PNAS
www.pnas.org

# Supplementary Information for

## Provincial and sector-level material footprints in China

Meng Jiang[a,1], Paul Behrens[b,c,1], Tao Wang[a,1], Zhipeng Tang[d], Yadong Yu[e], Dingjiang Chen[a,f], Lin Liu[a], Zijian Ren[a], Wenji Zhou[g,h], Shengjun Zhu[i], Canfei He[i], Arnold Tukker[b,j,2] and Bing Zhu[a,f,h,2]

[a]Department of Chemical Engineering, Tsinghua University, Beijing, 100084, China; [b]Institute of Environmental Sciences (CML), Leiden University, Einsteinweg 2, 2333 CC, Leiden, The Netherlands; [c]Leiden University College, Leiden University, The Hague, 2595 DG The Hague, The Netherlands; [d]Key Laboratory of Regional Sustainable Development Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; [e]School of Business, East China University of Science and Technology, Meilong Road 130, Shanghai, 200237, China; [f]Institute for Circular Economy, Tsinghua University, Beijing 100084, China; [g]Department of Manufacturing and Civil Engineering, Norwegian University of Science and Technology, Teknologivn 22, 2815 Gjøvik, Norway; [h]Energy Program, International Institute for Applied Systems Analysis, Schlossplatz 1, Laxenburg, A-2361, Austria; [i]College of Urban and Environmental Sciences, Peking University, Beijing, 100871, China; [j]Strategic Business Analysis, The Netherlands Organisation for Applied Scientific Research TNO, 2595 DA Den Haag, The Netherlands

[1]M.J., P.B. and T. W. contributed equally to this work.

[2]To whom correspondence should be addressed. Email: bingzhu@tsinghua.edu.cn or tukker@cml.leidenuniv.nl

**This PDF file includes:**

# Table of Contents

# 1. Additional results

## 1.1 Additional figures and tables

Table S1 Domestic extraction (DE) and material footprint (MF) of provinces and fraction of the MF that is covered (%Cov.) by DE, 2010 (million ton)

| Region | Prov | DE | MF | %Cov.* |
|---|---|---|---|---|
| **Northeast** | Liaoning | 774 | 949 | 82% |
| | Jilin | 500 | 666 | 75% |
| | Heilongjiang | 649 | 558 | 116% |
| **North Coast** | Beijing | 114 | 631 | 18% |
| | Tianjin | 121 | 419 | 29% |
| | Hebei | 1,790 | 946 | 189% |
| | Shandong | 1,785 | 1,686 | 106% |
| **East Coast** | Shanghai | 83 | 751 | 11% |
| | Jiangsu | 1,403 | 1,930 | 73% |
| | Zhejiang | 1,235 | 1,355 | 91% |
| **South Coast** | Fujian | 679 | 487 | 139% |
| | Guangdong | 1,208 | 1,507 | 80% |
| | Hainan | 161 | 198 | 81% |
| **Yellow River Midstream** | Shanxi | 1,180 | 525 | 225% |
| | Inner Mongolia | 1,570 | 697 | 225% |
| | Henan | 1,524 | 1,187 | 128% |
| | Shaanxi | 578 | 605 | 95% |
| **Yangtze River Midstream** | Anhui | 951 | 796 | 119% |
| | Jiangxi | 817 | 396 | 207% |
| | Hubei | 1,053 | 878 | 120% |
| | Hunan | 1,136 | 769 | 148% |
| **Southwest** | Guangxi | 850 | 839 | 101% |
| | Chongqing | 484 | 645 | 75% |
| | Sichuan | 1,610 | 1,334 | 121% |
| | Guizhou | 540 | 347 | 156% |
| | Yunnan | 899 | 802 | 112% |
| **Northwest** | Gansu | 607 | 592 | 103% |
| | Qinghai | 327 | 204 | 160% |
| | Ningxia | 161 | 191 | 84% |
| | Xinjiang | 458 | 371 | 124% |
| **China Total** | | **23,258** | **25,248** | **92%** |

*%Cov. = DE/MF.

The quotient of DE and MF shows which part of the footprint of consumption could be covered by the territorial extractions (DE) theoretically (1). %Cov. <1 shows the provinces have a positive Raw material Trade Balance (RTB), which indicates material

demand relies on out-of-the-territory to some extent. %Cov. >1 shows the provinces have a negative Raw material Trade Balance (RTB), which indicated its territory extraction supports external material demand (in the life cycle perspective).

Table S2 Material footprint of four main types of resources for 30 provinces/cities in China in 2010 (Gt).

| Region | Province | Biomass | Fossil | Metal | Nonmetal | MF |
|---|---|---|---|---|---|---|
| **Northeast** | Liaoning | 0.1 | 0.2 | 0.14 | 0.52 | 0.95 |
| | Jilin | 0.06 | 0.12 | 0.06 | 0.42 | 0.67 |
| | Heilongjiang | 0.08 | 0.1 | 0.05 | 0.32 | 0.56 |
| **North Coast** | Beijing | 0.08 | 0.13 | 0.06 | 0.36 | 0.63 |
| | Tianjin | 0.05 | 0.09 | 0.04 | 0.24 | 0.42 |
| | Hebei | 0.12 | 0.23 | 0.12 | 0.48 | 0.95 |
| | Shandong | 0.26 | 0.35 | 0.12 | 0.95 | 1.69 |
| **East Coast** | Shanghai | 0.14 | 0.16 | 0.06 | 0.4 | 0.75 |
| | Jiangsu | 0.17 | 0.35 | 0.15 | 1.25 | 1.93 |
| | Zhejiang | 0.13 | 0.23 | 0.15 | 0.85 | 1.36 |
| **South Coast** | Fujian | 0.06 | 0.07 | 0.05 | 0.3 | 0.49 |
| | Guangdong | 0.25 | 0.27 | 0.18 | 0.81 | 1.51 |
| | Hainan | 0.02 | 0 | 0.01 | 0.17 | 0.2 |
| **Yellow River Midstream** | Shanxi | 0.06 | 0.11 | 0.06 | 0.3 | 0.52 |
| | Inner Mongolia | 0.08 | 0.17 | 0.07 | 0.38 | 0.7 |
| | Henan | 0.21 | 0.21 | 0.08 | 0.69 | 1.19 |
| | Shaanxi | 0.08 | 0.16 | 0.04 | 0.33 | 0.61 |
| **Yangtze River Midstream** | Anhui | 0.08 | 0.14 | 0.06 | 0.52 | 0.8 |
| | Jiangxi | 0.06 | 0.05 | 0.04 | 0.24 | 0.4 |
| | Hubei | 0.1 | 0.09 | 0.04 | 0.65 | 0.88 |
| | Hunan | 0.09 | 0.11 | 0.04 | 0.52 | 0.77 |
| **Southwest** | Guangxi | 0.12 | 0.08 | 0.04 | 0.61 | 0.84 |
| | Chongqing | 0.05 | 0.07 | 0.02 | 0.5 | 0.64 |
| | Sichuan | 0.13 | 0.12 | 0.08 | 1 | 1.33 |
| | Guizhou | 0.05 | 0.04 | 0.02 | 0.24 | 0.35 |
| | Yunnan | 0.1 | 0.13 | 0.05 | 0.53 | 0.8 |
| **Northwest** | Gansu | 0.07 | 0.11 | 0.03 | 0.39 | 0.59 |
| | Qinghai | 0.04 | 0.03 | 0.01 | 0.13 | 0.2 |
| | Ningxia | 0.01 | 0.04 | 0.01 | 0.13 | 0.19 |
| | Xinjiang | 0.06 | 0.08 | 0.02 | 0.22 | 0.37 |
| China Total | | **2.89** | **4.05** | **1.88** | **14.45** | **23.26** |
| World Total | | **20.56** | **13.69** | **7.32** | **34.6** | **76.17** |

Table S3 Composition (sectoral) of the material footprint for 30 provinces/cities in 2010.

| Region | Province | Agriculture & Food* | Extraction & Mining | Manufacturing | Construction | Services |
|---|---|---|---|---|---|---|
| **Northeast** | Liaoning | 9% | 2% | 20% | 55% | 14% |
| | Jilin | 6% | 2% | 25% | 56% | 11% |
| | Heilongjiang | 13% | 6% | 22% | 39% | 20% |
| **North Coast** | Beijing | 7% | 2% | 6% | 39% | 46% |
| | Tianjin | 10% | 5% | 25% | 48% | 13% |
| | Hebei | 12% | 2% | 19% | 50% | 16% |
| | Shandong | 16% | 1% | 27% | 43% | 12% |
| **East Coast** | Shanghai | 16% | 4% | 22% | 39% | 20% |
| | Jiangsu | 6% | 2% | 26% | 50% | 17% |
| | Zhejiang | 6% | 3% | 18% | 58% | 15% |
| **South Coast** | Fujian | 11% | 3% | 15% | 55% | 17% |
| | Guangdong | 13% | 6% | 17% | 48% | 15% |
| | Hainan | 6% | 3% | 5% | 79% | 7% |
| **Yellow River Midstream** | Shanxi | 9% | 5% | 22% | 47% | 16% |
| | Inner Mongolia | 10% | 3% | 20% | 60% | 8% |
| | Henan | 13% | 1% | 38% | 30% | 18% |
| | Shaanxi | 12% | 4% | 24% | 43% | 16% |
| **Yangtze River Midstream** | Anhui | 9% | 2% | 11% | 59% | 20% |
| | Jiangxi | 16% | 3% | 14% | 55% | 12% |
| | Hubei | 12% | 2% | 18% | 56% | 12% |
| | Hunan | 13% | 2% | 18% | 55% | 13% |
| **Southwest** | Guangxi | 12% | 2% | 12% | 65% | 10% |
| | Chongqing | 8% | 1% | 15% | 64% | 13% |
| | Sichuan | 12% | 2% | 15% | 57% | 14% |
| | Guizhou | 13% | 3% | 13% | 55% | 16% |
| | Yunnan | 13% | 4% | 12% | 57% | 14% |
| **Northwest** | Gansu | 12% | 3% | 13% | 64% | 8% |
| | Qinghai | 19% | 4% | 9% | 52% | 16% |
| | Ningxia | 6% | 6% | 16% | 62% | 11% |
| | Xinjiang | 13% | 3% | 12% | 56% | 16% |

*Classification of sector aggregation is shown in Table S11

Table S4 Sector contribution to the material footprint for 30 provinces/cities in China in 2010 (ton/cap).

| Region | Province | MF/cap | Agriculture & Food* | Extraction & Mining | Manufacturing | Construction | Services |
|---|---|---|---|---|---|---|---|
| **Northeast** | Liaoning | 21.7 | 1.9 | 0.5 | 4.4 | 11.9 | 3 |
| | Jilin | 24.2 | 1.5 | 0.5 | 6.2 | 13.6 | 2.6 |
| | Heilongjiang | 14.6 | 1.9 | 0.8 | 3.2 | 5.7 | 2.9 |
| **North Coast** | Beijing | 32.2 | 2.1 | 0.7 | 1.9 | 12.6 | 14.9 |
| | Tianjin | 32.2 | 3.1 | 1.7 | 8.1 | 15.4 | 4 |
| | Hebei | 13.1 | 1.6 | 0.3 | 2.6 | 6.6 | 2.1 |
| | Shandong | 17.6 | 2.8 | 0.2 | 4.8 | 7.6 | 2.1 |
| **East Coast** | Shanghai | 32.6 | 5.3 | 1.1 | 7 | 12.8 | 6.4 |
| | Jiangsu | 24.5 | 1.6 | 0.4 | 6.3 | 12.2 | 4.1 |
| | Zhejiang | 24.9 | 1.5 | 0.8 | 4.4 | 14.5 | 3.7 |
| **South Coast** | Fujian | 13.2 | 1.4 | 0.4 | 1.9 | 7.2 | 2.2 |
| | Guangdong | 14.4 | 1.9 | 0.9 | 2.4 | 7 | 2.2 |
| | Hainan | 22.7 | 1.5 | 0.6 | 1.2 | 17.9 | 1.5 |
| **Yellow River Midstream** | Shanxi | 14.7 | 1.4 | 0.8 | 3.2 | 6.9 | 2.4 |
| | Inner Mongolia | 28.2 | 2.9 | 0.7 | 5.6 | 16.8 | 2.2 |
| | Henan | 12.6 | 1.6 | 0.2 | 4.8 | 3.8 | 2.3 |
| | Shaanxi | 16.2 | 2 | 0.7 | 3.9 | 6.9 | 2.6 |
| **Yangtze River Midstream** | Anhui | 13.4 | 1.2 | 0.2 | 1.4 | 7.8 | 2.7 |
| | Jiangxi | 8.9 | 1.4 | 0.3 | 1.3 | 4.9 | 1 |
| | Hubei | 15.3 | 1.8 | 0.3 | 2.7 | 8.5 | 1.9 |
| | Hunan | 11.7 | 1.5 | 0.2 | 2.1 | 6.5 | 1.5 |
| **Southwest** | Guangxi | 18.2 | 2.1 | 0.3 | 2.1 | 11.9 | 1.7 |
| | Chongqing | 22.3 | 1.8 | 0.2 | 3.3 | 14.2 | 2.8 |
| | Sichuan | 16.6 | 2 | 0.3 | 2.5 | 9.5 | 2.3 |
| | Guizhou | 10 | 1.3 | 0.3 | 1.3 | 5.5 | 1.6 |
| | Yunnan | 17.4 | 2.3 | 0.7 | 2.1 | 9.9 | 2.5 |
| **Northwest** | Gansu | 23.1 | 2.8 | 0.7 | 3 | 14.9 | 1.8 |
| | Qinghai | 36.2 | 6.9 | 1.5 | 3.2 | 19 | 5.7 |
| | Ningxia | 30.2 | 1.7 | 1.8 | 4.7 | 18.6 | 3.3 |
| | Xinjiang | 17 | 2.3 | 0.4 | 2.1 | 9.5 | 2.7 |

