# The Military Rise of China

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Despite the enormous interest in China's increasing military capabilities and ambitions, no statistical agencies produce public estimates of China's defence budget in real terms. Hence there is little understanding of how fast China's defense budget has grown in real terms or how fast it is catching-up with the USA. By constructing deflators and input price level estimates I find that: (i) China's has dramatically closed the gap and defense purchasing power is 59% of the USA; (ii) real personnel inputs have declined over time, but; (iii) real equipment spending has grown at a massive 10% per year since 2000. The growth in equipment spending accounts for almost all the growth in China's real defence spending. Hence, while China's defense forces are still relatively labour intensive, there has been a massive shift in its composition with rapidly growth in equipment per person. The results reconcile the increasing disparate accounts of China's military rise, and particularly the divide between defense budget data and descriptive narratives of China's military modernization.

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# Executive Summary

China's rising military capabilities are widely argued to be rivalling the USA particularly in the Indo-pacific region (Inhofe 2021, Romney, 2023, U.S. Department of Defense, 2022). Nevertheless, understanding of how China's defence budget compares with the USA, or how fast China is closing the gap, is not well understood. In particular, no statistical agency or defense department currently produces public estimates of China's defence sector price deflators or defense sector purchasing power, and these economic concepts are not widely used in defence policy circles.

The lack of economic analysis contributes to a growing disconnect between numerous studies that emphasise China's military modernization that emphasise China's vast capabilities and modernization, and published defence budget data that typically show China's defence budget as still being a small fraction of the USA (The Economist 2023, The Wall Street Journal 2023, Inhofe 2021, Sullivan 2023). This concern has culminated a new bipartisan bill, *The China Defense Spending Transparency Act*, June 2023, to provide an official Department of Defence perspective on China's military spending (Romney 2023 et al, Sullivan 2023).

This paper provides an analyses China's defence budget, using publicly available data, in order to describe the how China's real defence budget has changed over time in its size, composition and relative to the USA.

I find that China's defence spending in real (purchasing power) terms is approximately 60% larger than market exchange rates valuations. The composition of China's defence budget is more labour intensive than the USA however and China's spending on real military Equipment is estimated to only be 37% of the USA's equipment spending.

China's real (inflation adjusted) military equipment budget is growing very rapidly, and has increased at 10% per year on average for two decades. This represents a massive change in the structure of China's defence forces which consistent with rapid modernization and catch-up with the USA. The results thus reconcile the increasing disparate accounts of China's military rise, and particularly the divide between defense budget data and descriptive narratives of China's military modernization.

Specific findings are:

(i) While China's nominal defence budget grew at 9.3 percent per annum from 2010-2021, real growth, was just 5.9 percent per annum. Much of the nominal growth in China's military spending represents rising unit costs of personnel.

(ii) China's defence budget in purchasing power terms is 60% larger than market exchange rate values. Thus it is equal to $US 476 billion (compared to the market exchange rate value of $US 293 billion) which represents 59% of USA defence spending, based in SIPRI's definition of military spending.

(iii) The larger purchasing power arises mainly because China's defence personnel are estimated to receive about one quarter of the income of USA military, for personal of similar skill levels.

(iv) China's defence budget is far more labour intensive than the USA's and Most of the difference between the exchange rate and purchasing power measure of China's defense spending is due to China's large number of personnel.

(v) China military equipment budget is only 37% of the USA and the non-personnel budget (equipment and operations) are only 39% of the purchasing power of the USA's.

(vi) Nevertheless China's equipment spending is catching up rapidly – growing at over 10% per year for two decades. This represents a massive change in the structure of the PLA in terms of increasing equipment per person.

(vii) The findings of higher value of China's defense budget relative to the USA in real terms and the rapid growth in China's military equipment spending, are consistent with defense expert accounts of China's military modernization than conventional estimates of China's defense budget. The results thus reconcile the different perspectives in the literature around China's capabilities relative to the USA.

# 1. Introduction

China's military rise and modernization are thought to be rapidly changing the balance of power. As well as having the world's largest army and, by some measures, the world's largest navy, China has advanced anti-access aria denial (A2D2) capabilities, including so called "carrier killer" hypersonic missiles, and may have a technological edge in strategic defence technologies such as AI and quantum computing (Cordesman and Kendall 2016, U.S. Department of Defense, 2022, Allison and Glick-Unterman 2021, Mazarr et al 2022).

These assessments have generated concern over the speed of China's military growth and its intentions, resulting in new security alliances, restrictions on technology intensive trade and suggestions of a new cold war (Maizland 2020, Alison and Glick Unterman 2021, The Economist 2021, Eaglan 2023c, Gerwitz 2023, Taffer and Wallsh, 2023). They are also causing concerns as to how China's defence budget now compares with the USA and whether the USA is spending enough on its own defence (Milley, 2018, Inhofe 2021, Tirpak 2021, The Economist 2023, Romney 2023, O'Hanlon 2023, Gyhn 2023, Grossman, 2023).

Nevertheless, there is very little understanding of how China's real defence spending compares with the USA and how this has changed over time in real terms. Specifically, no statistical agency or defense department currently produce estimates of China defence sector price deflators or estimates of China's defense sector purchasing power. Consequently, almost all discussions of China's defence budget growth are based on nominal growth rates.[2] Likewise the vast majority

[2] The IISS recently commenced reporting military expenditure for China, the USA and Russia but only using GDP-PPP exchange rates Robertson (2022) shows that GDP -PPP and military-PPP exchange rates differ substantially in some countries. The USA Department of Defence's Annual Report on China's Military Developments, only discusses China's defence budget in nominal terms and only compares China's defense budget to the USA using market exchange rates, without considering the different price levels and purchasing power in China. The US Department of State produced a series of military spending comparisons including an ad-hoc approach to measuring military purchasing power parity exchange rates, but this was discontinued in 2021. It is available at https://www.state.gov/world-military-expenditures-and-arms-transfers/.

of comparisons of military spending between China and the USA, use market exchange rates, which don't take into account price differences between China and the USA.

Similarly, very few academic papers have sought to compare the growth China's military with other countries. Of these few studies, nearly all refer to data that is now over a decade old.[3] Comparisons of real defence spending levels based on purchasing power concepts are also often viewed with scepticism in defense establishment circles (see for example Freedberg 2018 Milley 2018, Zakaira, 2021, Korb 2022, Heim 2020 Tirpek 2021, Lofgren, 2021, Cato Institute, 2023).[4] Apart from a few academic papers, and statements by senior figures such as Joint Chiefs of Staff Chair, General Milley and some senior members of the United States Congress, the public case for using purchasing power concepts when assessing the size of China's defense sector relative to the USA, has been led by the media (Economist 2021, 2023, The Wall Street Journal, 2023), and policy think-tanks such as The Heritage Foundation (Bartels 2020) and The American Enterprise Institute (Eaglan 2023a, 2023b, 2023c).

The lack of economic analysis has led to a growing disconnect between descriptive assessments of China's defense capabilities by defense analysts, and all official and publicly available data on the size of China's defence budget relative to the USA (Inhofe 2021, Wall Street Journal 2023, Eaglan 2023c, Kuper 2023). The concern has culminated a new bipartisan bill, *The China Defense Spending Transparency Act*, introduced, in June 2023, to requiring the US Department of Defense to produce a report to Congress on the comparative size of China's defense budget,

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[3] Liff and Erickson (2013) considered China's real growth in defense spending but only deflated spending sing a GDP deflator and only examine data up to 2011. Robertson and Sin (2017) compare Chia and the USA but only consider data up to only 2010 and don't examine real growth rates. Robertson (2022) also compares China and USA military spending but only for a single in a single year for 59 countries.

[4] For example Washington Post and CNN Journalist Fareed Zakaria wrote "America's edge over China is more like a chasm … U.S. military spending remains larger than the defense budgets of the next 10 countries put together" (Zakaira, 2021). These comments echoed earlier remarks by former US President Barack Obama in his 2016 State of the nation address, who assured his audience, to much applause that "The United States of America is the most powerful nation on Earth. Period. It's not even close. … We spend more on our military than the next eight nations combined" (Obama, 2016)

including assessments based on purchasing power parity (Romney 2022, Romney 2023, Sullivan, 2023, Wall Street Journal 2023).[5]

In this paper I examine the rise of China's military spending over the last two decades in real terms, using an imputed defence sector deflator and a military purchasing power parity (PPP) exchange rate. I find that China's 2021 defense budget, in real terms, is 60% larger than market exchange rate valuations. Using the SIPRI definition of defense spending this equates to a real budget of $US 476 billion, or 59% of the USA's defence budget.

Despite this higher level of spending I also show that China's defense forces remain very labour intensive relative to the USA, with equipment spending only about 37% of the USA's equipment budget. Nevertheless, the increase in real equipment procurement is also by far the most dynamic part of China's military growth. China's real defence equipment spending has grown at 10.2% per annum over 2000-2021, which is 6% per annum faster than the USA.

The paper consists of two main sections. Section 2 examines Chinese defense budget data over time in local currency units (yuan) and deflates the components of China's defense budget using civilian price indices for machinery and estimated defense sector unit-personnel cost growth. The resulting real growth rates of these components, and real overall sector growth, can then be compared with USA defense spending growth rates.

Section 3 then aims to compare the real levels of military sending in China and the USA in real terms. For this purpose, we need to construct measures of real spending for each country, measured in a common currency. Section 3 therefore also discusses relative defense sector price levels in each country and constructs military purchasing power parity exchange rates.

Overall, the analysis of China's defence budget in real teams gives a picture of catch-up and transformation that is very consistent with defense-expert's accounts of China's military growth

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[5] The China Defense Spending Transparency Act was introduced to the US senate by Senators Romney, Sullivan, Manchin and King on 2nd September 2023 requires the department of defence to "provide the people of the United States with an accurate comparisons of the defense spending of the People's Republic of China and the United States" … and to "consider the effects of purchasing power parity",

and modernization thus address the disconnect between the view in the defence community and widely used economic data.

# 2. China's Real Defence Sector Growth

## 2.1 *Real and Nominal Defence Spending*

China's growth in military spending and military modernization has led to a rapid change in international security priorities and focused attention on the size of China's defense budget relative to the USA (Inhofe 2021, Tirpak 2021, Alison and Glick Unterman 2021, Eaglan 2023, Kuper 2023, The Economist 2021, 2023, Gyhn 2023, Grossman, 2023). Figure 1 shows the conventional view of China's defence budget, in current renminbi, as reported by SIPRI (2023). Chinese military spending in 2021 was estimated to be RMB 1.89 trillion, growing from less than RMB 200 billion in 2000, which represents a nominal growth rate of 11.7 percent per annum.The figure also shows the shares of each component of spending, with the little change in the overall composition of nominal spending.

