they were particularly important to Britain's war effort. Copper was required to produce electrical and mechanical devices, which were needed in aircraft, fighting vehicles, and ships, and for military communications and transport generally. Magnesium was a major steel alloy that was especially important in producing steel from low-

⁴³ The Times, *British War Production*, 136.

⁴⁴ Compare Table V to Table VI.

⁴⁵ Central Statistical Office, *Digest of the War*, 168-169 (Tables 148 and 149).

grade iron ore. It thus facilitated Britain's shift from imported iron ore to lower quality, home-produced ore.⁴⁶ Zinc was used to produce fuses, batteries, and other essential components for arms production. Together, copper and zinc made brass used to manufacture cartridges and shell cases.⁴⁷

The following table shows Britain's supplies of these non-ferrous metals:

Table V: Britain's Ore Imports, Metal Imports, and Metal Consumption of Copper, Magnesium, and Zinc, 1938-1945 (in thousands of tons)

	<u>Copper</u>				<u>Magnesium</u>				<u>Zinc</u>			
	Ore Imp.	Metal Imp.	Metal Con.	I/C Ratio	Ore Imp.	Metal Imp.	Metal Con.	I/C Ratio	Ore Imp.	Metal Imp.	Metal Con.	I/C Ratio
1938	29.6	259.6	258.0	1.1	192.7	1.6	?	?	157.3	165.0	141.6	2.3
1939	34.1	307.6	292.8	1.2	325.0	1.6	?	?	177.5	167.3	160.8	2.1
1940	32.7	472.8	446.6	1.1	247.1	0.6	8.0	31.0	226.2	204.6	154.8	2.8
1941	27.7	449.4	450.0	1.1	314.2	1.0	13.8	22.8	201.5	209.8	178.8	2.3
1942	26.5	441.0	490.8	1.0	421.2	3.1	20.8	20.0	142.7	211.7	186.3	1.9
1943	20.3	494.8	448.6	1.1	444.6	33.6	36.1	13.2	97.1	187.6	175.6	1.6
1944	21.8	451.5	348.1	1.4	315.3	20.4	36.0	9.3	179.0	119.3	176.8	1.7
1945	19.4	143.7	288.6	1.1	314.9	1.1	8.6	36.7	156.6	97.1	155.8	1.6

For all of these metals, imports of ore rose above peacetime levels for part of the war and wartime imports of metal exceeded peacetime levels. In all three cases, imports shifted from ore to metal, reducing the number of tons of imports needed to sustain a ton of consumption. The import/consumption ratios for magnesium and zinc declined substantially over the course of the war. This same trend is not visible for copper because ore imports always paled in comparison to metal imports, though after 1941, copper ore imports were reduced in favour of metal imports. For all three metals, an overall increase in imports, combined with an increase in refined metal as a share of these imports, drove wartime consumption far above peacetime levels.

⁴⁶ Ellis, *Statistical Survey*, 274.

⁴⁷ The Times, *British War Production*, 137.

The following table shows Britain's other non-ferrous metals:

**Table VI: Britain's Imports and Consumption of Other Non-Ferrous Metals, 1938-1945
(in thousands of tons)**

	<u>Lead</u>		<u>Nickle</u>		<u>Cryolite</u>		<u>Tin</u>		<u>Magnesite</u>	
	Imp.	Con.	Imp.	Con.	Imp.	Con.	Imp.	Con.	Imp.	Con.
1938	382.1	324.0	9.2	?	5.3	?	55.5	18.3	57.1	?
1939	334.3	336.0	7.7	?	4.7	?	54.0	27.3	48.5	?
1940	336.5	253.2	11.1	?	1.3	1.4	83.9	29.2	89.0	?
1941	139.3	214.8	7.3	22.5	3.6	2.2	65.5	30.0	80.3	22.7
1942	235.5	245.2	5.4	21.8	4.9	3.9	43.9	23.5	28.6	23.3
1943	226.5	212.7	5.0	17.2	1.6	2.9	52.0	17.6	55.9	17.3
1944	224.9	221.2	3.5	12.4	0.1	1.9	32.9	18.4	22.5	11.8
1945	165.4	236.3	1.3	8.5	0.8	?	44.9	16.4	3.9	?

Imports of nickle, tin, and magnesite increased early in the war, but declined thereafter, while imports of lead and cryolite fell more steadily. For all five metals, however, consumption did not decline as sharply as imports. Perhaps consumption rates were maintained above import rates by depleting previously established stocks.⁴⁸ Britain was also able to extract “calcined” and “dead brunt” magnesia for sea water. If consumption of these materials is counted, then magnesite consumption increased substantially.⁴⁹ Consumption of the other four metals did decline significantly.

It is doubtful that this decline imposed any appreciable cost on Britain's war effort. First, in qualitative terms, the functions served by these metals do not seem as essential as those performed by copper, magnesium, and zinc. Second, and more significantly, Britain's limited domestic production of lead and tin ores fell during the war. If these metals had been important to the war economy, home production would presumably have been increased, as it was for other materials, or at least been maintained at peacetime levels.

⁴⁸ Central Statistical Office, *Digest of the War*, 109 (Table 95).

⁴⁹ *Ibid.*

The total volume of Britain's imports of non-ferrous metals increased during the war.⁵⁰ This overall increase masked a shift away from the importation of bauxite and ores toward that of refined metal. Britain thus increased both the number of tons imported and the average value of each ton imported, vastly expanding the quantity of non-ferrous metal available to its industry. In particular, consumption of those metals essential to war production - aluminium, copper, magnesium, and zinc - increased. Declines in lead, tin, and nickel consumption do not seem to have been very costly.