*Classification of sector aggregation is shown in Table S11

77 Table S5 Material footprint embodied in both domestic and international trade in 2010.

| Region | Province | Consumption driven MF (Mt) | Capital investment-driven MF (Mt) | Material intensity of consumption-driven MF (ton/thousand yuan) | Material intensity of capital investment driven MF (ton/thousand yuan) | Ratio of material intensity of capital investment to consumption-driven MF |
|---|---|---|---|---|---|---|
| **Northeast** | Liaoning | 235 | 714 | 0.31 | 0.62 | 2 |
| | Jilin | 130 | 536 | 0.35 | 0.75 | 2.14 |
| | Heilongjiang | 218 | 340 | 0.4 | 0.6 | 1.5 |
| **North Coast** | Beijing | 323 | 308 | 0.41 | 0.51 | 1.24 |
| | Tianjin | 111 | 307 | 0.32 | 0.44 | 1.38 |
| | Hebei | 313 | 633 | 0.38 | 0.57 | 1.5 |
| | Shandong | 553 | 1,133 | 0.36 | 0.53 | 1.47 |
| **East Coast** | Shanghai | 336 | 415 | 0.36 | 0.56 | 1.56 |
| | Jiangsu | 563 | 1,366 | 0.33 | 0.65 | 1.97 |
| | Zhejiang | 366 | 989 | 0.29 | 0.76 | 2.62 |
| **South Coast** | Fujian | 142 | 345 | 0.23 | 0.43 | 1.87 |
| | Guangdong | 532 | 974 | 0.25 | 0.54 | 2.16 |
| | Hainan | 28 | 169 | 0.29 | 1.43 | 4.93 |
| **Yellow River Midstream** | Shanxi | 144 | 381 | 0.36 | 0.6 | 1.67 |
| | Inner Mongolia | 144 | 554 | 0.31 | 0.61 | 1.97 |
| | Henan | 425 | 761 | 0.42 | 0.48 | 1.14 |
| | Shaanxi | 201 | 405 | 0.44 | 0.59 | 1.34 |
| **Yangtze River Midstream** | Anhui | 273 | 523 | 0.44 | 0.85 | 1.93 |
| | Jiangxi | 132 | 263 | 0.29 | 0.54 | 1.86 |
| | Hubei | 270 | 607 | 0.37 | 0.71 | 1.92 |
| | Hunan | 226 | 543 | 0.3 | 0.62 | 2.07 |
| **Southwest** | Guangxi | 178 | 661 | 0.37 | 0.84 | 2.27 |
| | Chongqing | 173 | 472 | 0.45 | 1.03 | 2.29 |
| | Sichuan | 385 | 949 | 0.45 | 1.03 | 2.29 |
| | Guizhou | 116 | 231 | 0.4 | 0.9 | 2.25 |
| | Yunnan | 228 | 574 | 0.53 | 1.03 | 1.94 |
| **Northwest** | Gansu | 179 | 413 | 0.73 | 1.76 | 2.41 |
| | Qinghai | 62 | 142 | 0.87 | 1.3 | 1.49 |
| | Ningxia | 40 | 151 | 0.48 | 0.97 | 2.02 |
| | Xinjiang | 120 | 251 | 0.42 | 0.75 | 1.79 |
| **Overall China** | | **7,145** | **16,112** | **0.36** | **0.66** | **1.83** |

78

Table S6 Consumption and capital investment-driven MF and material intensity in 2010.

| Region | Province | Consumption driven MF (Mt) | Capital investment-driven MF (Mt) | Material intensity of consumption-driven MF (ton/thousand yuan) | Material intensity of capital investment driven MF (ton/thousand yuan) | Ratio of material intensity of capital investment to consumption-driven MF |
|---|---|---|---|---|---|---|
| **Northeast** | Liaoning | 235 | 714 | 0.31 | 0.62 | 2.00 |
| | Jilin | 130 | 536 | 0.35 | 0.75 | 2.14 |
| | Heilongjiang | 218 | 340 | 0.4 | 0.60 | 1.50 |
| **North Coast** | Beijing | 323 | 308 | 0.41 | 0.51 | 1.24 |
| | Tianjin | 111 | 307 | 0.32 | 0.44 | 1.38 |
| | Hebei | 313 | 633 | 0.38 | 0.57 | 1.50 |
| | Shandong | 553 | 1,133 | 0.36 | 0.53 | 1.47 |
| **East Coast** | Shanghai | 336 | 415 | 0.36 | 0.56 | 1.56 |
| | Jiangsu | 563 | 1,366 | 0.33 | 0.65 | 1.97 |
| | Zhejiang | 366 | 989 | 0.29 | 0.76 | 2.62 |
| **South Coast** | Fujian | 142 | 345 | 0.23 | 0.43 | 1.87 |
| | Guangdong | 532 | 974 | 0.25 | 0.54 | 2.16 |
| | Hainan | 28 | 169 | 0.29 | 1.43 | 4.93 |
| **Yellow River Midstream** | Shanxi | 144 | 381 | 0.36 | 0.60 | 1.67 |
| | Inner Mongolia | 144 | 554 | 0.31 | 0.61 | 1.97 |
| | Henan | 425 | 761 | 0.42 | 0.48 | 1.14 |
| | Shaanxi | 201 | 405 | 0.44 | 0.59 | 1.34 |
| **Yangtze River Midstream** | Anhui | 273 | 523 | 0.44 | 0.85 | 1.93 |
| | Jiangxi | 132 | 263 | 0.29 | 0.54 | 1.86 |
| | Hubei | 270 | 607 | 0.37 | 0.71 | 1.92 |
| | Hunan | 226 | 543 | 0.3 | 0.62 | 2.07 |
| **Southwest** | Guangxi | 178 | 661 | 0.37 | 0.84 | 2.27 |
| | Chongqing | 173 | 472 | 0.45 | 1.03 | 2.29 |
| | Sichuan | 385 | 949 | 0.45 | 1.03 | 2.29 |
| | Guizhou | 116 | 231 | 0.4 | 0.90 | 2.25 |
| | Yunnan | 228 | 574 | 0.53 | 1.03 | 1.94 |
| **Northwest** | Gansu | 179 | 413 | 0.73 | 1.76 | 2.41 |
| | Qinghai | 62 | 142 | 0.87 | 1.30 | 1.49 |
| | Ningxia | 40 | 151 | 0.48 | 0.97 | 2.02 |
| | Xinjiang | 120 | 251 | 0.42 | 0.75 | 1.79 |
| **Overall China** | | **7,145** | **16,112** | **0.36** | **0.66** | **1.83** |

Table S7 Composition (sources) of the material footprint for 30 provinces/cities in 2010.

| Region | Prov | Local supply | Inter-Prov_Imports | Intl_Imports |
|---|---|---|---|---|
| **Northeast** | Liaoning | 0.40 | 0.42 | 0.14 |
| | Jilin | 0.21 | 0.40 | 0.06 |
| | Heilongjiang | 0.28 | 0.22 | 0.06 |
| **North Coast** | Beijing | 0.05 | 0.49 | 0.09 |
| | Tianjin | 0.03 | 0.33 | 0.05 |
| | Hebei | 0.44 | 0.45 | 0.06 |
| | Shandong | 0.95 | 0.40 | 0.33 |
| **East Coast** | Shanghai | 0.00 | 0.60 | 0.15 |
| | Jiangsu | 0.50 | 1.11 | 0.32 |
| | Zhejiang | 0.59 | 0.46 | 0.31 |
| **South Coast** | Fujian | 0.20 | 0.17 | 0.11 |
| | Guangdong | 0.46 | 0.58 | 0.47 |
| | Hainan | 0.14 | 0.05 | 0.01 |
| **Yellow River Midstream** | Shanxi | 0.33 | 0.16 | 0.03 |
| | Inner Mongolia | 0.35 | 0.30 | 0.04 |
| | Henan | 0.68 | 0.43 | 0.08 |
| | Shaanxi | 0.17 | 0.39 | 0.05 |
| **Yangtze River Midstream** | Anhui | 0.39 | 0.35 | 0.06 |
| | Jiangxi | 0.25 | 0.11 | 0.04 |
| | Hubei | 0.67 | 0.17 | 0.04 |
| | Hunan | 0.44 | 0.28 | 0.05 |
| **Southwest** | Guangxi | 0.47 | 0.31 | 0.06 |
| | Chongqing | 0.27 | 0.35 | 0.02 |
| | Sichuan | 1.00 | 0.30 | 0.04 |
| | Guizhou | 0.20 | 0.13 | 0.02 |
| | Yunnan | 0.56 | 0.20 | 0.04 |
| **Northwest** | Gansu | 0.41 | 0.17 | 0.02 |
| | Qinghai | 0.14 | 0.06 | 0.01 |
| | Ningxia | 0.08 | 0.10 | 0.01 |
| | Xinjiang | 0.19 | 0.15 | 0.03 |
| **Total** | | 10.84 | 9.62 | 2.80 |

84 Table S8 Net resource transfer embodied in trade in 2010 (thousand ton)

| Origin | Destination | Biomass | Fossil Fuels | Metal | Nonmetal |
|---|---|---|---|---|---|
| Northeast | Rest of the world | 2.51 | | | |
| Northeast | East Coast | 7.07 | 3.78 | | |
| Northeast | South Coast | 0.73 | 4.02 | | |
| Northeast | Northwest | 29.68 | 8.44 | | |
| Northeast | North Coast | 0.51 | | | |
| Northeast | Southwest | 3.67 | 7.80 | 1.53 | |
| Northeast | Yangtze river midstream | 34.33 | 20.06 | 7.89 | 4.92 |
| Northeast | Yellow river midstream | 7.39 | | | 101.35 |
| North Coast | Rest of the world | | | 5.47 | |
| North Coast | East Coast | | | 10.52 | |
| North Coast | Northeast | | 6.17 | 20.16 | |
| North Coast | South Coast | | | 29.55 | 0.81 |
| North Coast | Yellow river midstream | 5.52 | 9.39 | 11.42 | 3.59 |
| North Coast | Yangtze river midstream | | | 28.28 | 77.06 |
| North Coast | Southwest | 45.99 | 38.44 | 77.41 | 132.59 |
| North Coast | Northwest | | | 6.08 | 442.31 |
| East Coast | Rest of the world | | | | 854.43 |
| South Coast | Rest of the world | | | | 2.94 |
| South Coast | East Coast | 2.73 | 1.54 | 3.83 | 77.86 |
| South Coast | Northeast | | | | 554.78 |
| Yellow river midstream | Rest of the world | 19.76 | 301.39 | | |
| Yellow river midstream | East Coast | | 70.31 | 0.51 | |
| Yellow river midstream | Northeast | 1.82 | 141.03 | 2.66 | |
| Yellow river midstream | South Coast | | 52.45 | 3.72 | 7.46 |
| Yellow river midstream | Northwest | 8.05 | 109.05 | 6.90 | 9.79 |
| Yellow river midstream | Yangtze river midstream | | 138.27 | 1.54 | 80.86 |
| Yellow river midstream | Southwest | 33.92 | 272.61 | 28.08 | 145.13 |
| Yellow river midstream | North Coast | | 384.95 | | 204.84 |
| Yangtze river midstream | Rest of the world | | | | 18.65 |
| Yangtze river midstream | East Coast | | | 1.02 | 37.79 |
| Yangtze river midstream | Southwest | 6.81 | | | 61.47 |
| Yangtze river midstream | South Coast | | | | 61.83 |
| Yangtze river midstream | Yellow river midstream | 23.42 | 8.88 | 4.69 | 95.37 |
| Yangtze river midstream | North Coast | 2.52 | | | 126.11 |
| Yangtze river midstream | Northeast | 27.89 | 37.97 | 14.77 | 357.78 |
| Yangtze river midstream | Northwest | 6.65 | | | 496.10 |
| Southwest | Rest of the world | | 7.16 | 0.85 | |
| Southwest | North Coast | 29.74 | 23.64 | 9.82 | 14.71 |
| Southwest | Yellow river midstream | | | 1.14 | 17.16 |
| Southwest | East Coast | 29.19 | 13.75 | 12.62 | 59.17 |
| Southwest | Northeast | 17.74 | | | 60.67 |
| Southwest | South Coast | 35.29 | 5.14 | | 73.18 |

| | | | | | |
|---|---|---|---|---|---|
| Southwest | Yangtze river midstream | | 7,157 | 847 | |
| Northwest | Rest of the world | | 10,784 | | 85,116 |
| Northwest | East Coast | 14,711 | 22,028 | 7,470 | 45,705 |
| Northwest | Southwest | 662 | 9,616 | 1,014 | 20,922 |
| Northwest | North Coast | 15,269 | 11,820 | | 10,133 |
| Northwest | Northeast | | 1,902 | | 3,943 |
| Northwest | South Coast | 1,087 | 7,717 | 1,380 | 2,887 |
| Northwest | Yangtze river midstream | 823 | 8,217 | 617 | |
| Northwest | Yellow river midstream | 2,305 | | | |
| Rest of the world | East Coast | 87,878 | 307,915 | 201,973 | |
| Rest of the world | South Coast | 115,340 | 139,595 | 133,637 | |
| Rest of the world | Northeast | | 57,328 | 46,067 | |
| Rest of the world | Yangtze river midstream | | 29,200 | 42,018 | |
| Rest of the world | Southwest | | 12,106 | 8,046 | |
| Rest of the world | Yellow river midstream | 3,988 | | 7,754 | |
| Rest of the world | Northwest | 330 | | 2,530 | |
| Rest of the world | North Coast | 44,986 | 198,309 | | |

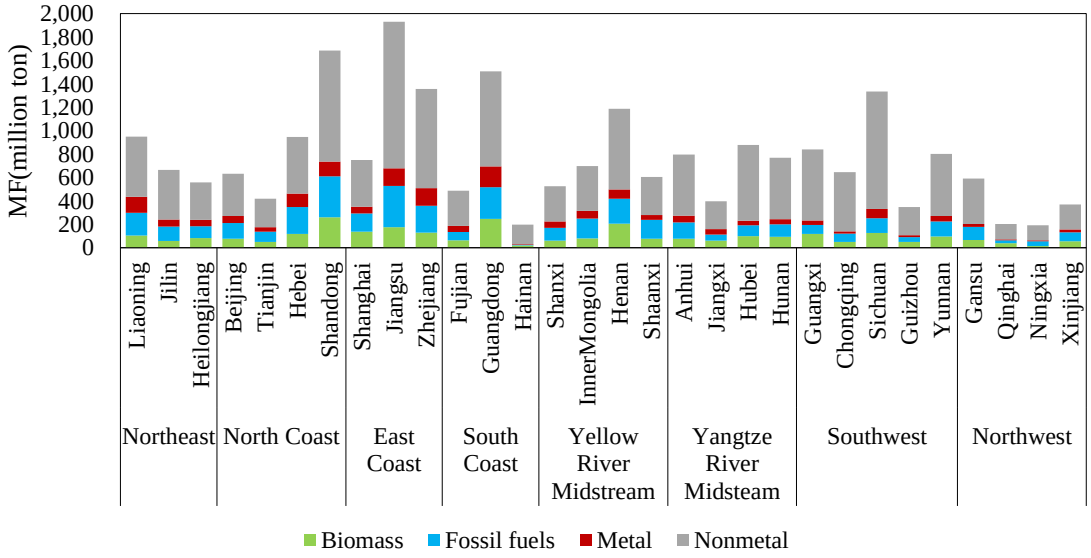



Figure S1 MF of four main types of resources for 30 provinces/cities in China in 2010.