To understand what this implies in real terms we need to adjust the nominal spending data for price changes, or "defence sector inflation". Unfortunately, China, and many other countries, do not publish defense sector prices.[6] In the absence of defence-sector-specific deflators, Liff and Erickson (2013) deflated China's defence spending by the GDP deflator.

For reference Figure 1 also shows "real" defence spending defined this way, in constant 2015 renminbi, using the World Bank World Development Indicators implicit GDP deflator (World Bank 2023). [7] By this measure, which implicitly assumes that the rate of inflation in the defense

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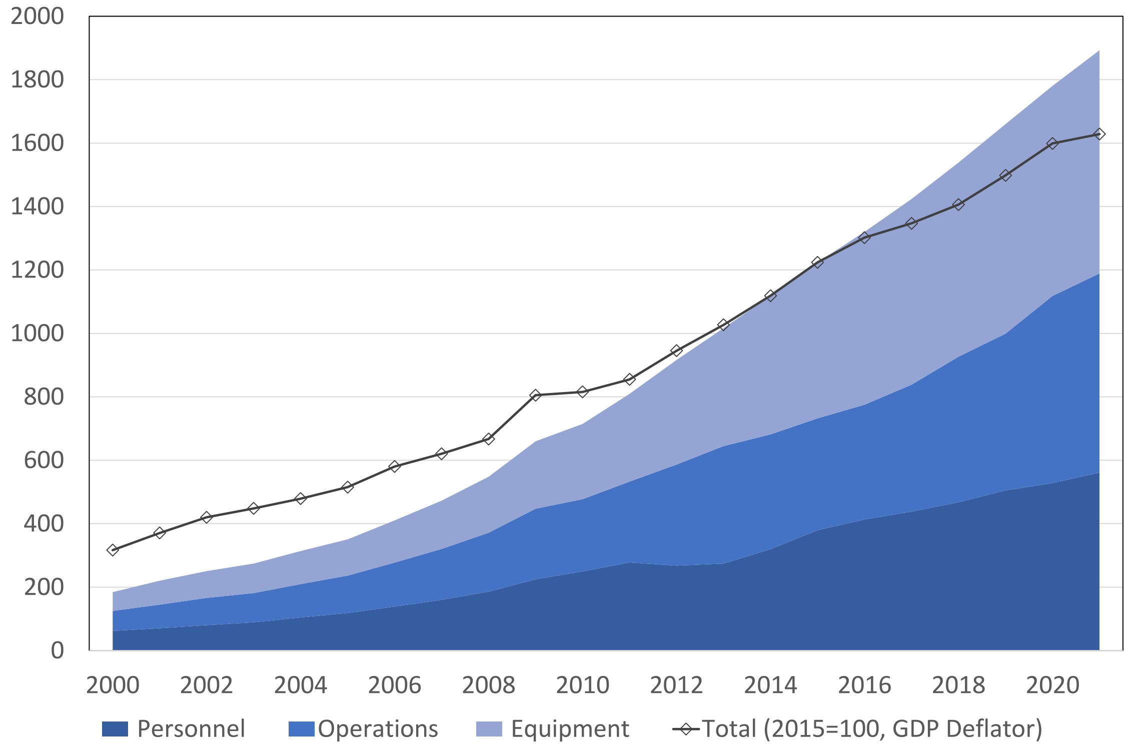
[6] Statistical agencies such as SIPRI and IISS thus report nominal spending in local currency and spending in real and current $US. For example, SIPRI convert Chinese spending to current $US using market exchange rates and then deflate using a USA GDP deflator. This process, however, conflates real military growth with exchange rate movements.

[7] The SIPRI budget differs from China's official budget as it includes some para-military activities, civilian funded military research and military related construction and subsidies (Tin and Fu 2021).

sector is the same as the economywide average, the real growth rate of defense spending is 8.1 percent per annum over 2000-21.[8]

The use of a single deflator, however, does not allow us to see how real defense spending on equipment, operations and personnel have changed relative to each other and, hence, how the structure of China's defense budget has changed. Specifically, given China's programme of military modernization, one might expect an increase in equipment spending relative to personnel. [9]

**Figure 1: Chinese Military Spending 2000-2021 (RMB billions)**




[8] As is well known, this has arisen without any increase in the defence burden (SIPRI 2023 U.S. Department of Defense 2022) and in fact military spending as fraction of GDP in China has declined slightly over this period

[9] For example see CSIS (2023) The division is based on the expenditure shares which are derived from the United Nations "Milex" database (UNIDO 2022) and various national defense white papers produced by China. Details of the budget shares are reported in the Appendix Table 1. Research spending, when reported as a separate item is included in Operations. Caution is warranted to since the expenditure shares refer to the original defence budget reported by China to the UN and not the adjusted budget reported by SIPRI.

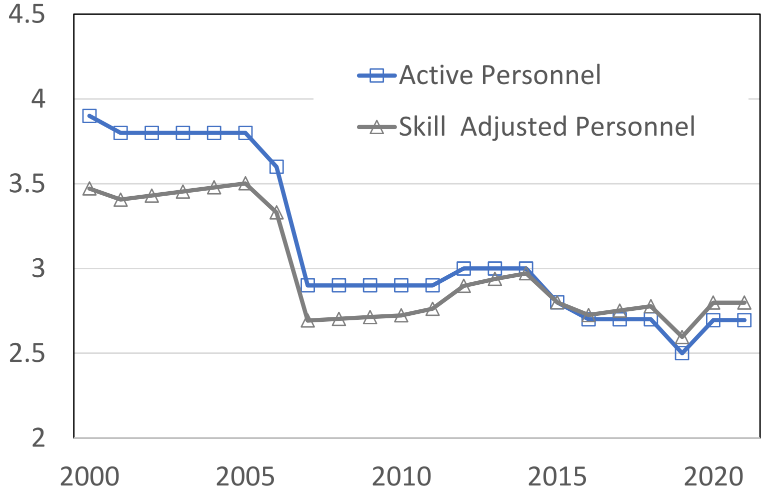
To understand these real structural changes within the defence budget, we can examine each input separately and measure the real growth of these inputs. With respect to Personnel, we can observe these real inputs directly in Figure 2, panel (i) which shows the number of active military personnel in the PLA as reported by the International Institute for Security Studies (IISS), (World Bank 2023). This definition includes all active-duty military personnel, including some paramilitary forces, insofar as they can be used to support or replace regular military forces. The number of armed forces personnel in China have not increased, but rather has fallen from nearly 4 million in 2000 to 2.7 million today. Thus, with the possible exception of improvements in skills, this suggests that real inputs of personnel have declined over time.

To get a broad-brush measure of skill levels, Figure 2 panel (i) also reports active personnel adjusted by a human capital index for the Chinese labour force. This index is based on the estimated effective productivity (or efficiency wage) from increases in the average years of schooling in the population from the Penn World Table (Feenstra et al 2015).[10] Although the skill index has increased significantly over time, by 16%, the efficiency adjusted series still shows a strong downward trend in skill-adjusted active personnel.

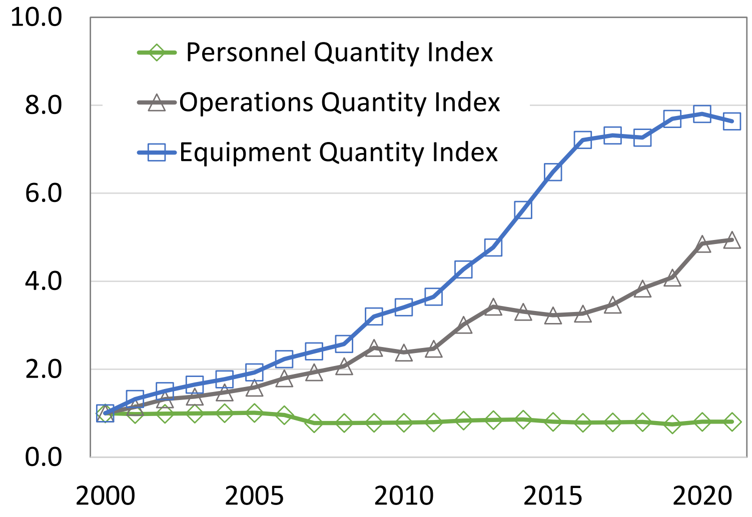
[10] The Penn Word Table uses the a Mincerian relationship between the effective units of labor $h$, and years of schooling, $s$, given by $h = e^{\varphi\, s}$, where $\varphi$ is an estimated return to schooling. The Penn word table draws on Barro and Lee (2013) and Cohen and Leker (2014). For further discussion see "Human capital in the PWT 9.0" in the Pen World Table repository https://www.rug.nl/ggdc/docs/human_capital_in_pwt_90.pdf. In 2019 the human capital index in China relative t the USA was 0.71, compared to 0.64 in 2000.

**Figure 2: Active Personnel and Price Deflators**

(i) Active Personnel (millions)




(ii) Quantity Indices 2000=1



Given the data on expenditure and personnel inputs it is straightforward to construct a unit-personnel cost index China's defence forces, by dividing the nominal personnel budget by the number of effective (skill adjusted) active personnel.[11] Because actual numbers have declined the implicit defense sector personnel unit cost index far exceeds the average inflation rate in the economy, as measured by the GDP deflator. Thus, real personnel growth in constant dollars, shown in Panel (ii) also declines and by construction exactly follows the trend real inputs in panel (i). [12] The implicit rapid growth in unit costs reflects growing salaries which are needed to match private sector wage growth due to labour productivity in Chinese manufacturing. [13]

Equipment expenditure is deflated using the implicit gross fixed investment (GFI) deflator, calculated as the ratio of nominal to real GFI from the World Bank (2023). The GFI price deflator has risen more slowly than the GDP deflator implying that real equipment spending has grown faster than the rate implied by using the GDP deflator. Operations spending is deflated using the GDP deflator as above.

Figure 2 panel (ii) then shows the relative growth of each of the defense spending components, indexed to 1 in 2000. While real personnel levels have declined, reflecting decline in (quality adjusted) personnel numbers, Operations and Equipment spending have grown rapidly in constant price terms. Real Equipment spending specifically grew at 10% per annum over 20 years. Over the last decade this growth has slowed slightly to 7.6%, but is clearly still very rapid.