Britain imported a wide variety of industrial materials other than ferrous and non-ferrous metals. One of the most significant and frequently overlooked non-metallic imports was timber. To quote *The Times's* survey, "Imports of softwood alone were the heaviest import item, being even greater than those of iron ore or wheat. In terms of value our oversea purchases of timber were by far the most important of our raw materials."⁵¹ During the war, timber was used to build aircraft, army huts, bridges and packing, and the Mulberry port. It was also needed to sustain many productive and distributive processes.⁵² In particular, pitwood was needed to operate mines, not only to sustain peacetime production, but to allow the substitution of home-produced for imported metal.

Britain's total timber imports declined from 9.5 million tons per year before the war to only 1.75 million tons in 1943, "a cut without parallel amongst the bulky raw materials." Over

⁵⁰ Appendix I.

⁵¹ *The Times*, *British War Production*, 142.

⁵² P. Ford, "The Allocation of Timber," in Chester, *British War Economy*, 145.

the same period, home production grew from 0.5 to 3.75 million tons.⁵³ The following table provides a more detailed breakdown between softwood and hardwood:

**Table VII: Britain's Imports and Domestic Production of Timber, 1939-1945
(in millions of cubic feet)**

	<u>Softwood</u>			<u>Hardwood</u>		
	Imports	Production	Total	Imports	Production	Total
1939	250.5	?	250.5 + ?	30.5	?	30.5 + ?
1940	138.8	29.3	168.1	26.9	22.3	49.2
1941	85.4	46.3	131.7	14.5	29.4	43.9
1942	51.5	49.2	100.7	12.2	41.4	53.6
1943	89.1	47.5	136.6	12.4	50.8	63.2
1944	75.0	32.4	107.4	16.2	47.0	63.2
1945	124.8	21.5	146.3	16.2	41.2	57.4

The Times observes that “No other raw material of magnitude shows anything like the same fall in imports, nor indeed was any bulk material replaced by home production to the same degree as timber.”⁵⁴

The primary goal of British timber policy was “the substitution of home-grown for imported timber.”⁵⁵ Increased domestic logging more than made up for reduced hardwood imports, but offset only a fraction of lost softwood imports. The secondary goal of British timber policy was therefore to substitute “hardwood for softwood where technically possible,”⁵⁶ which could not wholly offset the loss of softwood.⁵⁷

⁵³ Ibid., 144.

⁵⁴ The Times, *British War Production*, 142.

⁵⁵ Ibid., 143.

⁵⁶ Ibid.

⁵⁷ Ford, “Allocation of Timber,” 149.

Since Britain had very limited timber stocks when the war began,⁵⁸ wartime consumption was severely limited by the amount of timber that could be imported or produced during the war. But there were ways of increasing consumption above these limits. Britain had access to “200,000 tons of reconditioned timber salvaged from bombed houses.”⁵⁹ It also made more timber available to its domestic economy by cutting down its timber (mainly paper) exports. Exports of printing paper, other paper, and board fell from 176 thousand tons in 1938 and 156 thousand tons in 1939 to fewer than 30 thousand tons in each of 1943 and 1944.⁶⁰ However, since changes in imports and home production were in the millions of tons, these two factors exerted only a minor impact on overall consumption.

Because timber was used for so many purposes, it is difficult to assess the impact of all this on Britain’s war economy. However, the amount of timber available for purely military purposes was largely unaffected by the overall loss of softwood, while home production of mining timber succeeded in replacing lost imports.⁶¹ In these extremely important areas, reduced imports would not appear to have hindered British war production.

More broadly, reduced timber supply imposed an appreciable cost upon Britain’s economy. The task of allocating greatly reduced supplies with maximum efficiency was complicated by the vast number of purposes for which Britain used timber. A centralized Timber Control operated a system of “timber accounts” and “timber cheques” for the wartime departments and a system of Area Offices to monitor allocation on a geographic basis. Timber

⁵⁸ The Times, *British War Production*, 142.

⁵⁹ Ibid., 143.

⁶⁰ Central Statistical Office, *Digest of the War*, 172 (Table 150).

⁶¹ The Times, *British War Production*, 142.

could not be used without a licence and Timber Control Economy Officers “scrutinized every licence.”⁶²

On the other hand, many of the adjustments required by this bureaucracy do not seem particularly onerous. For example,⁶³

About a quarter of our softwood goes to make packing cases and boxes of various kinds. Great economies were secured by making the release of timber conditional upon arrangements for a high degree of returnability, while the endless types of agricultural packing were reduced to eight, and those of fish boxes were brought down to three or four economically designed sizes.

Other changes included relaxed Post Office requirements for telegraph poles, reduced consumption of matches and furniture, shorter ladies’ shoe heels, and thinner coffins.⁶⁴ In qualitative terms, these would seem to be relatively easy adjustments.

The unusual complexity of the system needed to allocate timber in wartime at least roughly reflects the severity of the economic pressures being addressed. However, many of the specific requirements imposed on the British economy would not seem to have been very costly.

A full account of Britain’s other imports of non-metallic material is beyond this paper’s scope. No other major material was as valuable as timber or was subject to such a drop in imports. Chemical imports increased steadily throughout the war. Imports of raw cotton, wool, silk, hemp, and jute, undressed hides and leather, jute manufactures, gums and resins, essential oils, and mineral phosphate of lime rose well above peacetime levels in 1939 and especially in 1940, thereby establishing stockpiles and facilitating declining imports later in the war. Imports of flax, cotton yarns and manufactures, fur, apparel, newsprint, and books were cut back

⁶² Ford, “Allocation of Timber,” 147-150.