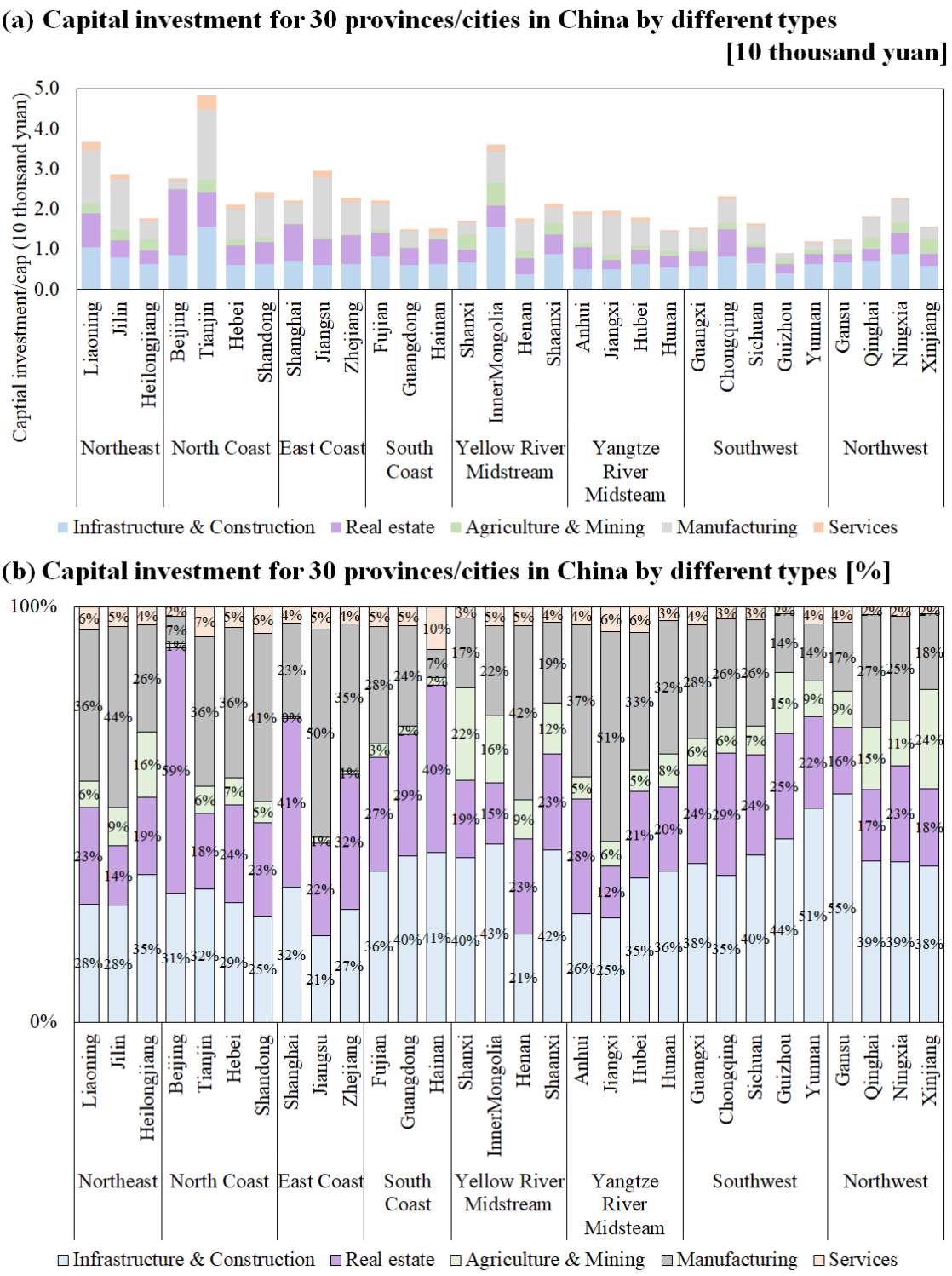



Figure S2 (a) Capital investment for 30 provinces/cities in China by different types (10 million yuan). (b) The fraction of different types of capital investment for 30 provinces/cities in China in 2010. (source: China statistical yearbook -2011(2)).

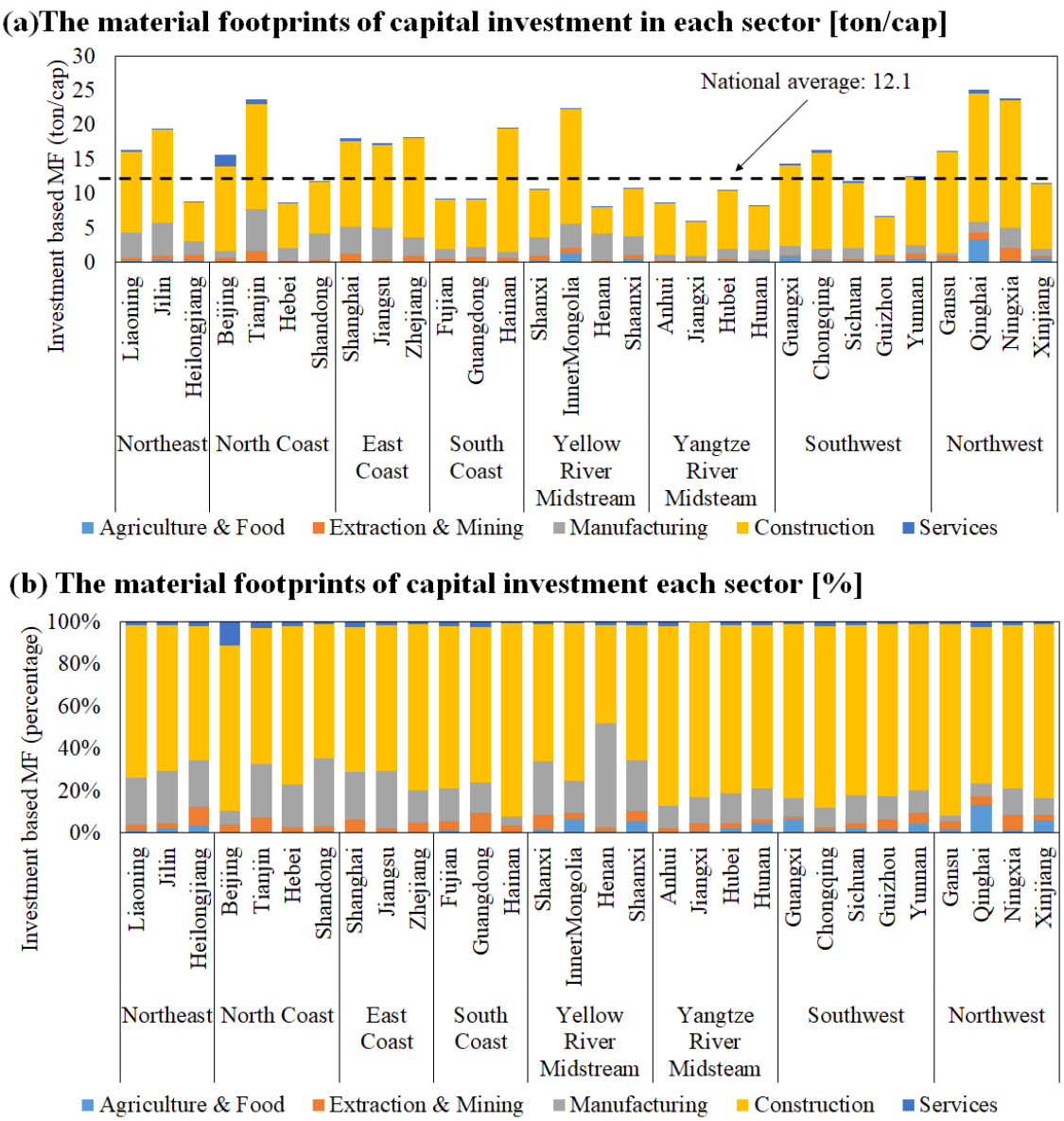



Figure S3 (a) Sectoral contribution to the investment-based material footprints of 30 provinces/cities. (b) Sectoral contribution to the investment-based material footprint of 30 provinces/cities shown in percentages. All data are for 2010.

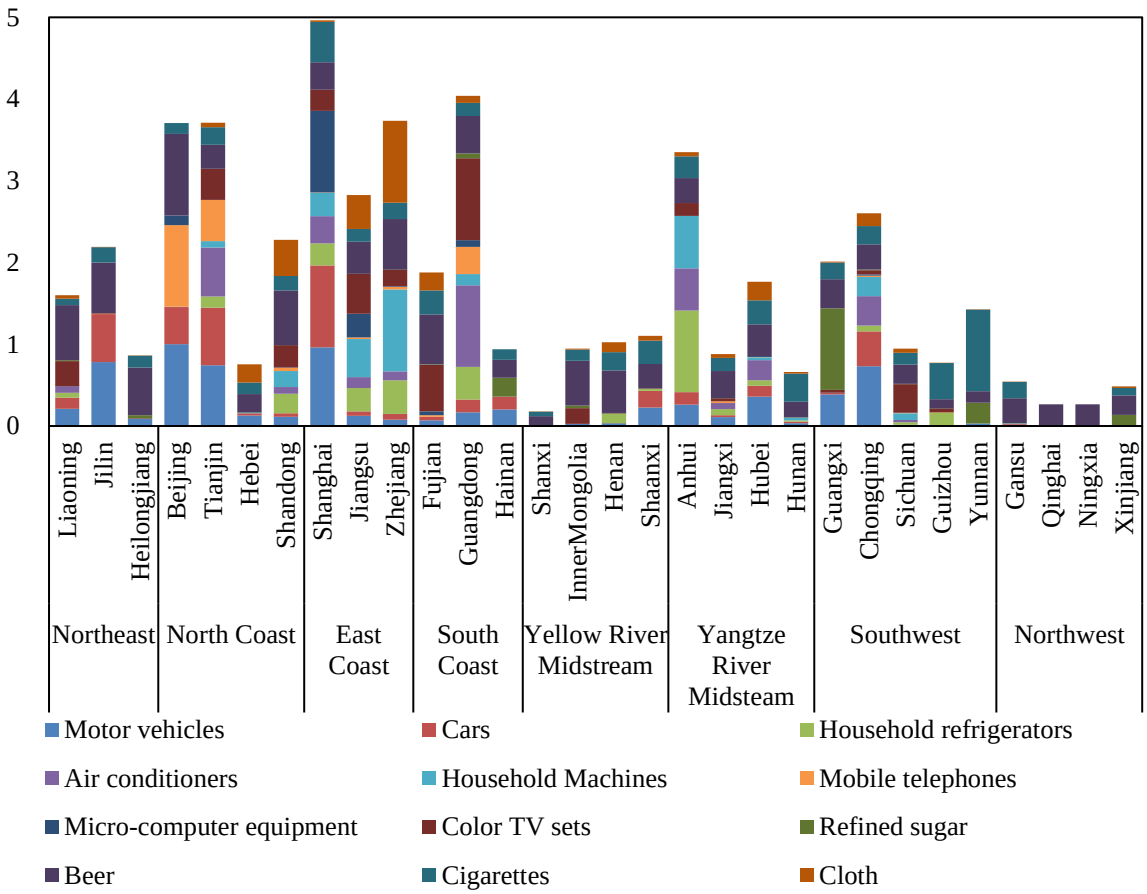



Figure S4 Relative per capita output of 12 consumer goods by province. The color distinguishes different types of consumer goods. Each block is calculated as (*per capita output of a type of consumer good of a province / the maximum per capita output of the type of consumer good among all provinces*). The range of each block is 0~1. The bar of each province consists of 12 blocks of consumer goods which indicate the relative per capita output of the province. All data are for 2010. (Source: China Statistical Yearbook 2011(2))