Thus the available Chinese defence budget data show a rapid transformation and increase in capital intensity of China's armed forces. This structural change can be seen in Figure 3 which

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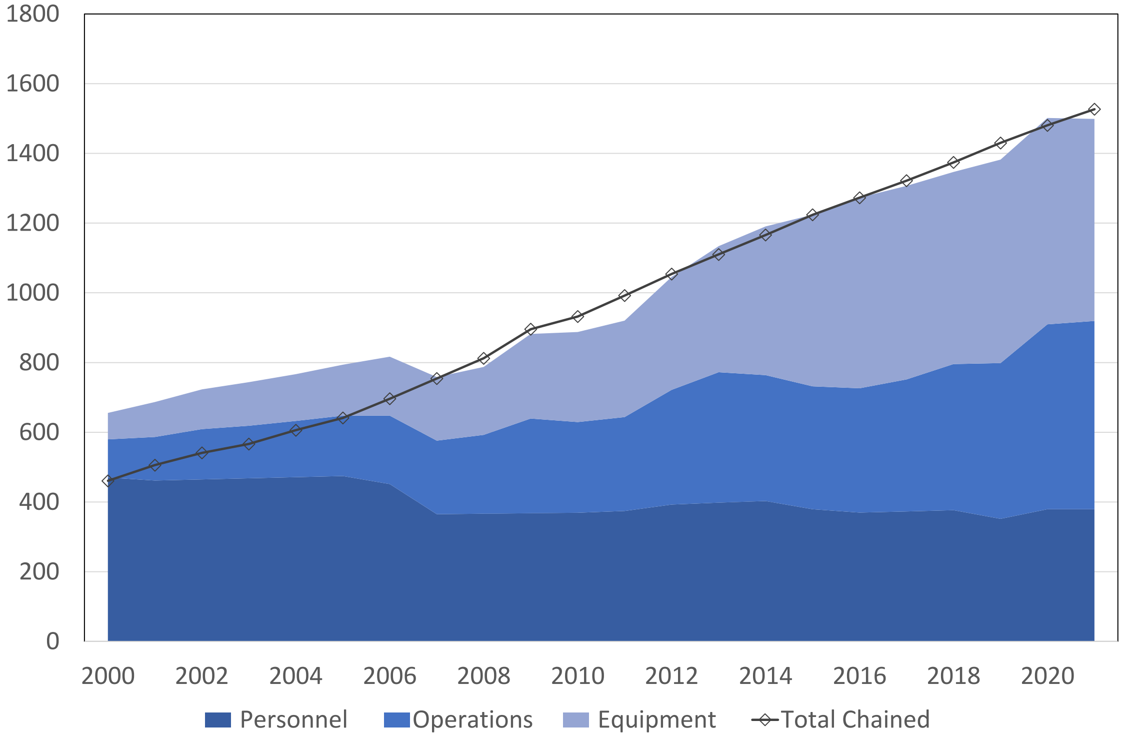
[11] If the personnel budget as reported to the UN includes any non-active personnel, then this is also included as part of the total unit cost per active personnel.

[12] Personnel costs rise at a little over 12 percent per annum, compared to the GDP deflator which only grows at 2 percent per annum. The data are shown in Table A3 in the Appendix.

[13] This is sometimes referred to Baumol's cost disease. See Robertson (2015) for a discussion.

adds up each real component in constant 2015 dollars. Comparing Figure 3 and Figure 1 shows that China's military rise has involved a large increase in equipment relative to personnel.[14]

**Figure 3: Real Chinese Military Spending (billions of RMB)**




Note: Components are in constant 2015 remninbi. The chained series uses a chain index to aggregate spending while mitigating substitution bias and is based in 2015 prices.

The implied constant price growth rate is just 4%, which is half the nominal growth deflated by the GDP deflator of 8.1% per annum.[15]

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[14] A simple growth decomposition attributes 60 % of the overall growth is due to Equipment growth and 40% due to Operations, with no growth in Personnel.

[15] The aggregate growth rate depends on the base year chosen – a result known as the "Gershenkron effect", after Gerschenkron (1947). For example a base year at the start of the sample period will give much less weight to personnel, and give more weight to equipment, since personnel costs were relatively low in earlier period. The Chain series mitigates this bias by updating the relative prices each period, while still representing the real quantity growth index of each component.

**Table 1: Real Military Expenditure Growth China (RMB Billion)**

| Year | GDP (current) | GDP constant prices | Mil Exp. current prices | Personnel constant 2015=100 | Operations constant prices | Equip. constant prices | Mil Exp. constant prices | Mil.Exp Fisher Chain index |
|---|---|---|---|---|---|---|---|---|
| 2000 | 10,028 | 17,251 | 184 | 470 | 109 | 76 | 656 | 461 |
| 2010 | 41,212 | 47,043 | 714 | 369 | 260 | 259 | 888 | 932 |
| 2021 | 114,367 | 98,406 | 1,893 | 379 | 540 | 580 | 1,499 | 1,527 |
| Growth 2000-21 | 12.3 | 8.6 | 11.7 | -1.0 | 7.9 | 10.2 | 4.0 | 5.9 |
| Growth 2010-21 | 9.7 | 6.9 | 9.3 | 0.2 | 6.9 | 7.6 | 4.9 | 4.6 |

**Table 2: Real Military Expenditure Growth USA ($US Billion)**

| Year | GDP (current) | GDP constant 2015=100 | Mil Exp. current | Personnel constant 2015=100 | Operations constant 2015=100 | Equip. constant 2015=100 | Mil Exp. constant 2015=100 | Mil.Exp Fisher Chain index |
|---|---|---|---|---|---|---|---|---|
| 2000 | 10,251 | 13,754 | 320 | 247 | 163 | 73 | 484 | 523 |
| 2010 | 15,049 | 16,383 | 738 | 273 | 371 | 191 | 836 | 662 |
| 2021 | 23,315 | 20,529 | 801 | 240 | 318 | 172 | 730 | 707 |
| Growth 2000-21 | 4.0 | 1.9 | 4.5 | -0.1 | 3.2 | 4.1 | 2.0 | 1.5 |
| Growth 2010-21 | 4.1 | 2.1 | 0.7 | -1.2 | -1.4 | -0.9 | -1.2 | 0.6 |

To mitigate substitution bias implicit in constant price indices, Figure 3 and Table 1 also show the growth rate of total military spending using a Fisher chain volume index which gives a growth rate of 6% per annum. This slower real overall growth simply reflects the fact that personnel numbers have declined.

For reference, we can compare this growth with the USA, as shown in Table 2. Over the period 2000-2001, the US real defence budget in constant 2015 dollars grew at 2% per annum, or 15% in the Fisher chained series. [16] USA real military equipment spending also grew much faster than the overall real defense budget at 4.1 percent per annum. Nevertheless, this real equipment expansion growth was still far slower than China's 10.2% growth rate.

Over the last decade 2010-21 in particular, real equipment spending fell in the USA by -0.9% while China's equipment spending grew at 7.6 percent – so China's real military equipment procurement has been growing at 8.6 percent per annum faster than the USA.

Thus the growth of China's military growth over 20 years is characterized by structural change, with declining personnel numbers and a massive increase in equipment. This pattern is very different from the picture of even nominal growths rates across each category, and constant expenditure shares. In particular it is consistent with descriptive accounts such as Allison and Glick Unterman (2021) and the US Department of Defence (2023) that emphasise China's military modernization.

# 3. China's Defence Spending Relative to the USA

In order to compare China's defence budget with the USA, we need to know what level of real inputs of defence the Chinese defence budget procures – its purchasing power. This can then be expressed in US dollars in order to compare with the USA and compare the real budget. By far the most common approach to comparing defence budgets, however, is to convert China's

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[16] For comparison the real growth of the US defence budget deflated using the National Defense Implicit Price Deflator (Federal Reserve Bank of St Louis 2023), grew at 2.2 percent per annum over 2000-2021 and declined at 0.8% per annum from 2010-2021.

spending in renminbi into US dollars using market exchange rates. Market exchange rates, however, tell us “how much you get” when you exchange your currency. This will not necessarily be equivalent to “how much is needed” to buy the same bundle of goods in two countries.

Conceptually to compare spending levels across countries we need a defence-sector, or military purchasing-power parity (PPP) exchange that indicates the relative unit costs of defence in each country (Brzoska 1995, Robertson, 2022).[17] Dividing the ratio of country’s defence budgets, in local currency, by the PPP exchange rate or unit defence cost ratio, gives a relative quantity index of real defence inputs in each country.[18]

As noted previously, no statistical agencies produce defence purchasing power numbers and the concept is not widely used in defence policy circles. Previous studies that have military purchasing-power concepts include Heston and Aten (1993), Gilboy and Heginbotham (2012), Robertson and Sin (2017), Bartels (2020) and Robertson (2022). Most of these studies are now quite dated. For example, Robertson and Sin (2017) only consider data for to 2000 and 2010, while Heston and Aten (1993) is even older and looked at data for the 1980’s. Robertson (2022) is more recent but focuses on just a single year across many countries. Furthermore, none of these studies has considered how the components of the budget in PPP terms have changed over time.

3.1 *Comparing Spending Components.*

The importance of allowing for price differences across countries is highlighted by considering personnel costs in China. Converting the Chinese military personnel budget using the market exchange rate gives a figure in US dollars that is only 40% of the USA’s personnel budget. But we know that total active military personnel in China was 2.70 million in 2021 compared to 1.39

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[17] Conceptually a PPP exchange rate is simply the ratio of nominal unit costs of a given good or service across two countries. The GDP-PPP exchange rate is the ratio of the nominal price of GDP in two countries, where GDP is a aggregate of all goods and services.

[18] Market exchange rates will provide an approximate purchasing power parity for traded goods, since in a free market, through arbitrage in traded goods. But they will generally not equate the price of labour and non-traded goods (Summers et al). A GDP- purchasing power exchange rate will typically be better than the market exchange rate as it takes into account local price differences. But these focus on economy-wide price averages.

million in the USA (World Bank 2022). Clearly the market exchange rate is not telling us how many $US dollars are needed to support an army the size of China's.

The difference arises because market exchange rates tend to reflect the average price ratio across countries of traded goods, such iron ore and consumer goods, and not the relative cost of labour.[19] For example, at market exchange rates, the base pay for a truck driver is five times higher in the USA than China than the USA. The salary is RMB 54,480 which converts to $US 7,800 – far smaller than USA salaries, that start at $US40,000.[20] This means that, on average, an employer only needs 1/5th of the market exchange rate (1.39 renminbi per dollar rather than around six or seven renminbi per dollar) to employ the same number of truck drivers in China as USA. Across the whole economy, labour incomes in China, for labour of similar skill levels, are approximately 1/5th of the USA.[21]

Consequently, when comparing the purchasing power of the defence personnel budgets, we need to compare the cost of employing a similarly skilled service person in each country – a point reiterated by US Joint Chiefs of Staff Chair, General Mark Milley (Milley 2018, Tirpek 2021).