⁶³ The Times, *British War Production*, 143.

⁶⁴ Ibid. and Ford, “Allocation of Timber.”

immediately,⁶⁵ while exports of cotton and woollen yarns and manufactures, artificial silk yarns and tissues, linen, hemp, jute, and chemical manufactures, footwear, and soap were greatly reduced.⁶⁶ In other words, imports of industrial materials were reduced much less severely than imports of consumer goods, while a rough balance between reduced imports and reduced exports left domestic consumption close to peacetime levels.

Ministry of Food imports were not inputs to military production in the same way that Ministry of Supply imports were. However, they were essential to war production and, indeed, to the war effort generally. Alan Milward writes,⁶⁷

Most economic theorists of war seem to have agreed that food is a good of unique strategic significance . . . although it is possible to devise a correct strategy which economizes on, for example, steel and coal, by exploiting more fully some other commodity in more plentiful supply, food does not fall into this category . . . The population must be fed and the troops fed better, otherwise the will to win will quickly disappear. And without food even resistance is impossible.

Immediately before World War II, Britain imported two-thirds of the calories it consumed.⁶⁸ Between 1940 and 1944, the volume of Ministry of Food imports was cut in half.⁶⁹ One response to this fall was to shift from importing staple crops that contained relatively few calories per unit of shipping space to importing foods that contained more.⁷⁰ While this policy prevented the calorific value of food imports from dropping as much as the physical volume of

⁶⁵ Central Statistical Office, *Digest of the War*, 168-170 (Tables 148 and 149).

⁶⁶ *Ibid.*, 171-172 (Table 150).

⁶⁷ Milward, *War, Economy and Society*, 245-246.

⁶⁸ Olson, *Wartime Shortage*, 117.

⁶⁹ Table I.

⁷⁰ Keith Murray, *Agriculture* (London: HMSO and Kraus Reprint, 1975), 45 (text and Table 3).

these imports, it made Britain's loss of staple crops even more severe.⁷¹

Britain sought to replace this loss of imported staple crops - grains, pulses, animal feed, and sugar - by growing more of these crops domestically. This policy meant shifting resources from raising livestock to growing crops, which was beneficial since crops yielded more calories per unit of land than livestock. The following table shows the amount of tilled land, temporary grassland, and permanent grassland in Britain during the war:

Table VIII: Britain's Agricultural Land, 1939-1945 (in thousands of acres)

	Tilled Land	Temporary Grassland	Permanent Grassland	Total
1939	8,342 (28.6%)	3,528 (12.1%)	17,331 (59.4%)	29,201
1940	9,826 (33.8%)	3,376 (11.6%)	15,896 (54.6%)	29,098
1941	11,916 (41.0%)	3,075 (10.6%)	14,066 (48.4%)	29,057
1942	12,839 (44.4%)	3,336 (11.5%)	12,752 (44.1%)	28,926
1943	13,659 (47.4%)	3,728 (12.9%)	11,420 (39.6%)	28,807
1944	13,708 (47.7%)	4,228 (14.7%)	10,809 (37.6%)	28,745
1945	13,063 (45.4%)	4,803 (16.7%)	10,892 (37.9%)	28,758

The extensive tilling of grassland reflects the shift to crops from livestock. Within the livestock sector, the growth of temporary grassland at the expense of permanent grassland reflects a shift from milk to meat, motivated by the fact that dairy cattle produce more calories and protein for less feed than animals raised for meat.⁷²

⁷¹ Appendix I.

⁷² Olson, *Wartime Shortage*, 24 and 124.

As the following table shows, the shift in land use was paralleled by a shift in livestock populations.

Table IX: Britain's Livestock, 1939-1945 (in thousands of animals)

	Cattle	Sheep & Lambs	Pigs	Poultry
1939	8,119	25,993	3,767	64,137
1940	8,361	25,465	3,631	62,121
1941	8,153	21,445	2,207	49,126
1942	8,248	20,764	1,872	43,212
1943	8,428	19,700	1,571	35,299
1944	8,616	19,435	1,631	38,481
1945	8,697	19,496	1,903	44,665

The population of cattle, which produced milk as well as meat was expanded, while the number of sheep, lambs, pigs, and poultry, which were raised only for meat declined.

Did these large transfers of resources from ranching to farming offset Britain's loss of imported staple crops?

Table X: Britain's Imports and Production of Wheat, Wheat Flour, Barley, and Sugar, 1939-1945 (in thousands of tons)

	Wheat			Wheat Flour			Barley			Sugar		
	Imp.	Prod.	Total	Imp.	Prod.	Total	Imp.	Prod.	Total	Imp.	Prod.	Total
1939	5,300	1,645	6,945	367	3,939	4,306	687	892	1,579	2,100	487	2,587
1940	5,800	1,641	7,441	577	4,391	4,968	457	1,104	1,561	1,400	501	1,901
1941	5,400	2,018	7,418	708	4,600	5,308	64	1,144	1,208	1,600	419	2,019
1942	3,500	2,567	6,067	374	4,394	4,768	-	1,446	1,446	800	474	1,274
1943	3,300	3,447	6,747	718	4,527	5,245	-	1,645	1,645	1,400	557	1,957
1944	2,800	3,138	5,938	791	4,470	5,261	-	1,752	1,752	1,200	391	1,591
1945	3,600	2,176	5,776	542	4,524	5,066	102	2,108	2,210	1,100	449	1,549