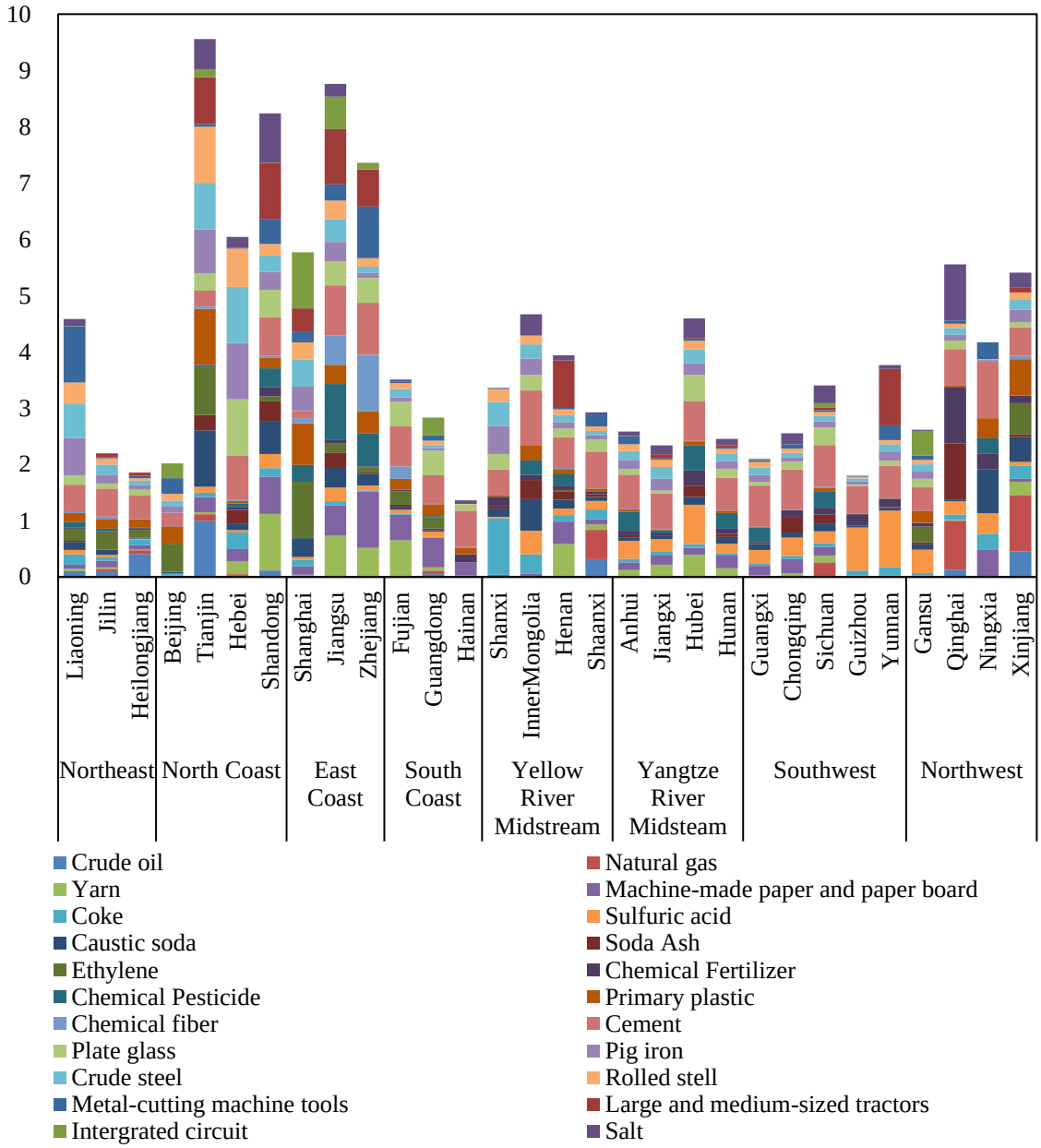



Figure S5 Relative per capita output of 22 intermediate industrial products by province. The color distinguishes different types of intermediate industrial products. Each block is calculated as (*per capita output of an intermediate industrial product of a province / the maximum of per capita output of the intermediate industrial product among all provinces*). The range of each block is 0~1. The bar of each province consists of 22 blocks of intermediate industrial products which indicates the relative per capita output of the province. All data are for 2010. (Source: China Statistical Yearbook 2011(2))

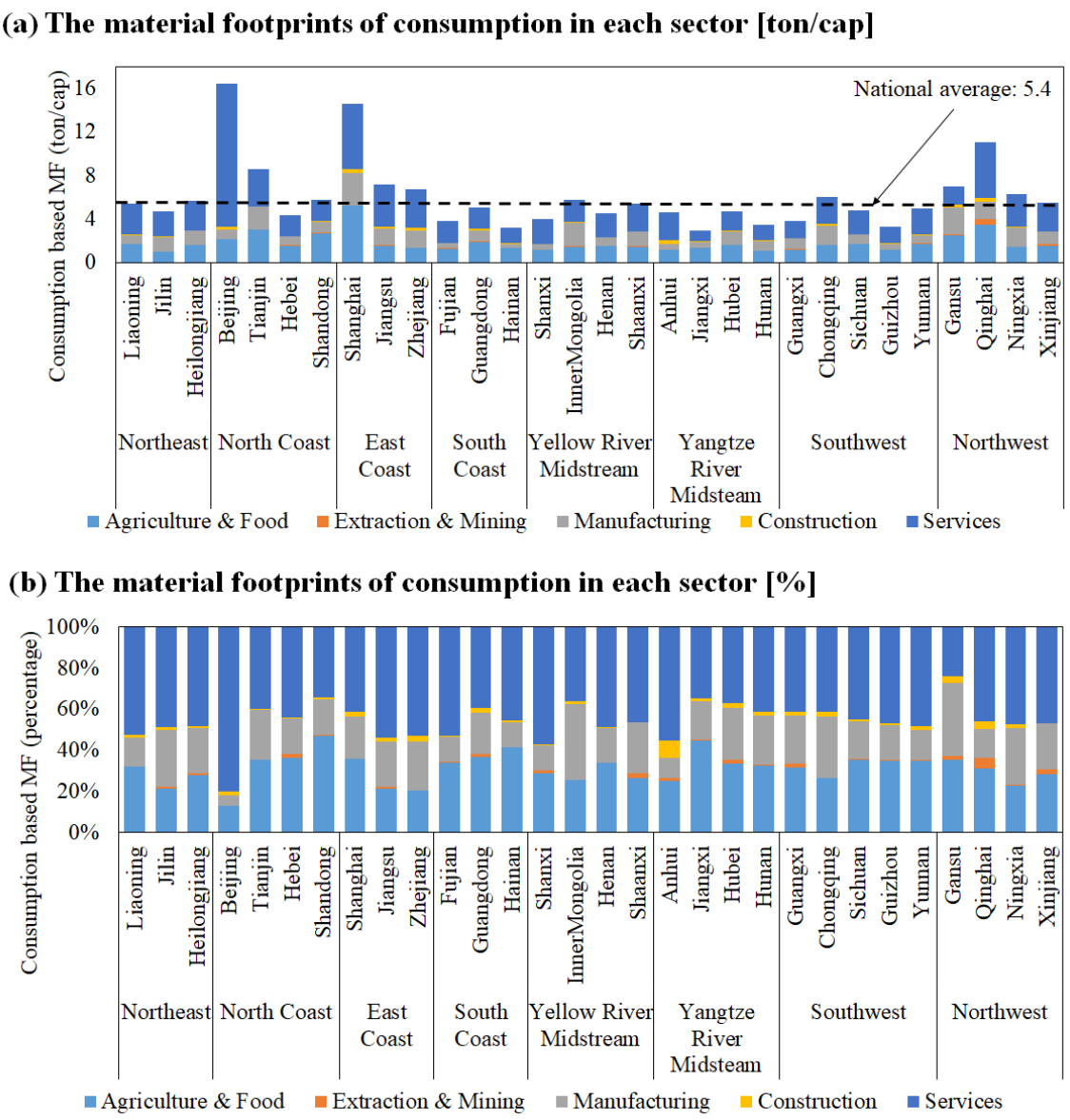
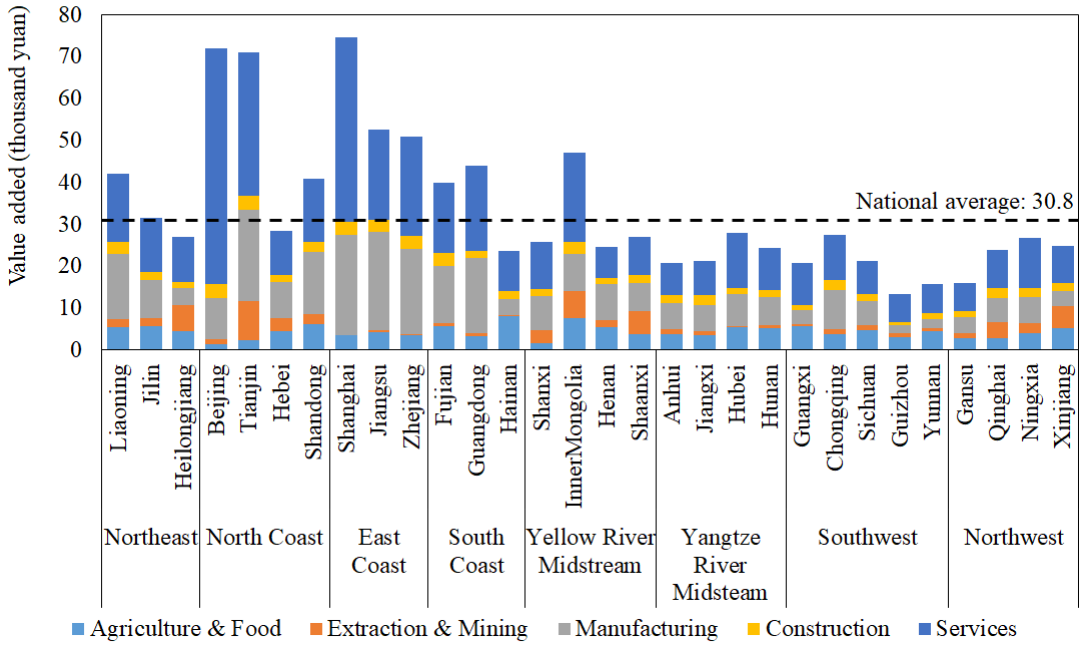



Figure S6 (a) Sector contribution to the consumption-based material footprint of 30 provinces/cities. (b) Sector contribution to consumption-based material footprint of 30 provinces/cities shown in percentage. All data are for 2010.

**(a) Sectoral contribution to per capita value added [thousand yuan]**




**(b) Sectoral contribution to per capita value added [%]**

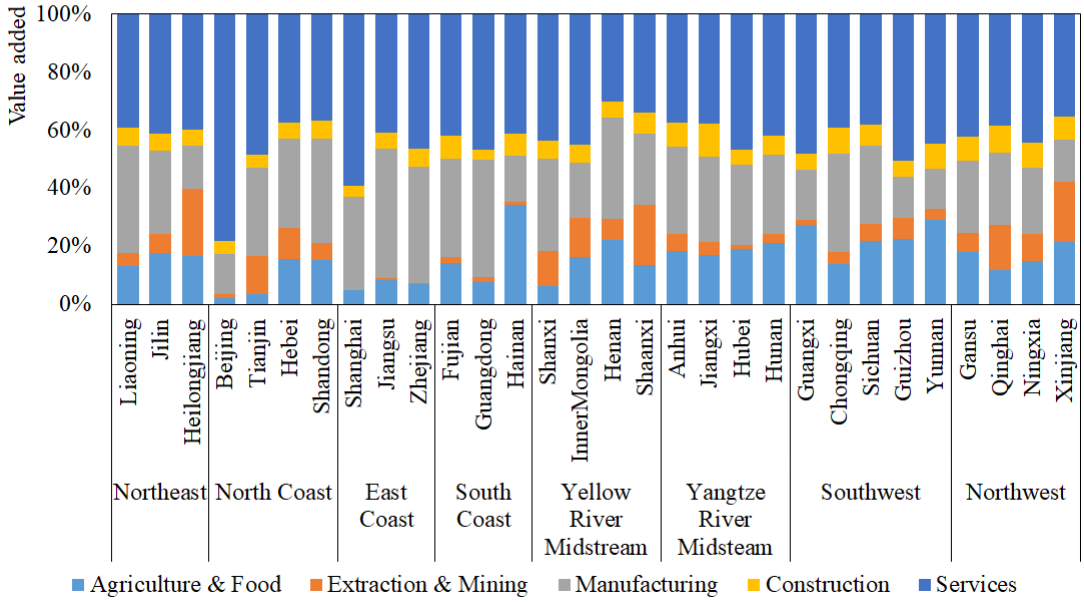



Figure S7 (a) Sector contribution to value added of 30 provinces/cities. (b) Sector contribution to value added of 30 provinces/cities shown in percentage. All data are for 2010.

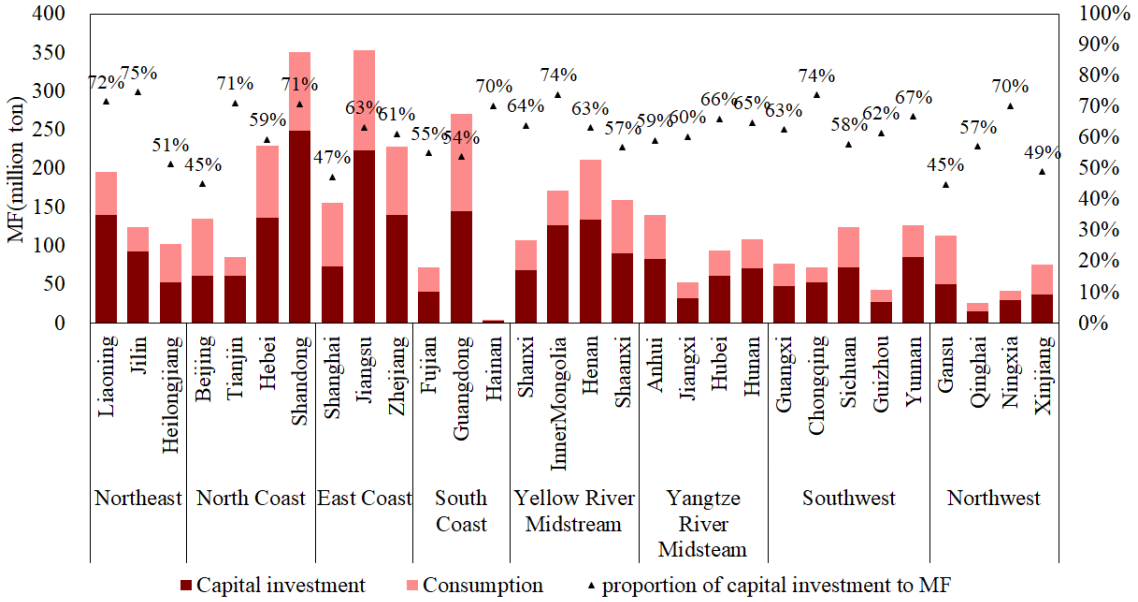



Figure S8 The contribution from capital investment and consumption to the overall per capita fossil fuels footprint of 30 provinces/cities in China. The left axis shows MF in million tons, the right axis shows the percentage indicated by triangle markers. All data are for 2010.