In fact, however, we already know the purchasing power of the defence personnel budget, at least approximately, using data on personnel inputs. China has 2.70 million active military personnel

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[19] This is known as the "Penn effect" or the "Balassa-Samuelson effect". See Robertson 2022 for further discussion

[20] An entry salary for a truck driver in the USA is $40,000 but may rise to $89,855 per year, https://www.indeed.com/cmp/USA-Truck/salaries?job_category=driver. Likewise a truck driver in China earns between RMB 54,480 ($US 7,886) and RMB 164,400 ($US23,797) per year, http://www.salaryexplorer.com/salary-survey.php?loc=44&loctype=1&job=239&jobtype=3. Hence, at market exchange rates, truck driver in the USA earns 3.8 to 5 times more than those in China.

[21] This is based on the Penn World Table. The average income received by labour in China in 2019 was RMB 72,720 which, at 2019 current market exchange rates of 6.9 RMB per dollar, is equal to $US10,526. The average labour income in the USA in 2019 was $US80,844. Hence USA labour incomes are "7.7 times higher". This doesn't quite compare like-with-like however, since skill levels differ. Skill levels in China's civilian labour force were 64% as skilled as the USA labour force in 2000, rising to 72% of skill levels in the USA in 2021, based on years of schooling in the labour force from the Penn World Table. Thus, when adjusted for skill differences, labour earnings in the USA are 5.5 times higher than China.

compared to 1.39 million in the USA. Adjusting for the fact that the USA labour force is more skilled on average, gives a skill adjusted number of 1.94 million in 2021. [22]

Accepting these personnel numbers as reasonable estimates of relative personnel inputs, and dividing the personnel budget (which includes active and non-active military personnel) by the number of active military personnel, gives the total personnel cost per active-duty personnel member of 1.62 renminbi per dollar in 2021, which is 3.98 times lower than the market exchange rate.

Hence for 2021, the personnel budget for China in PPP terms is 3.98 times larger than the exchange rate value of $87 billion, or $356 billion in current $US. [23] This number is reassuringly close to the civilian wage gap.

Table 3 summarises these data for all years 2000-2021. The unit-cost of personnel in the USA military was $US178,000 per active-duty personnel member in 2021.[24] For China the average unit cost of (adjusted) personnel is RMB 289 billion. The implicit PPP exchange rate for personnel in 2021 is thus 289/178 = 1.62 renminbi per dollar, and by construction it means that

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[22] Note that there is no adjustment for things like combat experience and morale. Here we are only trying to make the first step of evaluating the comparative size of each countries armed forces relative to its costs. Since moral and experience don't influence the current year budget they are not relevant to what we want to compare which is the real the size of relative force or real budget. There are many other non-budget factors that will affect performance but not cost, but the analysis here is limited to real inputs and costs, not outputs and productivity. These non-budget factors are a topic for defense specialists to consider and is beyond the scope of a comparison real expenditure.

[23] An alternative way to think of this is that China's personnel budget, if measured at the same prices as the USA, should be equal to the difference in size. Since China's effective personnel numbers are 1.4 times larger than the USA (1.94/1.39=1.4), this means it personnel budget in PPP terms must also be 1.4 times larger than the USA which by construction equates to $US 356 billion.

[24] Kapp and Torreon (2020) reported USA spending $100,000-$110,000 per year as the cost of an average active duty serviceperson, which includes cash, benefits, and contributions to retirement programs, as a conservative estimate. The Figure of $US160,000 – 180,000 however includes all salaries in the personnel budget including some reserves and civilians that appear on the Department of Defence budget, which explains why it is higher than the Kapp and Torreon (2020) figure.

the US dollar value of China's personnel budget is 1.4 times larger than the USA. [25] This value is similar to other studies such as Bartels (2022) and Allison and Glick-Unterman (2021) who likewise try to compare the cost of military personnel and the USA, as well as Robertson and Sin (2017) and Robertson (2022).

Comparing the number of active-duty personnel is obviously an imperfect measure of "personnel inputs", there is room for debate about comparative skills and training, and careful documentation by defence experts could likely make significant improvements. The data here nevertheless provide a starting point for a more detailed analysis and appear to be the only publicly available data we have of overall personnel strength.[26] If these personnel headcount numbers are even approximately correct, then they that illustrate that China's real personnel budget, when compared using the same prices, cannot be a fraction of the USA, as implied by a market exchange rates.

Next I consider the relative costs of Equipment and Operations. We don't have any direct observations of quantities so we need some evidence of relative price levels. I use the World Bank's International Comparisons Project data on civilian equipment prices in China versus the USA as an approximate difference in military equipment prices (World Bank 2020). The ICP provide this data for three years, 2005, 2011 and 2017. To compute prices for intermediate years

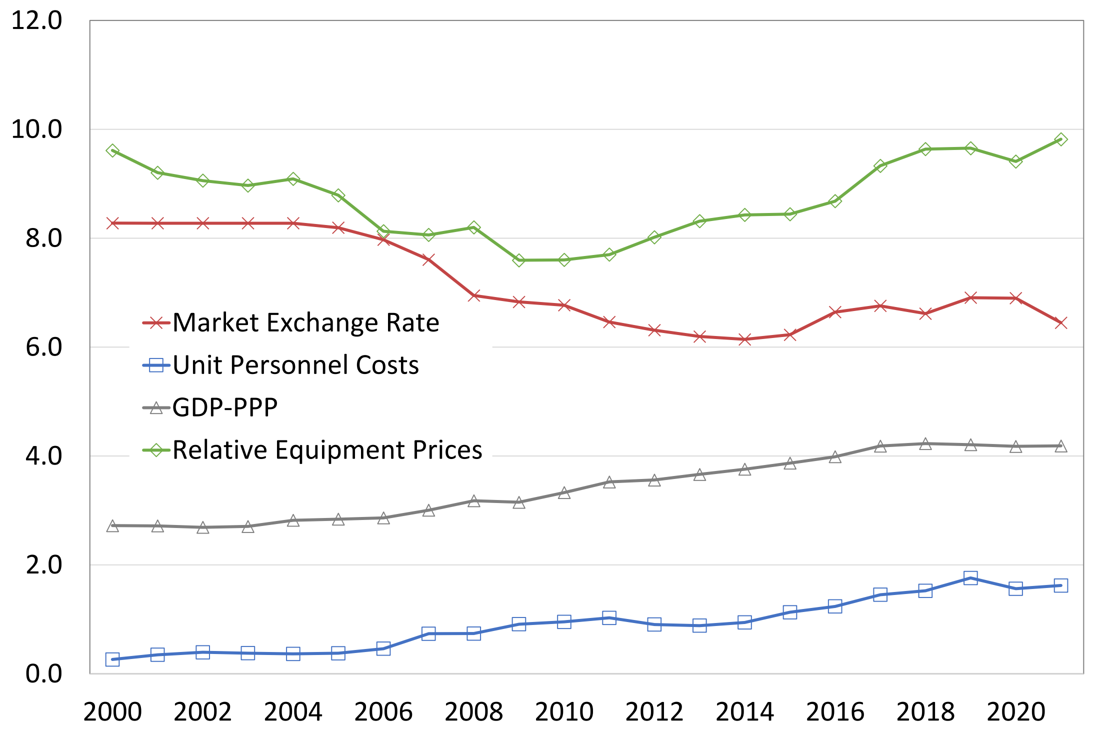
[25] We rely on the IISS estimates of "active personnel" in each country to compare numbers of personnel but the USA has a large number of civilian personnel, whereas the PLA has very few. Hence there is room to revise these estimates as better quality data comes to light. Bartels compares government sector wages in China versus the USA to estimate the price difference and Allison and Glick-Unterman (2021) compare the unit cost of personnel in the UDA, estimated to be $100-110k per annum, with a derived value for China based on the UN budget data and estimated number of reservists and the relative pay of reservists and regular soldiers, which they estimate to be around $24 000, thus obtaining what they describe as a conservative estimate that the USA pays around 4 time as much. Both Bartels and Allison and Glick-Unterman (2021) thus derive numbers that imply USA army personnel receive around 4-6 times PLA.

[26] In principle it would be better to break it down by service and distinct roles, such as soldiers, engineers pilots etc. One would then need estimates of the relative salary differences across roles and across countries. Such analysis may well be within the resource capabilities of Government Defence departments and organizations such as RAND or NATO.

I use the growth rates of the implicit investment price deflator for China from the World Bank WDI (World Bank 2023). These series are spliced together to give a relative price of equipment over time to convert Chinese defence equipment spending into US dollars in terms of purchasing power.

Finally, I use the GDP-PPP exchange rate from the Penn World Table as the exchange rate for Operations. This is far from ideal, but since Operations is a mix of traded and non-traded goods and services, such as personal services, maintenance services, storage, transport services, fuels etc, it's likely that the GDP-PPP exchange rate is preferable than the market exchange rate.

**Figure 4: Exchange Rates and Price Ratios (Renmibi per Dollar)**




The resulting "PPP exchange rates", for Personnel, Equipment and Operations, are shown in Figure 4. It can be seen that the exchange rate for Personnel – i.e. the ratio of local currency unit personnel costs – is far lower than the market exchange rate, reflecting the very low cost of labour in China relative to USA, as discussed above. It increased from 0.26 in 2000 to 1.6 RMB per dollar in 2021, reflecting massive wage growth in China over two decades. Nevertheless, since it is still well below the exchange rate it shows labour is still very cheap relative to the USA. Conversely the relative price of Equipment is higher than the market exchange rate, ranging between 9-10 renminbi per dollar.

We can use these specific price ratios, or PPP exchange rates, to deflate the nominal spending ratios in each category into real relative quantity indices – and thus obtain the relative real purchasing power of each country's defence budget by each category of spending. The resulting real quantity indices for Personnel, Operations and Equipment are shown in Figure 5.

The quantity index for real Personnel inputs is simply the ratio of "effective" active personnel in each country. By construction it is also equal to ratio of nominal expenditure in each country divided by the implicit personnel unit cost ratio in Figure 4. Thus it shows the real quantity of China's personnel being 1.4 times larger than the USA in 2021, reflecting the adjusted headcount of active personnel.[27]

Using the GDP-PPP exchange rate the real quantity of Operations in China is 41% of the USA (compared to the market exchange rate value of 27%). Finally dividing the ratio of nominal spending in China relative to the USA, by the derived equipment price index, using ICP equipment prices for China, gives a real volume index for Equipment that suggests the real quantity ratio for Equipment in China is 37% of the USA. This is smaller than the ratio implied by market exchange rates (56% of the USA), since the Equipment price index is higher than the exchange rate.[28]

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[27] It should be noted that this input is only personnel costs. For example, it may include pensions and housing benefits but doesn't include the equipment that soldiers might carry.