Increased wheat production almost wholly replaced lost imports. By processing wheat into flour less wastefully (e.g. by mandating the use of whole-wheat, rather than white, flour) and by importing more milled flour directly, Britain increased its supplies of wheat flour well above peacetime levels. In addition, Britain increased domestic supplies by virtually eliminating its

small wheat and flour exports.⁷³ Increased production more than made up for lost barley imports. Although larger sugar-beet harvests⁷⁴ did increase domestic sugar production, this change could not offset much of the decline in sugar imports. However, reduced exports of refined sugar and candy maintained wartime consumption of these items closer to peacetime levels.⁷⁵

However, this data does not provide a complete picture, since Britain imported some crops that were not produced domestically and produced some crops that could not be imported. The following table provides data on these crops:

**Table XI: Britain's Imports and Production of Other Staple Crops, 1939-1945
(in thousands of tons)**

	<u>Imports</u>				<u>Home Production</u>			
	Maize	Rice	Peas & Beans	Animal Feed	Potatoes	Oats	Fodder Crops	Hay
1939	2,300	143	135	1,700	5,218	2,003	13,883	7,056
1940	2,100	191	147	1,100	6,405	2,892	14,679	6,213
1941	700	179	158	300	8,004	3,247	16,855	5,925
1942	100	53	48	100	9,393	3,553	18,461	5,902
1943	100	131	70	-	9,822	3,064	17,699	5,882
1944	100	42	72	100	9,096	2,953	17,577	4,987
1945	500	25	66	200	9,791	3,245	18,646	6,502

In terms of weight, increased home production of potatoes, oats, and fodder crops far exceeded lost imports of maize, rice, peas, beans, and animal feed. Potatoes were particularly important to Britain's wartime food strategy because they yield more calories per acre than any other staple crop, with the sole exception of sugar beets.⁷⁶ Reduced domestic hay production reflects the

⁷³ Central Statistical Office, *Digest of the War*, 171 (Table 150).

⁷⁴ *Ibid.*, 57 (Table 55).

⁷⁵ *Ibid.*, 171 (Table 150).

⁷⁶ Murray, *Agriculture*, 43.

general shift away from livestock toward crops. It is therefore safe to conclude that the success British agricultural policy compensated for the loss of imported staple crops.

But what of other foods? Appendix II shows that Britain's imports of foods other than staple crops increased somewhat during the war. The following table provides a more detailed picture:

**Table XII: Britain's Imports and Production of Other Foods, 1939-1945
(in thousands of tons)**

	<u>Vegetables & Fruits</u>			<u>Meats</u>			<u>Dairy Products</u>			<u>Edible Fats</u>		
	Imp.	Prod.	Total	Imp.	Prod.	Total	Imp.	Prod.	Total	Imp.	Prod.	Total
1939	1,816	3,226	5,042	1,547	2,559	4,106	665	?	729+?	131	358+?	489+?
1940	1,034	3,200	4,234	1,436	2,351	3,787	507	256	763	78	561	639
1941	127	3,204	3,331	1,503	2,182	3,685	588	119	707	136	599	735
1942	137	4,439	4,576	1,608	1,665	3,273	707	140	847	253	505	758
1943	59	3,800	3,859	1,633	1,631	3,264	577	151	728	261	492	753
1944	242	4,088	4,330	1,768	1,705	3,473	581	162	743	239	474	713
1945	451	3,699	4,150	1,153	1,773	2,926	477	153	630	110	526	636

Increased home production largely balanced the reduction in imports of vegetables and fruits.

On the contrary, increased imports of meat offset some of the reduction in domestic production.

Because so much land was needed to produce a unit of meat, the strain on British imports was ultimately reduced by importing more meat to free up domestic land for more home production of crops and milk.

Likewise, greater imports of dairy products offset reduced home production, but the above figures are not complete. Britain increased milk production at the expense of meat production. Home production of dairy products declined only because liquid sales of milk increased from 72 million gallons per month in 1939 to 100 million per month in 1943 through 1945, while the volume used to manufacture dairy products fell from 36 to 15 million gallons.⁷⁷

⁷⁷ Ibid.

In effect, Britain opted to import its butter, cheese, and condensed milk, since these products contained many calories per unit of shipping space.⁷⁸

Imports of edible fats were increased because they contained many calories per unit of volume. The fact that these fats could partially replace lost meat and dairy products reinforced this increase in imports and also motivated an expansion of home production.

Increased agricultural production and changes in the composition of imports increased the wartime availability of wheat flour, barley, other staple crops, milk, and edible fats well above peacetime levels. Greater home production partially replaced reduced imports of sugar, vegetables, and fruits. Greater imports offset lower home production of meat and dairy products. In a broader sense, the increased availability of edible fats and milk also compensated for the loss of meat and dairy products. By rapidly carrying out a successful wartime food program, Britain cut its food imports in half without significantly reducing its food supplies.

Overall, Britain's agricultural output rose from 19 billion calories in an average pre-war year to 29 billion in 1943/44, an increase of 55%. Since four billion of the pre-war calories depended on imported feeds and seeds, while only one billion of the 1943/44 calories did, net wartime output was 91% higher than net pre-war output. Despite reduced meat production, "owing to the relatively greater reduction in the protein content of imported feedingstuffs, the increase in net home output of proteins was greater than that of calories; it was approximately 82 per cent. in 1942-3 and about 106 per cent. in 1943-4."⁷⁹

While the calorific value of domestic production was greatly expanded, the calorific value of imports was maintained by reorienting them toward foods that contained many calories

⁷⁸ Murray, *Agriculture*, 45 (Table 3).