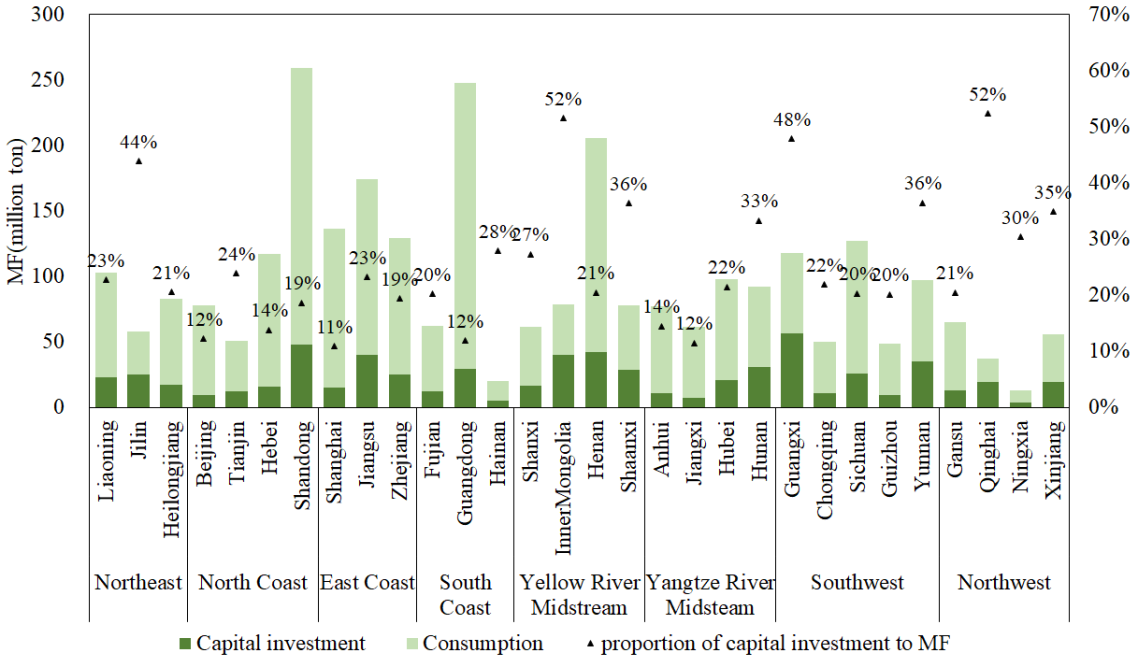



Figure S9 The contribution from capital investment and consumption to the overall per capita biomass footprint of 30 provinces/cities in China. The left axis shows MF in million tons, the right axis shows the percentage indicated by triangle markers. All data are for 2010.

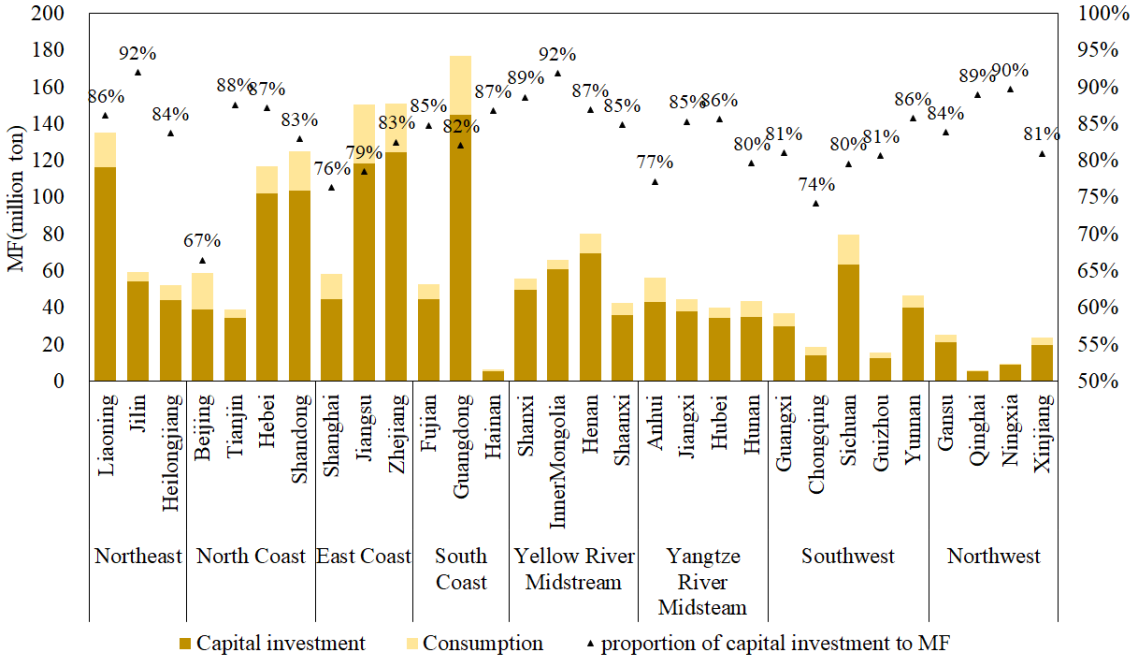



Figure S10 The contribution from capital investment and consumption to the overall per capita metal footprint of 30 provinces/cities in China. The left axis shows MF in million tons, the right axis shows the percentage indicated by triangle markers. All data are for 2010.

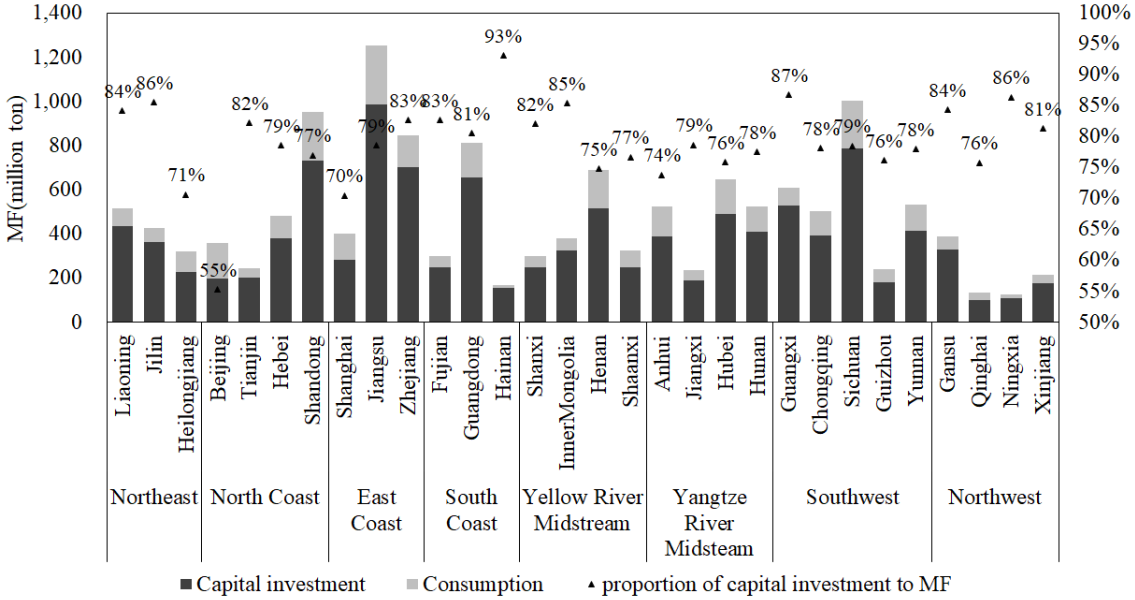



Figure S11 The contribution from capital investment and consumption to the overall per capita nonmetal footprint of 30 provinces/cities in China. The left axis shows MF in million tons, the right axis shows the percentage indicated by triangle markers. All data are for 2010.

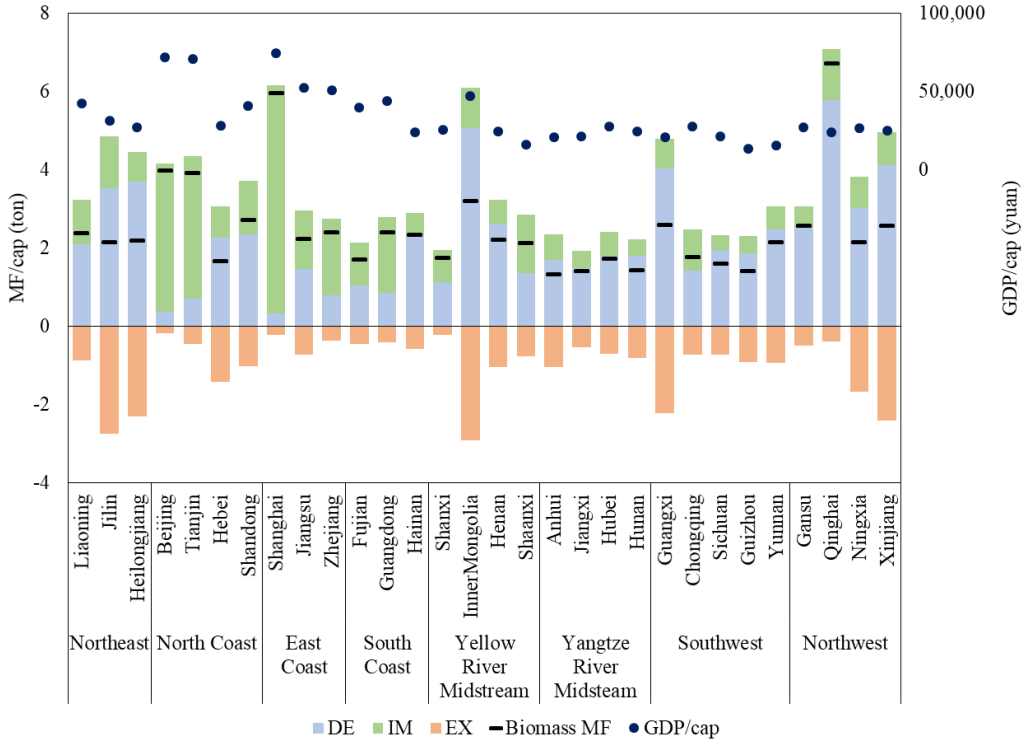



Figure S12 Per capita domestic extraction (DE) for biomass, material imports embodied in trade (IM), material exports embodied in trade (EX), material footprint (MF, shown in black bars) and GDP (shown in blue circles). All data are for 2010.

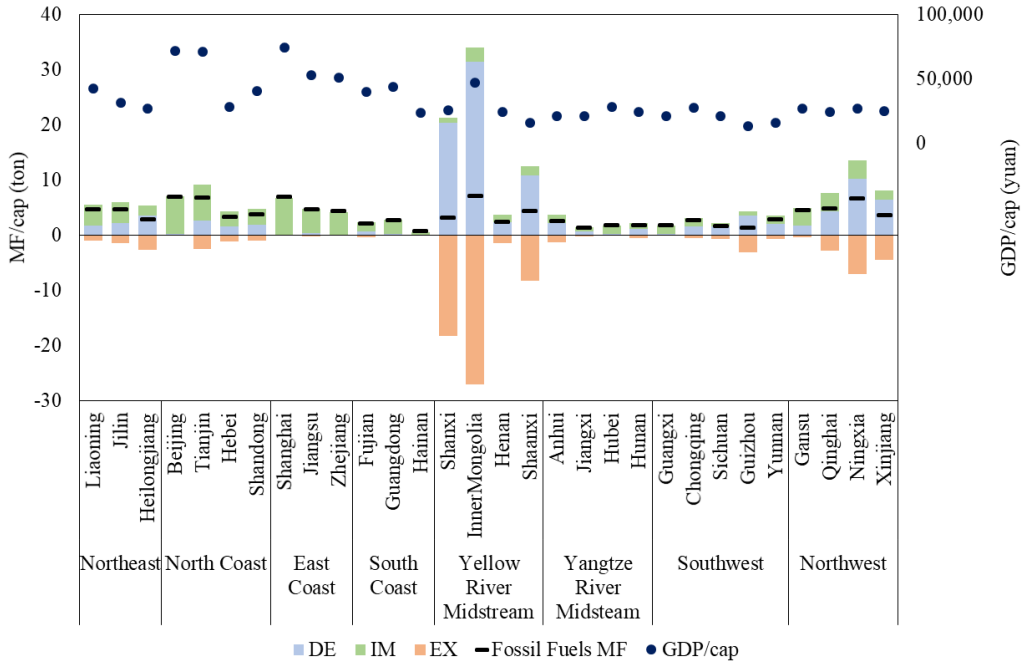



Figure S13 Per capita domestic extraction (DE) for fossil fuels, material imports embodied in trade (IM), material exports embodied in trade (EX), material footprint (MF, shown in black bars) and GDP (shown in blue circles) of 30 provinces/cities in China. All data are for 2010.

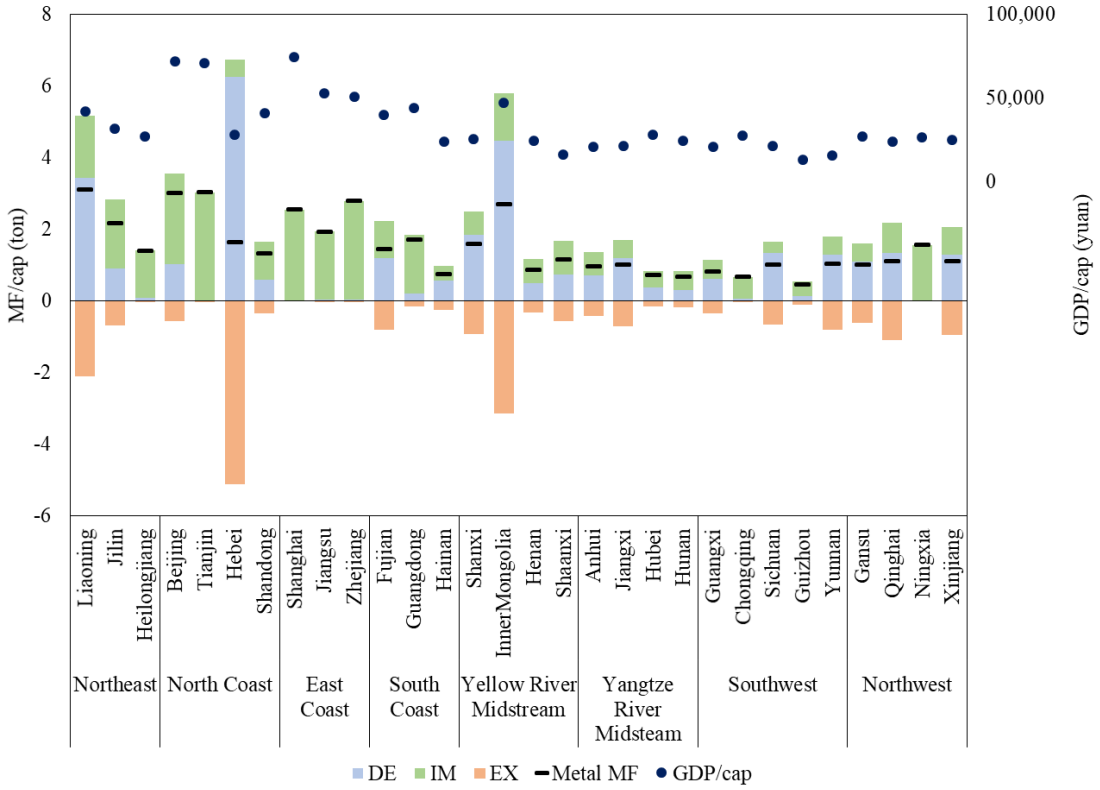



Figure S14 Per capita domestic extraction (DE) for metal, material imports embodied in trade (IM), material exports embodied in trade (EX), material footprint (MF, shown in black bars) and GDP (shown in blue circles) of 30 provinces/cities in China. All data are for 2010.