[28] Whether this civilian price index is suitable for military equipment is again a debatable point and much could be done to improve this estate by measuring the relative costs of assets, as was done by the CIA to measure Russia's defence budget during the cold war, if detailed asset data and comparable US costs were obtained.

**Figure 5: Quatity Ratios For Defence Inputs - China/USA**

(i) Effective Personnel Index – China/USA

(ii) Equipment and Operations Indices – China/USA

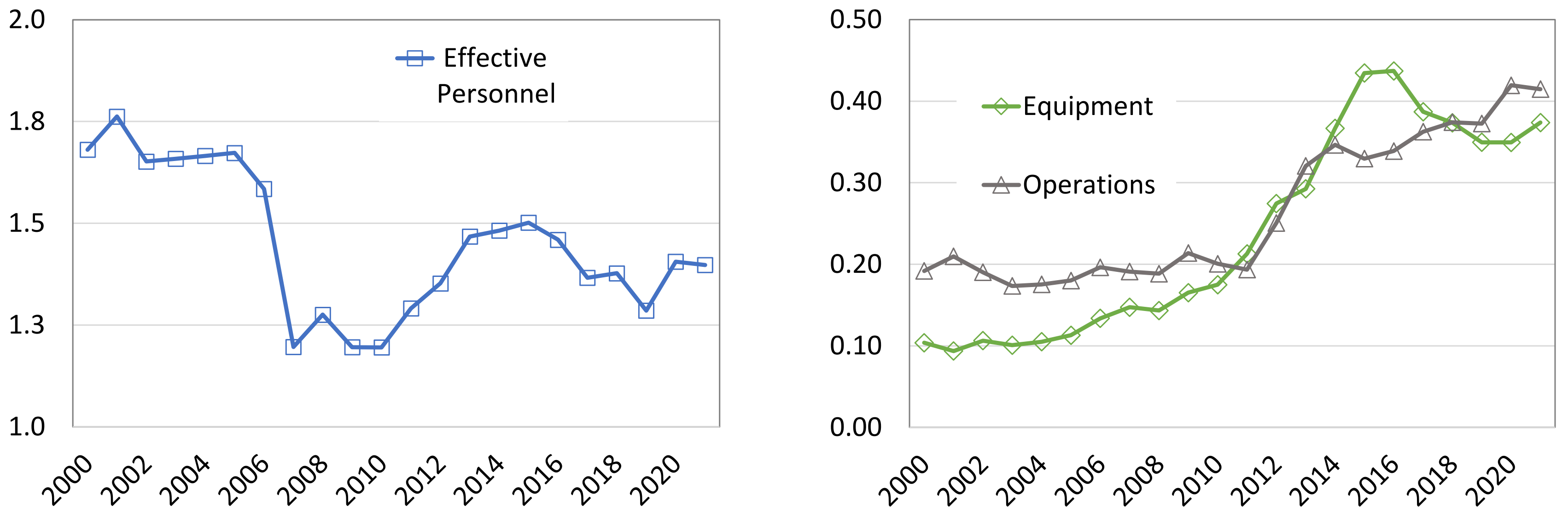


Figure 5 thus shows that China's defence budget purchasing power over Equipment and Operations are, respectively, the equivalent of 37% and 41% of the USA's budget. But in terms of military personnel buying power, China's defence budget procures 40% more than the USA. Thus China's defence forces are far more labour intensive than the USA.

The data thus show that China's strength relative to the USA is in numbers of personnel. In other aspects of military spending it is much smaller relative to the USA. This different composition may have operational implications. First it suggests that China's military has a comparative advantage in land based operations relative to air or maritime operations. Likewise however the difference in composition may simply reflect an incomplete modernization programme. Thus the PLA's labour intensity may also reflect legacy issues rather than a strategic choice. [29]

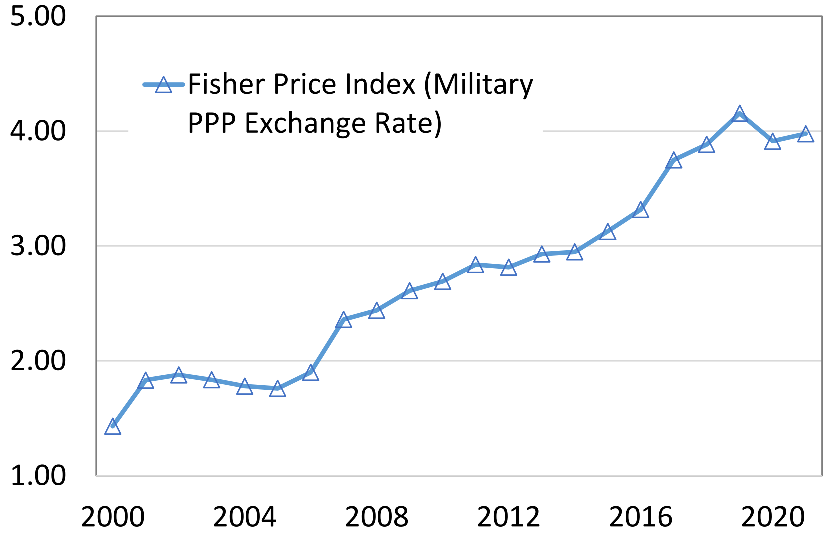
3.2 *Comparing Total Spending.*

While Figures 4 and 5 provide a clear view of the size of the components of China's defense sector relative to the USA, political and economic debate focuses on the overall figure. An overall index will be a weighted average of the three quantity indices in Figure 5. One way to do this is to evaluate China's defence sector inputs using US prices. This counterfactual value can be then compared with the overall US nominal budget an overall measure of China's defence purchasing power relative to the USA.

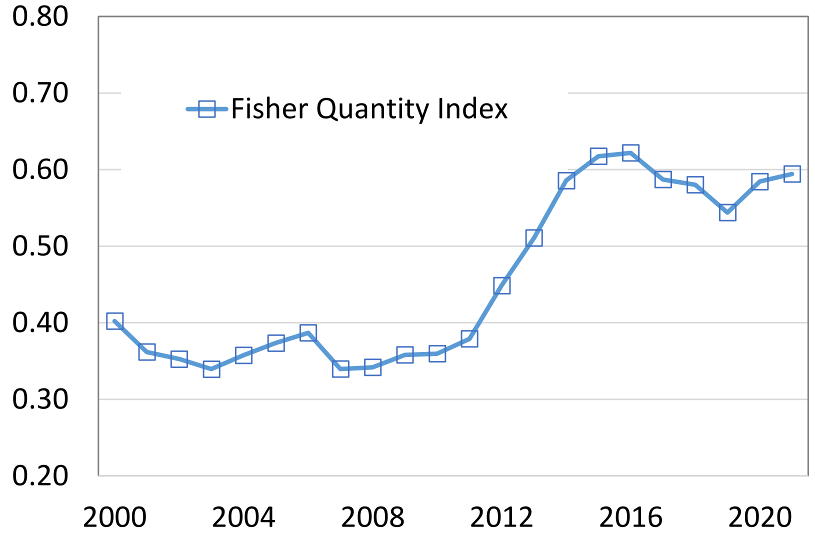
[29] As emphasised in Robertson (2022), all measures of military spending are only measures of inputs. Military power or capability also depends on the effectiveness in which the inputs can be brought together and factors such as morale, which may be independent of the inputs.

**Figure 6: China's Military Spending Relative to the USA**

(i) Fischer Military PPP Exchange Rate – renminbi per dollar




(ii) Real Military Spending Tornqvist Index – China / USA



Note, however, we can also compare USA and China's defence budgets by evaluating USA input quantities at Chinese prices, and comparing this with actual Chinese spending. The first approach is a *Laspeyres quantity index* of Chinese spending relative to the USA. It yields a dollar value China's defence budget equal to 70% of the USA (see Appendix 1). The second approach is a *Paasche quantity index* of China's defence budget, and this yields a very different value of China's overall defence budget, of just 40% of the USA.

This huge difference of 40% - 70% is an example of the "Paasche-Laspeyres spread", and reflects the "index number problem". It arises because the choice of base prices – US or Chinese – will affect how each quantity is weighted when they are summed to get the overall budget. Multiplying Chinese military personnel numbers by US personnel unit costs artificially inflates the comparative value of Chinese spending because, if China did face such high costs, they would spend less on personnel. Similarly evaluating US quantities at Chinese prices artificially inflates the USA budget relative to China.[30]

The standard solution to this index number problem is to use a superlative index number formula (ILO, et al 2004, Chap 15, 17, Diewert 2021). Using this approach we can create a weighted average of the prices in Figure 4 where the weights reflect an average of the cost shares in China and the USA. This relative aggregate price index can be interpreted as a military PPP exchange rate. Dividing the ratio of nominal spending in each country by the military–PPP exchange rate then gives the relative quantities of aggregate defence inputs in each country. [31]

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[30] These counterfactuals do not allow for substitution between inputs. This introduces upward bias in the Laspeyres index, since the counterfactual inflates the value of spending requires, and downward bias in the Paasche case since the counterfactual USA spending artificially inflates the base. Recent studies by Allison and Glick-Unterman (2021) and Bartels also consider total spending comparisons. However Allison and Glick-Unterman (2021) revert to GDP-PPP to compare the overall budget for 2017 with the USA while Bartels (2021) implicitly uses a Laspeyres quantity index.

[31] Alternatively, we can take an average of the relative quantity indices in Figure 5, where the relative input quantities and weighted by an average of each country's prices. This directly gives the relative size of each countries defence input bundle. By design, both approaches give the same answer so that dividing the ratio of

Figure 6, panel (i) shows the military–PPP exchange rate, using a Fisher index, which the geometric average of the Paasche and Laspeyres indices.[32] The military–PPP exchange rate has risen steeply reflecting the increase in personnel costs. It is much lower than the market exchange rate however and is very close to the GDP-PPP exchange rate.

Dividing the ratio of total spending in each country by the military–PPP exchange rate then gives the real relative quantity index in Figure 6 (ii). In 2021, China's defence budget is equivalent to 59% of USA, rising rapidly from 35% in 2010. Further details across all years are given in the Appendix table A3.

It can be seen that there was particularly rapid catch-up in the 5 year period 2011-2016. Figure 7 shows the same information expressed in US dollars. It converts the quantity index, in Figure 6 panel (ii), into current $US, by multiplying the quantity ratio by the USA current price defence spending. China's 2021 defence budget in PPP terms thus equates to $US 476 billion, compared to the market exchange rate value of $US 293 billion.