⁷⁹ *Ibid.*, 242 (Table 18) and Olson, *Wartime Shortage*, 125.

(and often much protein) per unit of volume. These initiatives, combined with a rationing program that distributed food more equally in wartime than it had been in peacetime, meant that the average Briton ate better during the war than before.⁸⁰

During World War II, Britain's departmental imports were cut in half. However, the Ministry of Supply was generally able to give British industry the same level of material inputs that it consumed in peacetime, while the Ministry of Food "maintained the population as a whole at a slightly more satisfactory level of health than before the war."⁸¹ Greatly reduced imports apparently had little negative effect upon war production.

However, it would be spurious to claim that reduced imports had no impact on British military output or that this paper can quantify the small magnitude of this impact. The paper has shown that the overall decline in British imports was disproportionately distributed among different types of imports. Imports of some non-ferrous metals, some non-metallic materials, and some foods increased during the war. Furthermore, greatly reduced imports of ferrous metals and staple crops did not reduce British steel and food supplies. In fact, Britain gave its industry more steel and its workforce more food during the war than it had in peacetime.

Britain's supplies of some non-ferrous metals, timber, and some other non-metallic materials were reduced by lost imports. This quantitative reduction had little effect on military output because these goods were not qualitatively important to Britain's war economy. On the whole, Britain was able to make adjustments that offset the economic cost of lost imports.

The British did so in three main ways. First, Britain reduced its exports of finished steel, timber products, other non-metallic products, wheat flour, refined sugar, and other foods to

⁸⁰ Milward, *War, Economy and Society*, 281.

⁸¹ *Ibid.*

maintain the domestic availability of these items near, at, or above peacetime levels. Second, Britain altered the composition of its imports to maintain or increase the productive value of reduced volumes. It substituted steel for iron, aluminium for bauxite, non-ferrous metals for non-ferrous ores, flour for unmilled wheat, and dairy products for milk. Third, Britain produced more iron ore, timber, staple crops, and of some other foods domestically to replace lost imports of these products. These adjustments were highly successful in abating the cost of lost imports. But how much did it cost Britain to make these adjustments?

Lowering exports decreased the inflow of foreign exchange, which reduced Britain's capacity to buy imports, outside of the Lend-Lease and Mutual Aid programs. However, since this paper has taken the whole decline in Britain's imports as a given, the part of this decline attributable to reduced exports is beyond the paper's scope and cannot be counted as a separate adjustment cost. Export reduction also weakened Britain's post-war trade position. During the war, Britain surrendered many of its pre-war export markets to local suppliers, the USA, or other countries. It had difficulty regaining these markets after the conflict.⁸²

Changing the composition of British imports had three major costs. First, importing processed goods rather than raw materials was more expensive in terms of foreign exchange, outside of Allied assistance programs. As has already been mentioned, this cost falls outside the paper's scope.

Second, Britain's ports and internal transportation were designed for normal peacetime imports. Radically changing the mix of products arriving at British ports and needing to be moved inland strained Britain's fixed infrastructure.⁸³ However, these pressures do not appear to

⁸² This is an issue identified in the standard works on Britain's war economy (see note 16 above) and in Barnett, *Audit of War*.

⁸³ Behrens, *Merchant Shipping*, and Smith, *Conflict Over Convoys*.

have imposed a great cost on Britain's economy. The number of workers employed in "transport and shipping" in Britain fell below 1939 levels between 1940 and 1943, and increased marginally above 1939 levels only in 1944 and 1945 as Britain's mix of imports was returning to peacetime norms.⁸⁴ Whatever difficulties were caused by the changed composition of British imports were not sufficient to draw more labour into the affected sector.

Third, substituting finished imports for raw imports undermined the structure of British industry. Before World War II, the British economy imported raw materials, processed them, and then used them to manufacture civilian goods for home consumption and export abroad. During the war, it became an economy that imported refined materials to produce military goods. This shift weakened processing and refining industries in Britain and strengthened them in countries that exported to Britain.⁸⁵

Like the other two types of adjustment, increased home production had present and future costs. During the war, Britain had to devote resources to producing iron ore, timber, staple crops, and various other foods in excess of normal peacetime levels. However, this commitment of resources proved to be very small on the aggregate level. Presumably, more workers were needed to mine more iron ore, but whatever increase occurred was small enough to be more than made up for by decreased employment in other types of "mining and quarrying." The total number of workers employed in this sector declined from 849 to 818 thousand between 1939 and 1943.⁸⁶ The number of workers employed in logging increased from 10 to 70 thousand,⁸⁷ a huge

⁸⁴ Central Statistical Office, *Digest of the War*, 8 (Table 9).

⁸⁵ Barnett, *Audit of War*.

⁸⁶ Central Statistical Office, *Digest of the War*, 8 (Table 9).

⁸⁷ The Times, *British War Production*, 142.

proportional increase, but only a tiny fraction of Britain's total civilian labour force. The number employed in woodworking increased from 102 to 119 thousand.⁸⁸ The cost of replacing lost Ministry of Supply imports with domestic production thus accounted for fewer than 100 thousand workers, about half of one percent of Britain's wartime civilian labour force of 17.5 million.⁸⁹

The cost of substituting domestic agricultural output for Ministry of Food imports was higher. The total number of workers employed in agriculture increased from 711 to 843 thousand between 1939 and 1943,⁹⁰ an increase of 19%, accounting for about three quarters of one percent of Britain's total workforce. However, these aggregate figures ignore changes in the composition of Britain's agricultural labour force. As the number of experienced regular male workers declined, the number of inexperienced regular female workers, casual male and female workers, Women's Land Army workers, and prisoners of war grew.⁹¹ In other words, unskilled labour displaced skilled labour. One credible attempt to weight different classes of agricultural workers differently shows that the effective size of Britain's agricultural workforce increased by only 8% during the same period.⁹² If this figure is accepted, then the real cost of expanding domestic agricultural production was effectively closer to one third of one percent of Britain's civilian labour force.