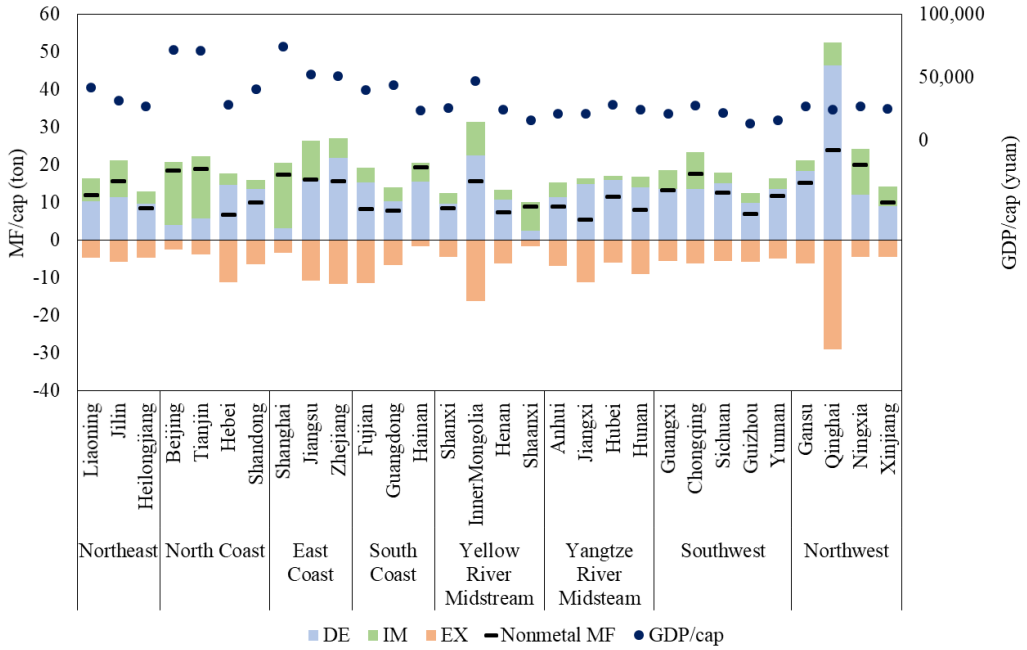



Figure S15 Per capita domestic extraction (DE) for nonmetal, material imports embodied in trade (IM), material exports embodied in trade (EX), material footprint (MF, shown in black bars) and GDP (shown in blue circles) of 30 provinces/cities in China. All data are for 2010.

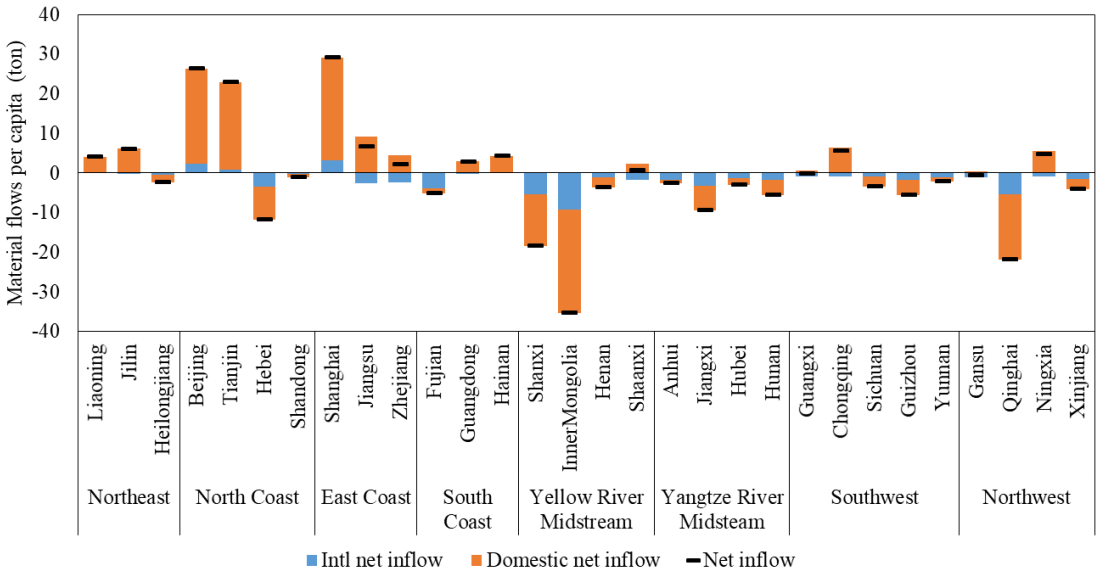



Figure S16 Net material flow embodied in trade, distinguishing the domestic net imports and international net imports of 30 cities/provinces of China. The blue columns show the international net inflow. The orange columns show the domestic inflows. The black bar shows the overall net inflow of a single province. All data are for 2010.

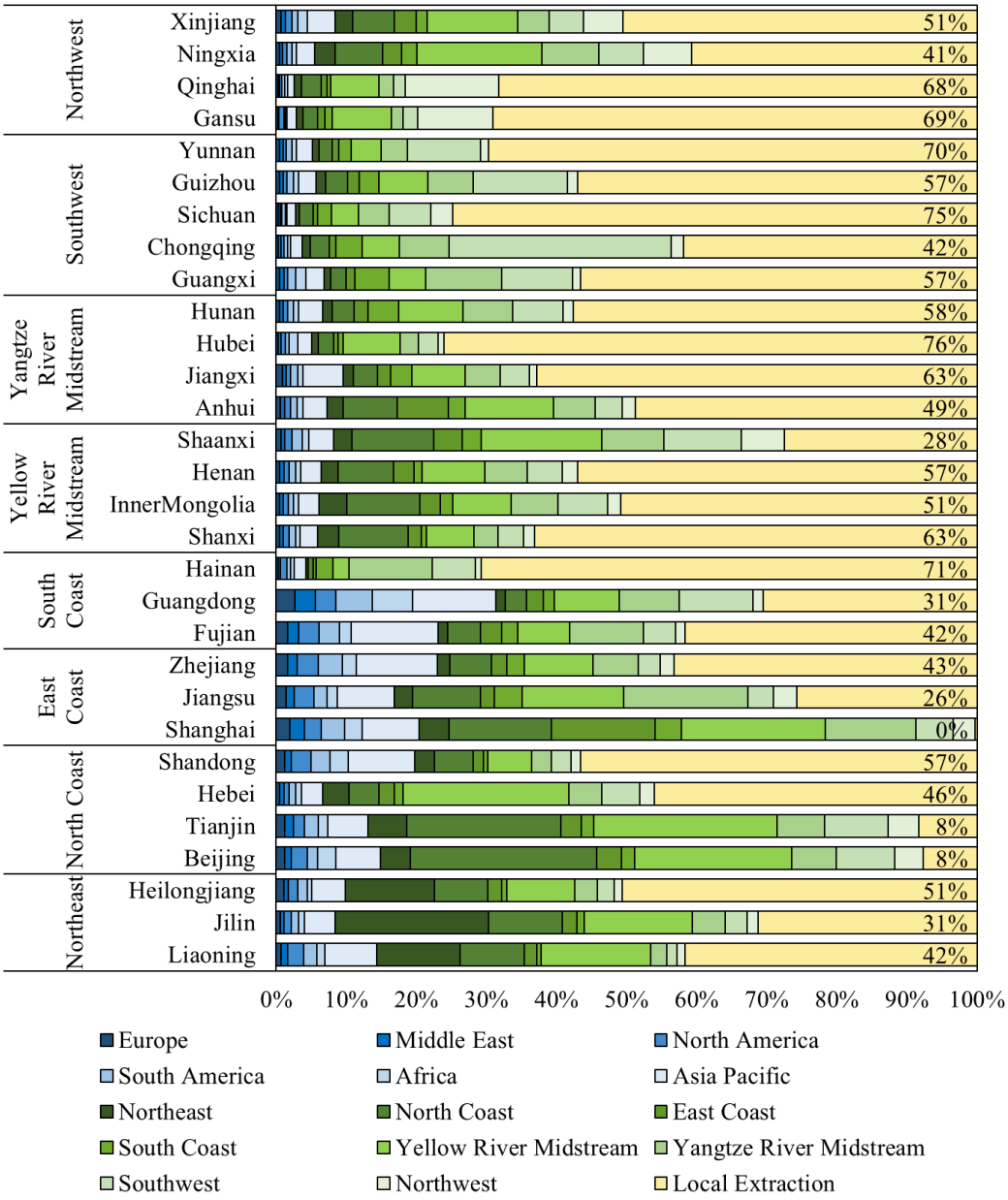



Figure S17 The outsourced origin of MF for provinces (in percentages) in 2010.

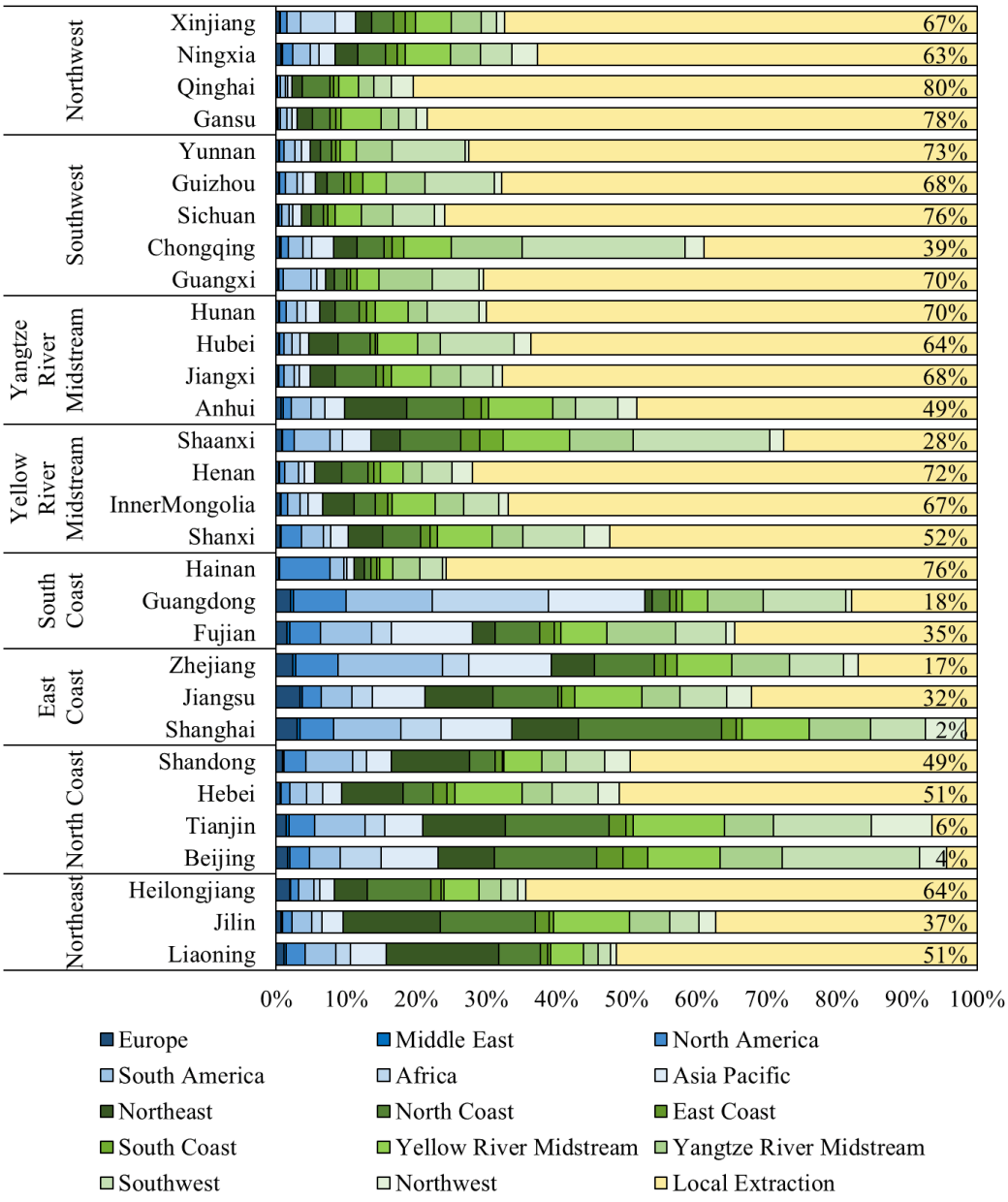



Figure S18 The outsourced origin of the footprint of biomass for provinces (in percentages) in 2010.