Comparing with the USA in this way shows that the rapid catch up over the period 2011-2016, in Figure 6, mostly reflects the dynamics of the USA budget, with the USA spending increasingly more as a fraction of GDP due to the Afghan war then declining as it withdrew troops. China's spending growth was fairly smooth over the whole two decades. Thus the combination of US demobilisation and continued rapid growth in China's budget, meant that the spending gap narrowed very quickly but the relative evel level has been fairly stable since about 2016 as the USA's spending recovered.

As noted above however, this aggregate figure mostly reflects China's enormous personnel budget, the composition of each defense sector is very different, with a far larger number of

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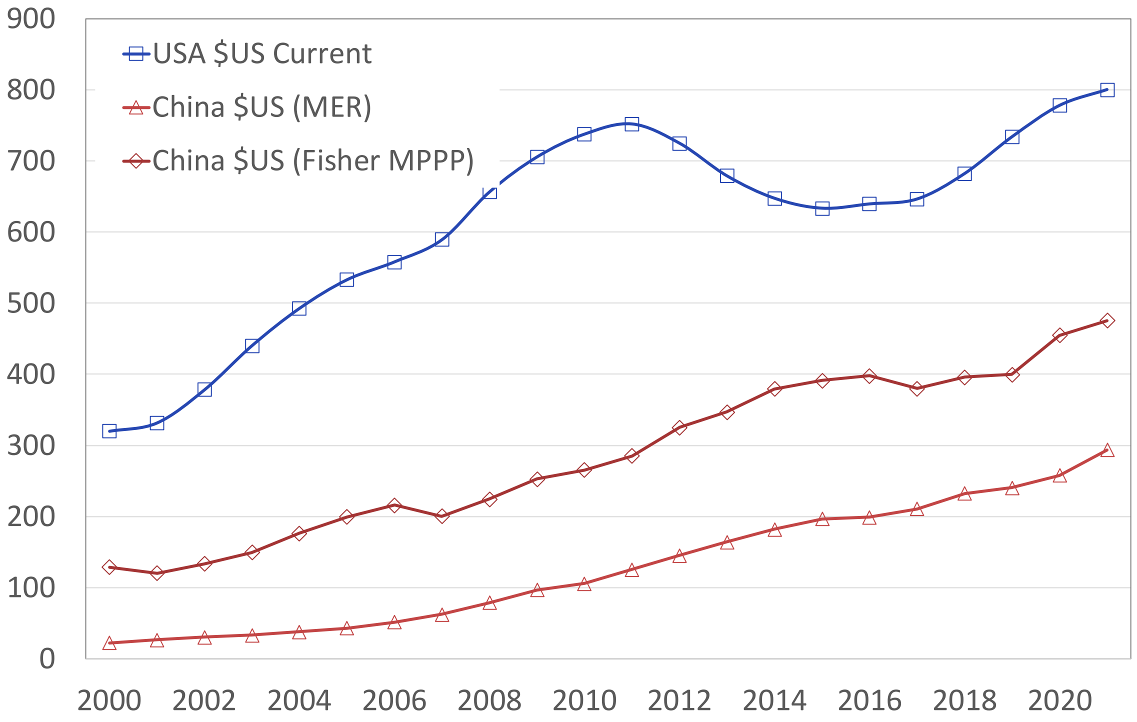
nominal spending by the quantity ratio will give the military purchasing power exchange rate (ILO, et al 2004, Chapter 15, pp.264-265).

[32] The results for Tornqvist, Fisher and Walsh indices are compared in Figure A2 in the appendix. As can be seen there is very little difference between these three approaches.

personnel but also a level of real equipment spending that is still only 37% of the USA.[33] In particular Operations spending has been growing rapidly relative to the USA since 2016 (see panel (ii) Figure 5). Moreover all of the absolute catch-up shown in Figure 7 is driven by increased Equipment and Operations spending.

**Figure7: Chinese and US Military Relative Spending 2000-2021 ($US billions)**




Finally much of China's spending in both Operations and Equipment may well also be "off-the-books", particularly through civil-military fusion in R&D. This indicates the ongoing need for greater transparency and better quality primary data (Allison and Glick-Unterman, 2021 Eaglan 2023).

[33] Similarly, if we compare shares of spending at the common military PPP prices, China's personnel budget accounts for 45% of overall spending compared to 19% in the USA's (See Appendix 2).

Thus, conditional on the data, a careful consideration of purchasing power and local price changes, shows that China's real defense budget in purchasing power terms is currently 60% larger than market exchange rate values and about 59% of the USA, or the equivalent of $US476 billion using SIPRI's definition. Spending levels have been catching up rapidly with the USA. If further "off-the-books" spending is added to the official defense budget, then the overall purchasing power will also be correspondingly larger, and if much of China's equipment spending is off-the-books, then the recent equipment growth figures may well also be understated.

# 7. Conclusion

Despite growing concerns over China's military build-up and suggestions of a new cold-war era, there have been few attempts to describe the growth of China's real defence spending or how the composition of China's defense sector has changed. Specifically, there have been no attempts in the literature to derive real estimates of China's real military growth over recent decades, or determine the extent to which China's defence budget has closed the gap with the USA.

Using standard index number techniques and applying this to the limited data available, I derive estimates of the China's real military growth relative to the USA. I find that, in 2021, China's real defence budget, in purchasing power terms, is 60% larger than exchange rate values. Using the SIPRI definition of defense spending this equates to 59% of the USA's defense budget compared to the market exchange rates value (36.6% of the USA). I also show that China's military is far more "labour intensive" than the USA, which may be important when assessing the operational implications China's large defence budget.

Looking at the data in real terms and over time, however, shows that the most notable feature of China's rise has been a massive increase in real equipment spending per person. It is this rise in equipment spending that accounts for almost all the growth in China's real defence spending. Real equipment spending has grown at double digit rates, averaging over 10% per annum since 2000. Likewise, it been rapidly catching up with the USA.

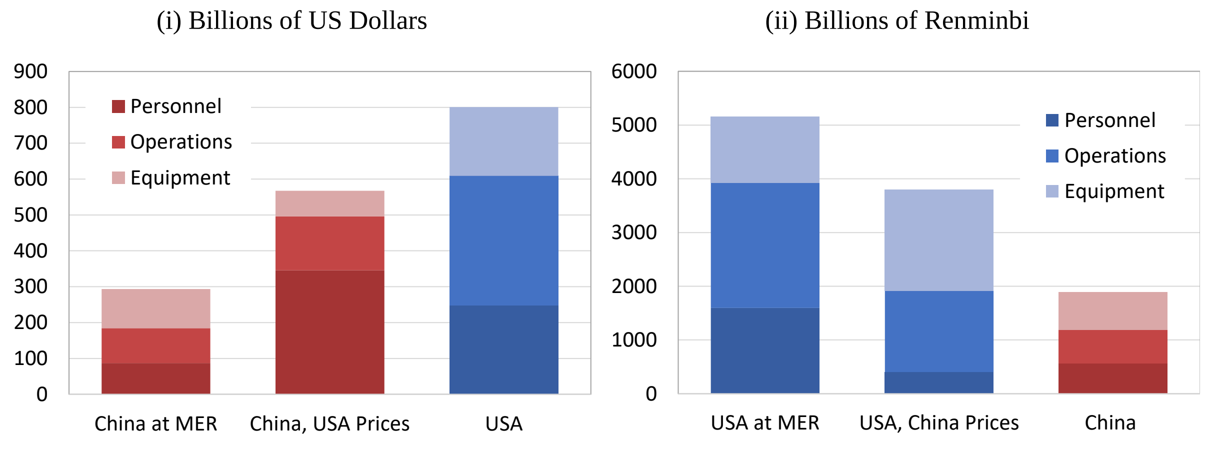
This is rapid growth in the equipment budget represents a massive increase in the capital intensity of China’s defense forces, which is consistent with descriptions of China’s military modernization. Thus, taking account of differing defense sector prices – across time and countries – reconciles the disconnect in the literature between narratives of China’s growth emphasising modernisation and advanced capabilities, and publicly available defense spending data that suggests China’s military is still very small relative to the USA.

# Appendix 1. The Paasche-Laspeyres Spread

Panel (i) of Figure A1 shows USA defense spending of $801 billion in 2021, by category, and Chinese spending measured at market exchange rates of $US 293 billion, which is 36% of the US figure. It also shows China's inputs of Operations, Equipment and Personnel evaluated at US prices, by converting each component of Chinese defence spending using the relevant price ratio in Figure 4. As noted above Chinese personnel expenditure alone, in US dollars, is valued at $US346 billion. This single input is larger than the market exchange rate value of China's overall defence budget.

Adding this to the value of operations spending ($US149.9b) and equipment spending (71.7b) gives China's total defence budget in US dollars of $US 568 billion, which is 71% of the USA defence budget and nearly double the market exchange rate figure. It can be seen that, when valued at USA prices, the size of the personnel budget is very large relative to other expenditure categories reflecting the relatively high wages in the USA.

**Figure A1: Laspeyres and Paascche**




As is well known from index number theory, however, this comparison is biased, since evaluating Chinese input quantities at US prices, doesn't allow for substitution toward lower cost inputs and so likely overstates the minimum expenditure necessary to procure the same level of defence services.[34] Thus the estimate that China's spending is likely to be an overestimate of China's real defence budget relative to the USA.

An equally valid approach is to compare US spending at Chinese prices, as shown in panel (ii). At market exchange rates the USA defence budget is estimated to be 3.8 trillion RMB in 2021. This estimate of USA spending in RMB is also biased however since it doesn't allow for substitution. In particular it can be seen that when we evaluate US quantities at Chinese prices the equipment part of the budget becomes proportionally larger since equipment is relatively expensive in China. Comparing this US counterfactual to China's actual expenditure in RMB of 1.89 trillion suggests China's real military budget is 49.9 percent of USA's. This is larger than the market exchange rate comparison, but it is less than the previous estimate which put Chinese spending at 71% of the USA.

This counterfactual value of spending for the USA – evaluating US quantities at Chinese prices – also overstates what would be needed to acquire a similar level of real defence services. Hence the 49% value likely understates the relative size of China's real defence budget.

These differences reflect the familiar Paasche-Laspreyres index number problem. In comparing China to the USA, the ratio of Chinese counterfactual spending to USA in panel (i) of 71% is a Laspeyres quantity index of China's military spending relative to the USA and the ratio of USA spending in renminbi with Chinese spending in panel (ii) of 49.9%, isa Paasche quantity index of China's military spending compared to the USA. These Lapeyres and Paasche indices suffer from substitution bias but can also be thought of as bounds on he likely range of values of China's real budget relative to China, subject to the data limitations. [35]

[34] The exception is if there is no substitution. If the iso-quant curves are Leontief then there is no bias.