Another cost of expanding home food production was a vast increase in the use of

⁸⁸ Central Statistical Office, *Digest of the War*, 27 (Table 27).

⁸⁹ *Ibid.*, 8 (Table 9).

⁹⁰ *Ibid.*, 16 (Table 18).

⁹¹ *Ibid.*

⁹² H. T. Williams cited in Broadberry and Howlett, "Victory at All Costs," 63 (Table 2.16).

capital equipment in British agriculture. “Thus between 1939 and 1945 the production of tractors increased by 48 per cent, of disc harrows by 514 per cent, of potato spinners by 381 per cent, and of threshing machines by 121 per cent.”⁹³ There is no doubt that the resources used to manufacture agricultural machinery could have been used to produce armaments or industrial machinery. While it is difficult to quantify the cost of this capital equipment in terms of labour, it seems unlikely that the effective cost of supplementing both departmental programs with increased home production much exceeded one percent of Britain’s civilian workforce.

The future costs of replacing imports with home production were twofold. On the one hand, Britain greatly reduced its domestic resource stocks. To replace lost Ministry of Supply imports Britain depleted its stocks of iron ore and timber far faster than it would have in peacetime.⁹⁴ Intensive farming eroded the agricultural value of British soil, at least temporarily. This was partly responsible for the reduction in agricultural output between 1943/44 and 1944/45.⁹⁵ As well, the shift away from meat toward crops reduced Britain’s population of livestock (except for cattle) well below pre-war levels.⁹⁶ Import substitution left Britain with less iron ore underground, less timber in its woodlands, less fertility in its soil, and less livestock in its countryside.

On the other hand, this same process built up the primary industries that depended on these stocks, vindicated their claim to strategic significance, and established a strong precedent

⁹³ Ibid., 62.

⁹⁴ The depletion of timber stocks is discussed in *The Times*, *British War Production*, 143.

⁹⁵ Olson, *Wartime Shortage*.

⁹⁶ Table IX.

of government support for them.⁹⁷ Import substitution thereby contributed to the post-war circumstances in which the British state was obliged to prop up declining industries, tying up public funds that could have been used to finance a more effective industrial strategy and economic resources that could have made a greater marginal contribution in other sectors.⁹⁸

In some senses, Britain's wartime adjustments were expensive. However, they occupied a total of only about one percent of Britain's civilian labour force during the war. Most of their burden was not felt until after the conflict. Indeed, it could be argued that these adjustments simply shifted the costs of lost wartime imports forward into the post-war period.

Lost wartime imports reduced British military output by a very small amount. In the face of vastly reduced imports, adjustments within Britain's import program and in its larger economy supplied the war economy with more steel, more of the most important non-ferrous metals, more of some non-metallic materials, more staple crops, and more of some other foods than Britain had consumed in peacetime. Although Britain had to make do with less timber and less of some other non-metallic materials and foods, these losses did not significantly hinder its war economy. Even if it cannot be precisely quantified, the immediate cost of reduced imports was very small. The adjustments that successfully curtailed this cost occupied only about one percent of Britain's civilian labour force. The overall impact of reduced imports upon British war production could not have exceeded more than a few percentage points of total military output.

While the above conclusion is significant in its own right, it does not fully explain the effect of Germany's submarine blockade on Britain's war production. On the one hand, British

⁹⁷ Olson, *Wartime Shortage*.

⁹⁸ Barnett, *Audit of War*.

imports were limited by factors other than the effect of U-Boats on merchant shipping. A case can be made that British port capacity and the availability of cargos restricted imports more than wartime constraints on shipping.⁹⁹ If this argument is correct, then the German submarine blockade was responsible for only a small fraction of the already small impact of lost imports on British war production.

On the other hand, the U-Boats forced adjustments not examined in this paper. In order to prevent British imports from falling even more severely than they did, the Allies had to produce and repair vast numbers of merchant ships to make good those sunk or damaged at sea. Resources used to build merchant shipping could otherwise have been used to build naval vessels or other armaments. Much of this expense was borne by the United States and Canada, rather than by Britain, but it was a significant cost imposed on the Allies by Germany's submarine blockade.

Outside the sphere of war production, the German submarine blockade affected Britain's armed forces more directly. Defending shipping against German forces tied down Allied escort ships and aircraft. Appendix I suggests that the overall decline in British imports did not reduce the quantity of oil imported for Britain's military. Whether wartime losses of shipping constrained British military operations more generally is debatable.¹⁰⁰

The pressures and uncertainties created by the German submarine blockade may also have distorted British war administration. If wartime management is seen as an optimization problem, then the U-Boats certainly made it more difficult by forcing British planners to take a

⁹⁹ This case, or parts of it, is suggested by Behrens, *Merchant Shipping*, and Smith, *Conflict Over Convoys*.