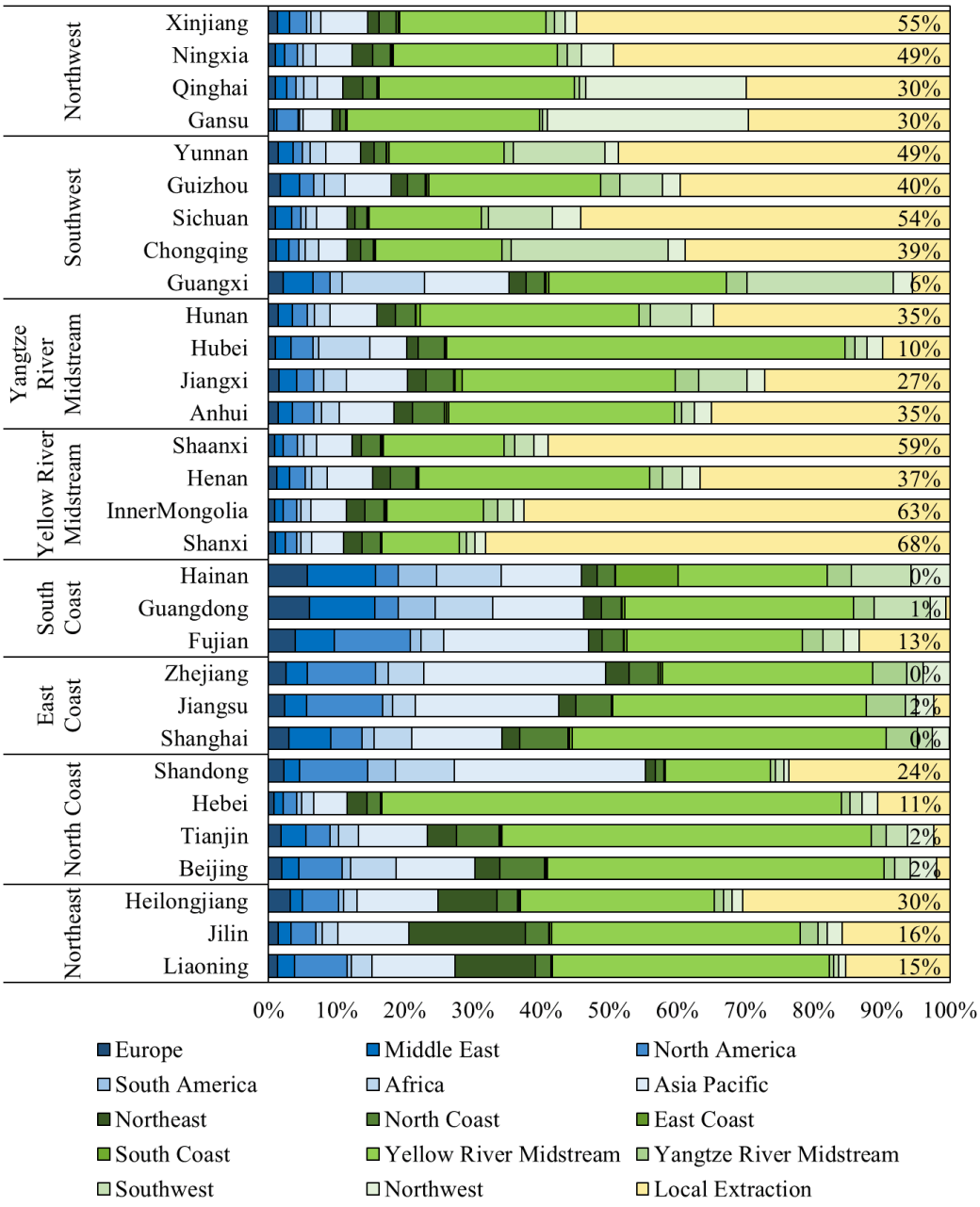



Figure S19 The outsourced origin of the footprint of fossil energy for provinces (in percentages) in 2010.

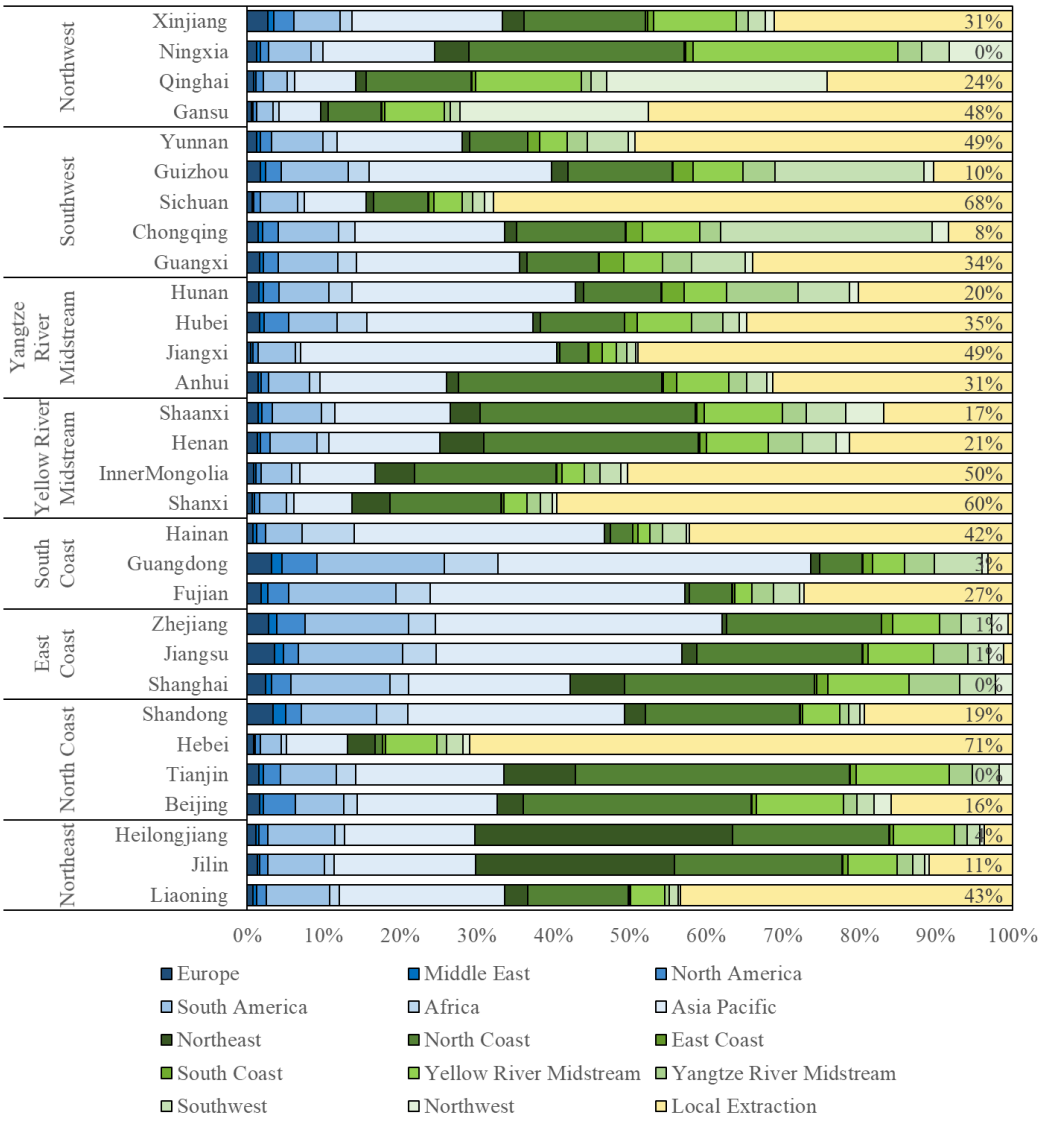



Figure S20 The outsourced origin of the footprint of metallic minerals for provinces (in percentages) in 2010.

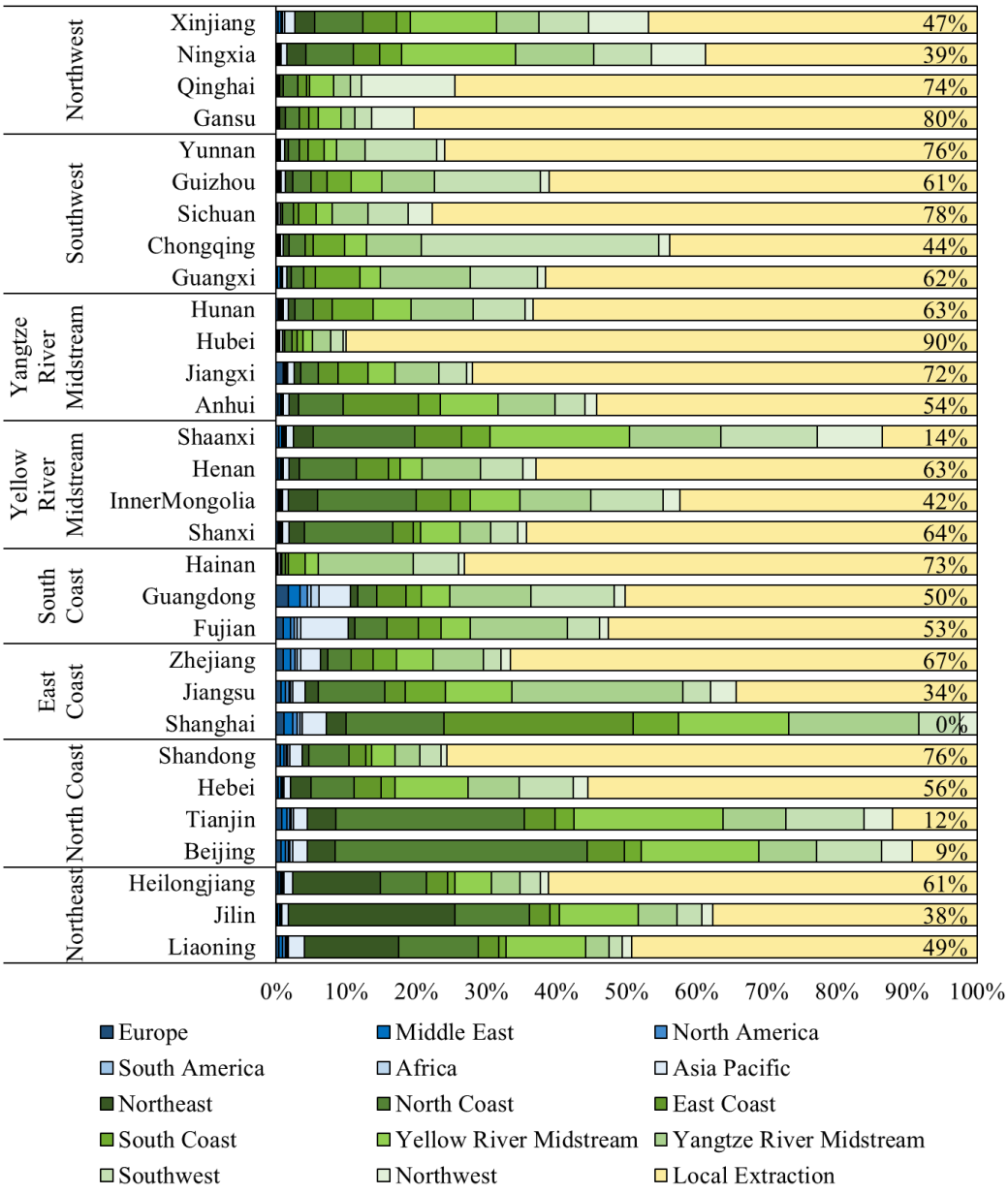



Figure S21 The outsourced origin of the footprint of non-metallic minerals for provinces (in percentages) in 2010.

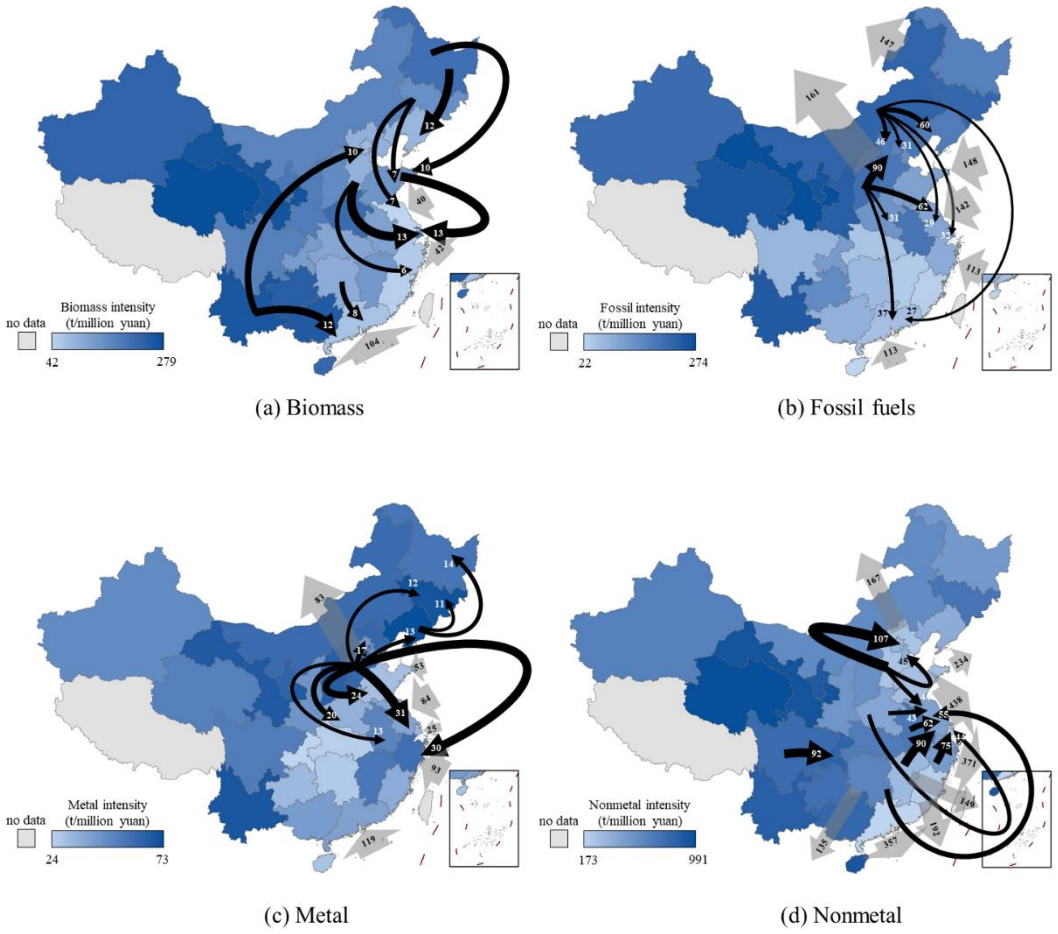



Figure S22 Net transfer of resources (biomass, fossil fuels, metal, and nonmetal) embodied in trade at the provincial level in 2010. Major intra-national and international fluxes are included. The domestic transfers (black arrows) and international transfers (grey arrows) are shown. The arrows in each figure have a different scale for ease of inspection. Colors indicate the material intensity of each resource.