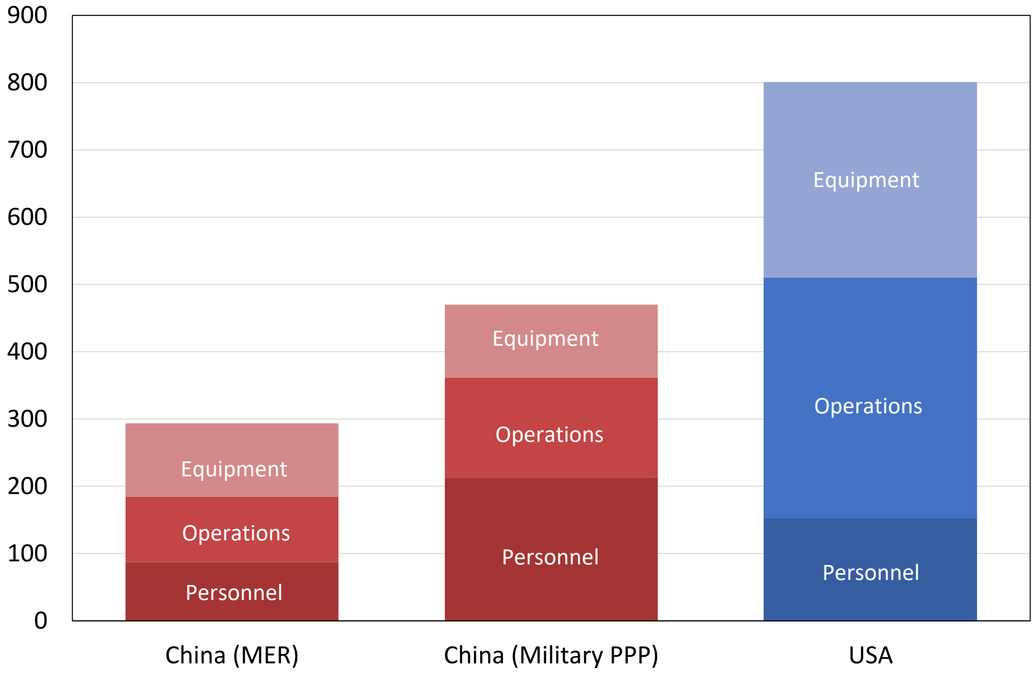
[35] Under the assumption that both China and the USA share the same homothetic production function for producing defense services, then these Paasche and Laspeyres measures of China's real budget relative to the USA define the bounds of the true volume ratio.

# Appendix 2. Relative Composition of Military Spending

It was noted in the text that while China's personnel inputs are far larger than the USA and overall spending s approximately 60% of the USA, the equipment budget in China is much smaller, at only 37% of the USA.

This labour intensity of China's defense budget can also be seen by decomposing total defense spending (at a common set of intermediate common prices) using a Walsh index. The Walsh index is an alternative to the Fisher or Tornqvist indies that allows a decompaction of total spending into budget shares implied by the implicit common set of intermediate prices at which we are comparing the two countries defense budgets. [36]

**Figure A2: China-USA Comparative Defence Budgets 2021 ($US billion)**

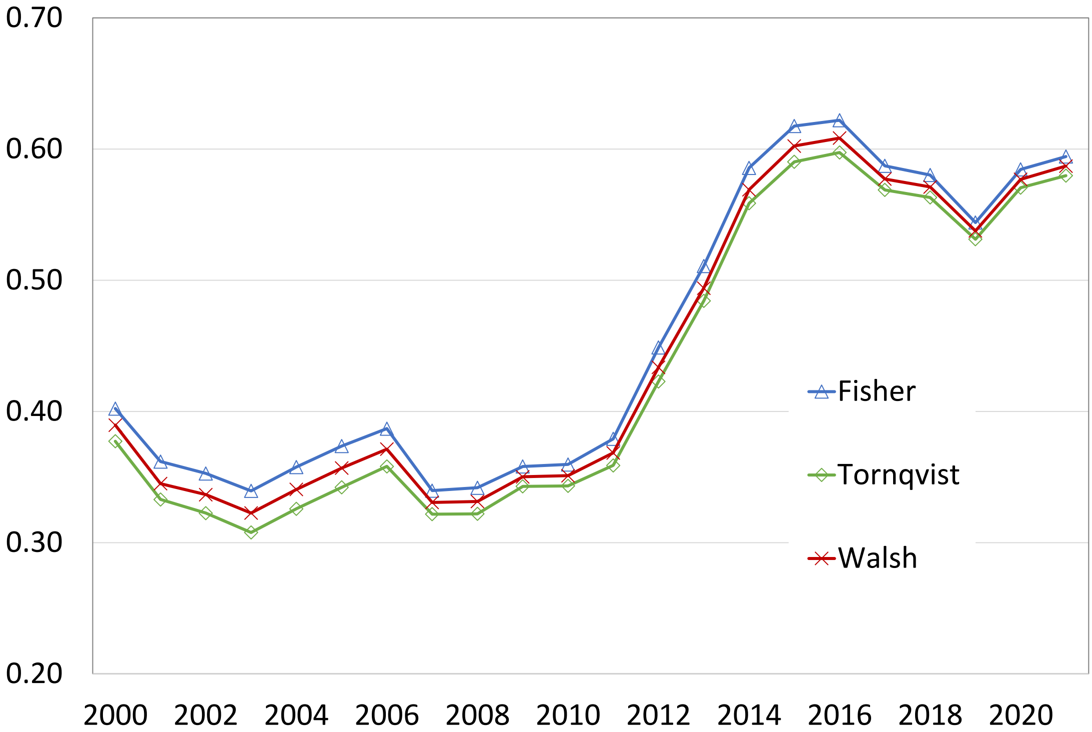



[36] Unlike the Fisher and Tornqvist indices, the Walsh index can be decomposed into price weighted contributions of each component, as in Figure 8 below. I am grateful to Robert Hill for suggesting the Walsh index in this context.

This decomposition is shown in Figure A2. Personnel costs account for 45% of the China's budget while the USA's personnel component at these common prices accounts for 19% of its budget. Similarly, while the USA's share of Equipment at a these common intermediate prices is 36% of expenditure, China's is only 23% of expenditure. The visual comparison clearly shows the different structure of the USA and Chinese defense budgets.

# Appendix 2. Alternative Index Number Volumes

**Figure A3: Alternative Estimates of China's Defence Budget Relative to the USA**



# Appendix Tables

**Table A1: China's Defence Sector Budget Shares**

| | Personnel | Operations and Research | Procurement | Notes on Source |
|---|---|---|---|---|
| 2000 | 0.334 | 0.345 | 0.321 | |
| 2001 | 0.320 | 0.337 | 0.343 | |
| 2002 | 0.319 | 0.343 | 0.338 | |
| 2003 | 0.325 | 0.336 | 0.339 | |
| 2004 | 0.332 | 0.336 | 0.333 | Interpolated |
| 2005 | 0.338 | 0.336 | 0.326 | |
| 2006 | 0.338 | 0.338 | 0.324 | |
| 2007 | 0.338 | 0.340 | 0.322 | |
| 2008 | 0.339 | 0.339 | 0.322 | Interpolated |
| 2009 | 0.340 | 0.337 | 0.322 | |
| 2010 | 0.349 | 0.319 | 0.332 | |
| 2011 | 0.343 | 0.315 | 0.342 | |
| 2012 | 0.292 | 0.348 | 0.360 | |
| 2013 | 0.270 | 0.364 | 0.366 | |
| 2014 | 0.286 | 0.323 | 0.391 | |
| 2015 | 0.310 | 0.288 | 0.402 | |
| 2016 | 0.313 | 0.274 | 0.413 | |
| 2017 | 0.308 | 0.281 | 0.411 | |
| 2018 | 0.304 | 0.298 | 0.398 | Interpolated |
| 2019 | 0.304 | 0.298 | 0.398 | Interpolated |
| 2020 | 0.297 | 0.332 | 0.372 | |
| 2021 | 0.297 | 0.332 | 0.372 | Assumed equal to 2020 |

Source UN (2022)

## Table A2: Nominal and Market Exchange Rate data

| | USA Defense Spending $US billion | | | | China Defence Spending RMB Billion | | | | | China Total | China/ USA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Personnel | Operations | Equipment | Total | Personnel | Operations | Equipment | Total | MER | MER $US b | MER |
| 2000 | 139.3 | 121.6 | 59.2 | 320.1 | 61.5 | 63.5 | 59.1 | 184.1 | 8.3 | 22.2 | 0.07 |
| 2001 | 114.3 | 130.0 | 87.5 | 331.8 | 70.4 | 74.1 | 75.4 | 219.9 | 8.3 | 26.6 | 0.08 |
| 2002 | 122.5 | 168.0 | 87.9 | 378.5 | 80.0 | 86.0 | 84.7 | 250.7 | 8.3 | 30.3 | 0.08 |
| 2003 | 141.4 | 196.2 | 102.9 | 440.5 | 89.2 | 92.2 | 93.0 | 274.3 | 8.3 | 33.1 | 0.08 |
| 2004 | 170.6 | 213.1 | 109.3 | 493.0 | 104.0 | 105.4 | 104.3 | 313.7 | 8.3 | 37.9 | 0.08 |
| 2005 | 187.8 | 230.3 | 115.1 | 533.2 | 118.5 | 117.8 | 114.3 | 350.6 | 8.2 | 42.8 | 0.08 |
| 2006 | 189.2 | 246.8 | 122.4 | 558.3 | 138.6 | 138.7 | 132.9 | 410.3 | 8.0 | 51.5 | 0.09 |
| 2007 | 181.2 | 280.3 | 128.1 | 589.6 | 159.6 | 160.9 | 152.2 | 472.7 | 7.6 | 62.1 | 0.11 |
| 2008 | 196.8 | 309.8 | 150.2 | 656.8 | 185.7 | 185.6 | 176.5 | 547.8 | 6.9 | 78.8 | 0.12 |
| 2009 | 206.2 | 330.3 | 169.5 | 705.9 | 224.6 | 222.6 | 212.7 | 659.9 | 6.8 | 96.6 | 0.14 |
| 2010 | 218.5 | 341.2 | 178.3 | 738.0 | 249.3 | 227.9 | 237.2 | 714.4 | 6.8 | 105.5 | 0.14 |
| 2011 | 209.4 | 374.0 | 169.0 | 752.3 | 277.7 | 255.0 | 276.9 | 809.5 | 6.5 | 125.3 | 0.17 |
| 2012 | 218.3 | 357.1 | 149.9 | 725.2 | 267.5 | 318.8 | 329.8 | 916.1 | 6.3 | 145.1 | 0.20 |
| 2013 | 211.2 | 315.0 | 153.0 | 679.2 | 274.5 | 370.0 | 372.1 | 1016.5 | 6.2 | 164.1 | 0.24 |
| 2014 | 228.8 | 277.5 | 141.5 | 647.8 | 320.0 | 361.4 | 437.4 | 1118.8 | 6.1 | 182.1 | 0.28 |
| 2015 | 223.4 | 276.3 | 134.1 | 633.8 | 379.4 | 352.5 | 492.0 | 1223.9 | 6.2 | 196.5 | 0.31 |
| 2016 | 228.6 | 267.6 | 143.7 | 639.9 | 413.3 | 361.8 | 545.3 | 1320.3 | 6.6 | 198.7 | 0.31 |
| 2017 | 220.8 | 263.9 | 162.0 | 646.8 | 438.2 | 400.4 | 585.3 | 1423.8 | 6.8 | 210.7 | 0.33 |
| 2018 | 222.7 | 289.7 | 170.1 | 682.5 | 467.7 | 458.5 | 612.3 | 1538.5 | 6.6 | 232.5 | 0.34 |
| 2019 | 223.0 | 315.5 | 195.8 | 734.3 | 504.7 | 494.7 | 660.8 | 1660.2 | 6.9 | 240.3 | 0.33 |
| 2020 | 240.3 | 336.8 | 201.4 | 778.4 | 528.0 | 590.4 | 662.1 | 1780.5 | 6.9 | 258.0 | 0.33 |
| 2021 | 247.5 | 361.3 | 191.8 | 800.7 | 561.3 | 627.6 | 703.9 | 1892.7 | 6.4 | 293.5 | 0.37 |