¹⁰⁰ In *Conflict Over Convoys*, Smith argues that a shortage of shipping greatly restrained British operations. In *Merchant Shipping*, Behrens points out that there were no major instances in which Britain had sufficient military resources to carry out a given operation, but was prevented from doing so only by a lack of shipping.

further variable into account. However, there is strong evidence that Britain was able to mitigate this variable by stockpiling imported supplies. From 1941 through 1944, Britain's stocks of imported goods fluctuated between just under 15 million tons and just over 18 million tons, always remaining well in excess of the Shipping Committee's estimated distributional minimum of 11.5 million tons and far in excess of the Ministry of Production's estimate of 9.8 million tons.¹⁰¹ This paper has provided many more specific examples of how stockpiling shielding domestic supplies from the variability of imports.

This paper's rough assessment of the amount by which reduced wartime imports curtailed British war production provides a partial estimation of the effectiveness of Germany's submarine blockade. However, a complete analysis of the factors outlined above could add or subtract significantly from this estimate. To determine whether or not the submarine blockade was successful as a means of economic warfare one would have to weigh this modified estimate against an assessment of how much it cost Germany to carry out this campaign. While the conclusion that reduced overseas imports had little effect on British war production is significant in its own right, it is only the starting point for a complete analysis of how close Germany came to winning the Battle of the Atlantic.

¹⁰¹ Behrens, *Merchant Shipping*, 325 (Appendix LIV).

Appendix I: Britain's Wartime Imports by Category, 1941-1944

Departmental Imports	Ministry of Supply		Ministry of Food		Munitions & Tanker Imports		Imports from Ireland	Grand Total
	Ferrous Metal	Non-Ferrous Metal	Other Foods	Staple Crops	Other Dry Cargo	Tanker Imports		
1941	29,700	7,474	5,356	9,298	778	13,603	505	44,586
1942	22,111	5,015	5,597	5,009	780	10,710	489	34,090
1943	24,359	5,253	5,756	5,769	2,013	15,118	346	41,836
1944	22,749	4,382	5,899	5,097	2,398	20,532	414	46,093
43/41	82%	70%	107%	62%	259%	111%	69%	94%
44/41	77%	59%	110%	55%	308%	151%	82%	103%
Total	98,919	22,124	22,608	25,173	5,969	59,963	1,754	166,605

Note: Data on Ministry of Supply imports are from Central Statistical Office, *Digest of the War*, 187 (Table 163). "Ferrous Metal" includes iron ore, iron, steel, and allied materials. "Non-Ferrous Metals" include non-ferrous ores and metals. "Non-Metallic Materials" include all other Ministry of Supply imports. Data on Ministry of Supply imports are from Central Statistical Office, *Digest of the War*, 186 (Table 162). "Staple Crops" include grain and pulses, animal feedingsuffs, and sugar. "Other Foods" include all other Ministry of Food imports. "Departmental Imports" are the sums of Supply and Food imports. "Munitions and Other Dry-Cargo Imports," "Tanker Imports," and "Imports from Ireland" are from Central Statistical Office, *Digest of the War*, 184 (Table 161). "Grand Total" is the sum of "Departmental Imports," "Munitions and Other Dry-Cargo Imports," "Tanker Imports," and "Imports from Ireland." The fact that this data is unavailable for 1940 could be said to understate the decline in imports because treating 1941 as the base year ignores the drop between 1940 and 1941. However, this categorization of British imports is useful, and the data in tables on specific imports does cover the period before 1941.

Appendix II: Britain's Iron and Steel Trade, 1938-1945

Iron Ore Imp.	Steel Components			Semi-finished Steel			Finished Steel			Total		
	Imp.	Exp.	Net Imp.	Imp.	Exp.	Net Imp.	Imp.	Exp.	Net Imp.	Imp.	Exp.	Net Imp.
1938	5,100 [92%]	1,043	942 [17%]	374	22	352 [6%]	459	1,338 (879) [-16%]	6,976	1,461	5,515	
1939	5,200 [82%]	1,027	949 [15%]	830	11	819 [13%]	509	1,139 (630) [-10%]	7,566	1,228	6,338	
1940	4,508 [55%]	1,670	1,645 [20%]	2,074	11	2,063 [25%]	795	818 (23) [- 1%]	9,047	854	8,193	
1941	2,241 [34%]	1,571	1,550 [24%]	2,296	1	2,295 [35%]	761	347 414 [6%]	6,869	369	6,500	
1942	1,935 [46%]	424	419 [10%]	1,599	1	1,598 [37%]	472	175 297 [7%]	4,430	181	4,249	
1943	1,924 [41%]	497	492 [11%]	1,463	2	1,461 [32%]	835	74 761 [16%]	4,719	81	4,638	
1944	2,148 [58%]	341	338 [9%]	999	1	998 [27%]	394	157 237 [6%]	3,882	161	3,721	

1945 4,191 [100%] 355 34 321 [8%] 117 2 115 [3%] 33 463 (430) [-10%] 4,696 499 4,197

Note: Iron Ore "Imp." are from Central Statistical Office, *Digest of the War*, 168 (Table 148). Steel Components include iron and steel scrap, pig iron, and ferro-alloys. Component "Imp." are from Central Statistical Office, *Digest of the War*, 168 (Table 148) [scrap], and from Central Statistical Office, *Digest of the War*, 169 (Table 149) [pig iron and ferro-alloys]. Semi-finished and finished steel "Imp." are from Central Statistical Office, *Digest of the War*, 169 (Table 149). All "Exp." are from Central Statistical Office, *Digest of the War*, 171 (Table 150). "Net Imp." equal "Imp." minus "Exp." Percentages are of total "Net Imp." Due to rounding, they sometimes do not sum to one hundred.

Appendix III: Britain's Bauxite and Aluminium Supplies, 1939-1945

Year	Bauxite		Aluminium		Domestic Al. Production		Total Imports	Primary Al. Available	Imports to Primary Ratio	Total Al. Available	Imports to Total Ratio
	Imports	Primary	Imports	Secondary	Primary	Secondary					
1939	302.1	57.7	25.0	?	359.8	82.7	4.4	82.7+?	<4.4		
1940	112.4	66.1	19.0	37.9	178.5	85.1	2.1	123.0	1.5		
1941	87.2	132.7	22.7	53.2	219.9	155.4	1.4	208.6	1.1		
1942	47.8	131.6	46.8	78.8	179.4	178.4	1.0	257.2	0.7		
1943	241.8	213.0	55.7	93.5	454.8	268.7	1.7	362.2	1.3		
1944	172.1	149.7	35.5	104.5	321.8	185.2	1.7	289.7	1.1		
1945	162.6	21.1	31.9	81.0	183.7	53.0	3.5	134.0	1.4		

Note: "Bauxite Imports" are from Central Statistical Office, *Digest of the War*, 168 (Table 148) and "Aluminium Imports" are from Central Statistical Office, *Digest of the War*, 169 (Table 149). "Total Imports" is the sum of these two. "Domestic Al. Production" is from Central Statistical Office, *Digest of the War*, 110 (Table 96). "Primary Al. Available" is the sum of "Aluminium Imports" and primary "Domestic Al. Production." "Imports to Primary Ratio" is "Total Imports" divided by "Primary Al. Available." "Total Al. Available" is the sum of "Primary Al. Available" and secondary "Domestic Al. Production." "Imports to Total Ratio" is "Total Imports" divided by "Total Al. Available."

NOTES ON TABLES

Table I: Britain's Dry-Cargo Imports, 1940-1944

All data presented in both Olson, *Wartime Shortage*, 129 and Smith, *Conflict Over Convoys*, 249-250 (Tables I, II, and III).

Table II: Britain's Iron Ore Supplies, 1939-1945

"Imports" and "Home Production" are from Central Statistical Office, *Digest of the War*, 101 (Table 90). "Stock Reduction (Addition)" and "Actual Consumption" are calculated from the same source. "Quantity Available" is the sum of "Imports," "Home Production," and "Stock Reduction (Addition)."

Table III: Britain's Imports and Consumption of Allied Materials, 1939-1945

All data are from Central Statistical Office, *Digest of the War*, 108 (Table 94).

Table IV: Britain's Steel Supplies, 1939-1945

"Domestic Production" is from Broadberry and Howlett, "Victory at All Costs," 59 (Table 2.14) and Ellis, *Statistical Survey*, 276 (Table 85). Where the two sources disagree, Ellis's figures are shown second. "Imports" and "Exports" are from Central Statistical Office, *Digest of the War*, 169 (Table 149). "Net Imports" is calculated by subtracting "Exports" from "Imports." "Total Available" is the sum of "Domestic Production" and "Net Imports."

Table V: Britain's Ore Imports, Metal Imports, and Metal Consumption of Copper, Magnesium, and Zinc, 1938-1945

For all three metals, "Ore Imp." is from Central Statistical Office, *Digest of the War*, 168 (Table 148), "Metal Imp." is from Central Statistical Office, *Digest of the War*, 169 (Table 149), and "Metal Con." is from Central Statistical Office, *Digest of the War*, 109 (Table 95). "I/C Ratio" is calculated by dividing "Metal Con." by the sum of "Ore Imp." and "Metal Imp."

Table VI: Britain's Imports and Consumption of Other Non-Ferrous Metals, 1939-1945

For all metals, "Imp." is taken either from Central Statistical Office, *Digest of the War*, 168 (Table 148) or from 169 (Table 149). "Con." is taken from Central Statistical Office, *Digest of the War*, 109 (Table 95).

Table VII: Britain's Imports and Domestic Production of Timber, 1939-1945

For both softwood and hardwood, "Imports" are from Central Statistical Office, *Digest of the War*, 168 (Table 148) and "Production" is from Central Statistical Office, *Digest of the War*, 112 (Table 97). "Total" is calculated from "Imports" and "Production." Figures on softwood are converted from standards to cubic feet on the basis that one standard equals 165 cubic feet.

Table VIII: Britain's Agricultural Land, 1939-1945

"Tilled Land," "Temporary Grassland," "Permanent Grassland," and "Total" are from Central Statistical Office, *Digest of the War*, 57 (Table 55). Percentages are calculated from these figures.

Table IX: Britain's Livestock, 1939-1945

All data are from Central Statistical Office, *Digest of the War*, 61 (Table 61).

Table X: Britain's Imports and Production of Wheat, Wheat Flour, Barley, and Sugar, 1939-1945

For all goods, "Imp." are from Central Statistical Office, *Digest of the War*, 167 (Table 147). For wheat and barley, "Prod." is from Central Statistical Office, *Digest of the War*, 59 (Table 57 + Table 58). For wheat flour and sugar, "Prod." is from Central Statistical Office, *Digest of the War*, 68 (Table 68). For all goods, "Total" is the sum of "Imp." and "Prod."

Table XI: Britain's Imports and Production of Other Staple Crops, 1939-1945

All data on imports are from Central Statistical Office, *Digest of the War*, 167 (Table 147). All data on home production are from Central Statistical Office, *Digest of the War*, 59 (Table 57 + Table 58).

Table XII: Britain's Imports and Production of Other Foods, 1939-1945

For all foods, "Imp." are from Central Statistical Office, *Digest of the War*, 167 (Table 147), "Prod." is from Central Statistical Office, *Digest of the War*, 68 (Table 68), and "Total" the sum of "Imp." and "Prod."

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