## Table A3: Unit Personnel Costs and Implicit Exchange Rate

| | Active Personnel (millions) | | Effective Skill Ratio | Personnel Expenditure | | Expenditure per effective person | | Implicit unit Cost Exch. Rate | China Personnel Expend. in PPP | USA Personnel Expend. in PPP | Personnel Quantity index |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | China | USA | China /USA | China (RMB billions) | USA (Dollars billions) | China | USA | RMB per Dollar | $US billion) | (RMB billion) | China /USA |
| 2000 | 3.90 | 1.50 | 0.65 | 61.5 | 139.3 | 24.4 | 92.8 | 0.263 | 234.1 | 36.6 | 1.68 |
| 2001 | 3.80 | 1.40 | 0.65 | 70.4 | 114.3 | 28.5 | 81.6 | 0.349 | 201.4 | 39.9 | 1.76 |
| 2002 | 3.80 | 1.50 | 0.65 | 80.0 | 122.5 | 32.3 | 81.7 | 0.395 | 202.4 | 48.4 | 1.65 |
| 2003 | 3.80 | 1.50 | 0.65 | 89.2 | 141.4 | 35.8 | 94.3 | 0.380 | 234.6 | 53.8 | 1.66 |
| 2004 | 3.80 | 1.50 | 0.66 | 104.0 | 170.6 | 41.6 | 113.7 | 0.366 | 284.2 | 62.4 | 1.67 |
| 2005 | 3.80 | 1.50 | 0.66 | 118.5 | 187.8 | 47.2 | 125.2 | 0.377 | 314.2 | 70.8 | 1.67 |
| 2006 | 3.60 | 1.50 | 0.66 | 138.6 | 189.2 | 58.3 | 126.1 | 0.462 | 299.7 | 87.5 | 1.58 |
| 2007 | 2.90 | 1.60 | 0.66 | 159.6 | 181.2 | 83.4 | 113.2 | 0.737 | 216.7 | 133.5 | 1.20 |
| 2008 | 2.90 | 1.50 | 0.66 | 185.7 | 196.8 | 97.1 | 131.2 | 0.740 | 251.0 | 145.6 | 1.28 |
| 2009 | 2.90 | 1.60 | 0.66 | 224.6 | 206.2 | 117.4 | 128.8 | 0.911 | 246.5 | 187.9 | 1.20 |
| 2010 | 2.90 | 1.60 | 0.66 | 249.3 | 218.5 | 130.4 | 136.5 | 0.955 | 261.1 | 208.6 | 1.20 |
| 2011 | 2.90 | 1.50 | 0.67 | 277.7 | 209.4 | 143.4 | 139.6 | 1.027 | 270.3 | 215.1 | 1.29 |
| 2012 | 3.00 | 1.50 | 0.68 | 267.5 | 218.3 | 131.9 | 145.5 | 0.906 | 295.2 | 197.8 | 1.35 |
| 2013 | 3.00 | 1.40 | 0.68 | 274.5 | 211.2 | 133.6 | 150.9 | 0.886 | 309.9 | 187.0 | 1.47 |
| 2014 | 3.00 | 1.40 | 0.69 | 320.0 | 228.8 | 154.2 | 163.4 | 0.944 | 339.0 | 215.9 | 1.48 |
| 2015 | 2.80 | 1.30 | 0.70 | 379.4 | 223.4 | 194.4 | 171.9 | 1.131 | 335.5 | 252.7 | 1.50 |
| 2016 | 2.70 | 1.30 | 0.70 | 413.3 | 228.6 | 217.8 | 175.9 | 1.239 | 333.7 | 283.1 | 1.46 |
| 2017 | 2.70 | 1.40 | 0.71 | 438.2 | 220.8 | 229.1 | 157.7 | 1.453 | 301.7 | 320.7 | 1.37 |
| 2018 | 2.70 | 1.40 | 0.71 | 467.7 | 222.7 | 242.6 | 159.1 | 1.525 | 306.7 | 339.6 | 1.38 |
| 2019 | 2.50 | 1.40 | 0.72 | 504.7 | 223.0 | 280.5 | 159.3 | 1.760 | 286.7 | 392.6 | 1.29 |
| 2020 | 2.70 | 1.38 | 0.72 | 528.0 | 240.3 | 272.2 | 174.1 | 1.563 | 337.8 | 375.6 | 1.41 |
| 2021 | 2.70 | 1.39 | 0.72 | 561.3 | 247.5 | 289.3 | 178.3 | 1.622 | 346.0 | 401.6 | 1.40 |

## Table A4: Input Prices and Military PPP Exchange Rates and Quantity Indices

| | Input Cost Ratios | | | Quantity Ratios | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit Personnel Costs | Operations (GDP-PPP price ratio) | Machinery and Equipment | Personnel Input Ratio | Operations Input ratio | Equipment Input Ratio | Fisher Price Index | Fisher quantity index | China $US Current MPPP-Fisher | USA Current $US | Törnqvist Quantity Index | Walsh Quantity Index |
| 2000 | 0.26 | 2.72 | 9.61 | 1.68 | 0.19 | 0.10 | 1.43 | 0.40 | 128.7 | 320.1 | 0.38 | 0.39 |
| 2001 | 0.35 | 2.72 | 9.20 | 1.76 | 0.21 | 0.09 | 1.83 | 0.36 | 120.1 | 331.8 | 0.33 | 0.34 |
| 2002 | 0.40 | 2.69 | 9.06 | 1.65 | 0.19 | 0.11 | 1.88 | 0.35 | 133.5 | 378.5 | 0.32 | 0.34 |
| 2003 | 0.38 | 2.71 | 8.97 | 1.66 | 0.17 | 0.10 | 1.83 | 0.34 | 149.5 | 440.5 | 0.31 | 0.32 |
| 2004 | 0.37 | 2.82 | 9.09 | 1.67 | 0.18 | 0.11 | 1.78 | 0.36 | 176.3 | 493.0 | 0.33 | 0.34 |
| 2005 | 0.38 | 2.84 | 8.79 | 1.67 | 0.18 | 0.11 | 1.76 | 0.37 | 199.2 | 533.2 | 0.34 | 0.36 |
| 2006 | 0.46 | 2.86 | 8.13 | 1.58 | 0.20 | 0.13 | 1.90 | 0.39 | 216.0 | 558.3 | 0.36 | 0.37 |
| 2007 | 0.74 | 3.01 | 8.06 | 1.20 | 0.19 | 0.15 | 2.36 | 0.34 | 200.3 | 589.6 | 0.32 | 0.33 |
| 2008 | 0.74 | 3.18 | 8.20 | 1.28 | 0.19 | 0.14 | 2.44 | 0.34 | 224.5 | 656.8 | 0.32 | 0.33 |
| 2009 | 0.91 | 3.15 | 7.60 | 1.20 | 0.21 | 0.17 | 2.61 | 0.36 | 252.8 | 705.9 | 0.34 | 0.35 |
| 2010 | 0.95 | 3.33 | 7.60 | 1.20 | 0.20 | 0.17 | 2.69 | 0.36 | 265.4 | 738.0 | 0.34 | 0.35 |
| 2011 | 1.03 | 3.52 | 7.70 | 1.29 | 0.19 | 0.21 | 2.84 | 0.38 | 285.2 | 752.3 | 0.36 | 0.37 |
| 2012 | 0.91 | 3.56 | 8.02 | 1.35 | 0.25 | 0.27 | 2.81 | 0.45 | 325.4 | 725.2 | 0.42 | 0.43 |
| 2013 | 0.89 | 3.66 | 8.32 | 1.47 | 0.32 | 0.29 | 2.93 | 0.51 | 347.0 | 679.2 | 0.48 | 0.49 |
| 2014 | 0.94 | 3.76 | 8.43 | 1.48 | 0.35 | 0.37 | 2.95 | 0.59 | 379.4 | 647.8 | 0.56 | 0.57 |
| 2015 | 1.13 | 3.87 | 8.44 | 1.50 | 0.33 | 0.43 | 3.13 | 0.62 | 391.5 | 633.8 | 0.59 | 0.60 |
| 2016 | 1.24 | 3.99 | 8.68 | 1.46 | 0.34 | 0.44 | 3.32 | 0.62 | 398.0 | 639.9 | 0.60 | 0.61 |
| 2017 | 1.45 | 4.18 | 9.33 | 1.37 | 0.36 | 0.39 | 3.75 | 0.59 | 379.8 | 646.8 | 0.57 | 0.58 |
| 2018 | 1.52 | 4.23 | 9.64 | 1.38 | 0.37 | 0.37 | 3.88 | 0.58 | 396.0 | 682.5 | 0.56 | 0.57 |
| 2019 | 1.76 | 4.21 | 9.65 | 1.29 | 0.37 | 0.35 | 4.16 | 0.54 | 399.5 | 734.3 | 0.53 | 0.54 |
| 2020 | 1.56 | 4.18 | 9.41 | 1.41 | 0.42 | 0.35 | 3.91 | 0.58 | 455.0 | 778.4 | 0.57 | 0.58 |
| 2021 | 1.62 | 4.19 | 9.82 | 1.40 | 0.41 | 0.37 | 3.98 | 0.59 | 475.9 | 800.7 | 0.58 | 0.59 |

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