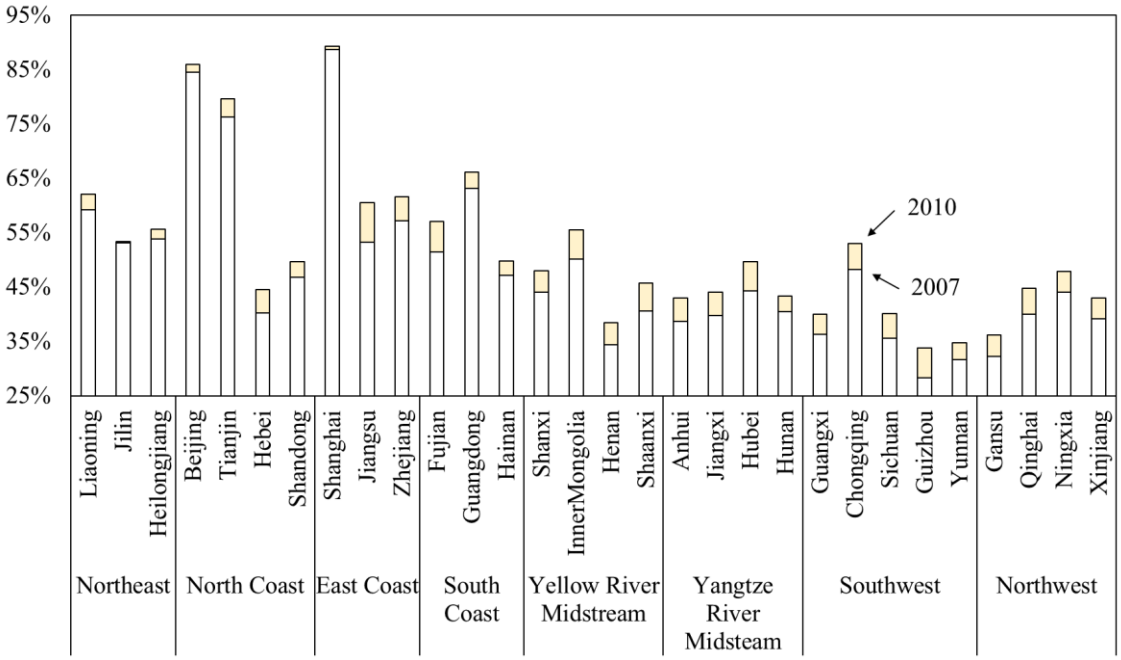



Figure S23 Urbanization rate for 30 provinces/cities in China between 2007 and 2010 (source: China statistical yearbook -2011(2)).

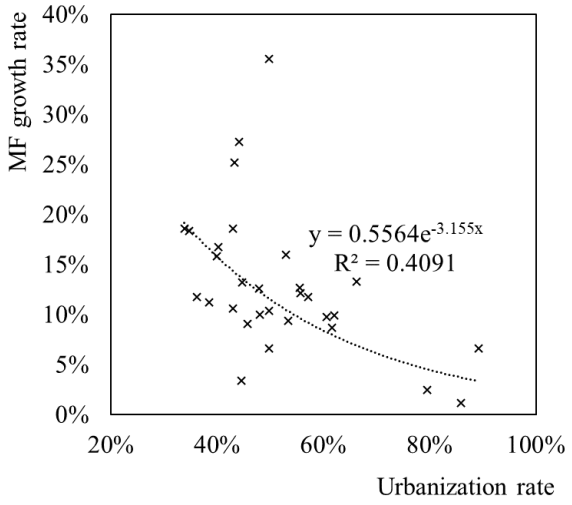



Figure S24 Scatter plots of urbanization rate in 2010 vs. MF growth rate between 2007 and 2010 of 30 provinces/cities (Source: China Statistical Yearbook 2011(2))

As it is shown in Figure S24, the provinces having lower urbanization rates tend to have a higher MF growth rate over the period. Those provinces are mainly located in the less developed northern and western parts of China as it is shown in Figure S23.

## 1.2 Decomposition analysis

We applied an index decomposition analysis (IDA) (3) to analyze drivers at both sub-national and sectoral levels. We decompose the drivers of MF into total population change, changes in population distribution (interpreted as migration), material intensity, economic structure, and per capita value added, which are shown in the following formula:

$$TMF = \sum_{r}^{s}\sum_{i}^{n} \frac{MF_i^r}{VA_i^r} \cdot \frac{VA_i^r}{VA^r} \cdot \frac{VA^r}{POP^r} \cdot \frac{POP^r}{TPOP} \cdot TPOP$$

$$= \sum_{r}^{s}\sum_{i}^{n} IMF_i^r \cdot ES_i^r \cdot PVA^r \cdot SPOP^r \cdot TPOP^r$$

$$\Delta TMF = \sum_{r}^{s}\sum_{i}^{n} \Delta MF_i^r$$

$$= \sum_{r}^{s}\sum_{i}^{n} \Delta_{IMF} MF_i^r + \Delta_{ES} MF_i^r + \Delta_{PVA} MF_i^r + \Delta_{SPOP} MF_i^r + \Delta_{TPOP} MF_i^r$$

where $TMF$ describes the total material footprint of the nation. $IMF_i^r$ refers to the material footprint consumed by sector $i$ per unit of value added in province $r$. $ES_i^r$ refers to the share of the value added for sector $i$. $PVA^r$ refers to per capita GDP (affluence) in province $r$. $SPOP^r$ refers to the share of population in province $r$ to the national population. $TPOP^r$ refers to the national population. Changes in those factors contributing to the change of total material footprint could be expressed in the additive form by following the LMDI (3) formula as:

$$\Delta_{IMF} MF_i^r = \omega_i^r \ln\left(\frac{IMF_i^r{}_0}{IMF_i^r{}_t}\right)$$

$$\Delta_{ES} MF_i^r = \omega_i^r \ln\left(\frac{ES_i^r{}_0}{ES_i^r{}_t}\right)$$

$$\Delta_{PVA} MF_i^r = \omega_i^r \ln\left(\frac{PVA^r{}_0}{PVA^r{}_t}\right)$$

$$\Delta_{SPOP} MF_i^r = \omega_i^r \ln\left(\frac{SPOP^r{}_0}{SPOP^r{}_t}\right)$$

$$\Delta_{TPOP} MF_i^r = \omega_i^r \ln\left(\frac{TPOP^r{}_0}{TPOP^r{}_t}\right)$$

$$\omega_i^r = \frac{MF_i^r(t) - MF_i^r(0)}{\ln MF_i^r(t) - \ln MF_i^r(0)}$$

where $\Delta_{IMF} MF_i^r$, $\Delta_{ES} MF_i^r$, $\Delta_{PVA} MF_i^r$, $\Delta_{SPOP} MF_i^r$ and $\Delta_{TPOP} MF_i^r$ refer to the contributions to material footprint changes from material intensity, economic structure, affluence, population structure and overall population to sector $i$ and region $r$ in the time interval ($t$ to 0).

As it is shown in Fig. S25, affluence dominates MF growth in all provinces. In most provinces, material intensity is reduced, but with some exceptions. Western provinces such as Inner Mongolia, Qinghai, Gansu as well as Hainan have significantly increased their material intensity (contributing between 14% to 40% of their MF growth). Only two provinces in which the changing economic structure drives a (relative) reduction in MF: Beijing (-16%) and Qinghai (-10%), providing evidence that Beijing is transitioning from a capital investment-driven to a consumption-driven economy. For the remaining provinces, we see that provincial economies were becoming more, not less, material-intensive over the period. Migration effects are large enough to be seen clearly in the changing material footprints across China - the footprints of coastal areas increase while inland areas decrease, in line with migration patterns. We find some evidence that policies such as the China Western Development program(4) may have helped lift the growth of underdeveloped provinces with a 13% increase between 2007 and 2010, faster than in the coastal areas (11%). However, they did so with a 14% growth in MF over the same period.

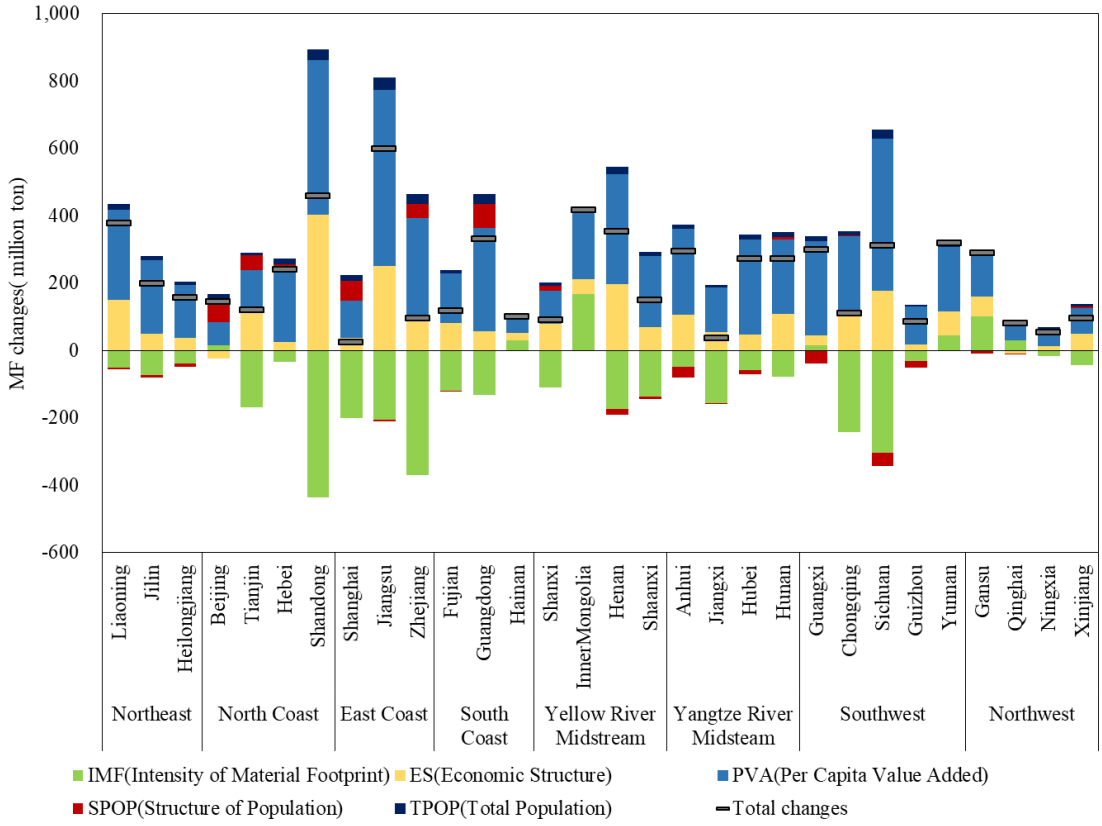



Figure S25 Factors contributing to changes in MF by province between 2007 and 2010.

## 1.3 Gini coefficients and Lorenz curves

The Gini coefficients and Lorenz curves for 20 provinces/cities in China are calculated following (5, 6). The results are shown in Fig. S26 and Table S9.

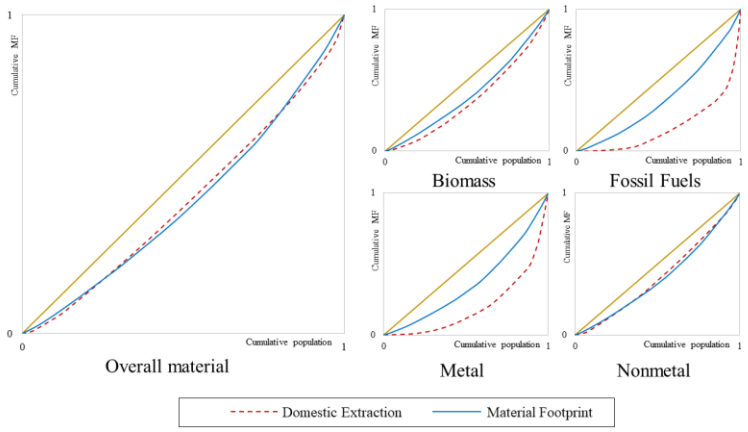



Figure S26 Five Lorenz curves for the overall material footprint and four categories of resources (biomass, fossil fuels, metal and nonmetal). All data are for 2010.

Table S9 Gini coefficients of overall materials and four categories of resources (biomass, fossil fuels, metal and nonmetal) in DE and MF. All data are for 2010.

| | Biomass | Fossil Fuels | Metal | Nonmetal | Overall MF |
|---|---|---|---|---|---|
| DE | 0.27 | 0.66 | 0.60 | 0.17 | 0.17 |
| MF | 0.17 | 0.26 | 0.28 | 0.19 | 0.18 |

## 1.4 Comparison with other studies

Table S10 Comparison of our results and other studies

| No. | Studies | Method | Year | Scope | Total MF | **Our study in 2007** | **Our study in 2010** | Units |
|---|---|---|---|---|---|---|---|---|
| 1 | Wiedmann et al. 2013(7) | GMRIO | 2008 | China | 16.3 | 16.7 | 23.3 | Gt |
| 2 | Giljum et al. 2015(8) | GMRIO | 2007 | China | 15.3 | 16.7 | 23.3 | Gt |
| 3 | Xu et al.2017(9) | GMRIO | 2008 | China | 14.5 | 16.7 | 23.3 | Gt |
| 4 | Tukker et al. 2016(1) | GMRIO | 2007 | China | 22.6 | 16.7 | 23.3 | Gt |
| 5 | Wu et al.2016(10) | GMRIO | 2008 | China | 13.5 | 16.7 | 23.3 | Gt |
| 6 | Wang et al. 2014(11) | SRIO | 2007 | China | 20.4 | 16.7 | 23.3 | Gt |
| 7 | UNEP IRP, 2018(12) | GMRIO | 2007 | China | 17.9 | 16.7 | 23.3 | Gt |
| 8 | UNEP IRP, 2018(12) | GMRIO | 2010 | China | 21.8 | 16.7 | 23.3 | Gt |
| 9 | Wang et al. 2018(13) | SRIO | 2007 | Liaoning | 1.0 | 0.6 | 0.9 | Gt |
| 10 | Wang et al. 2018(13) | SRIO | 2012 | Liaoning | 1.9 | 0.6 | 0.9 | Gt |

Our results are close to others that use a similar method (by using a Global Multi-regional Input-output model, GMRIO) even though we employ different input-output and resource databases. Our results are significantly smaller than studies based on SRIO (i.e. Single-regional Input-output model). MF accounting based on SRIO relies on domestic technology assumptions (11). We anticipate that our approach based on GMRIO and province-international trade data is more robust.

## 2. Method demonstration and data sources

### 2.1 Grouping criteria of provinces

We grouped 30 provinces into 8 clusters following government recommendations (by the Division of Development Strategy and Regional Economy of Development Research Center of the State Council of China) (14). This guidance suggests that provinces could be clustered based on a range of characteristics: provinces adjacent to each other; provinces with similar natural conditions and resource endowment; provinces with similar levels of economic development; provinces with inter-connected economies facing similar development issues; and, provinces with similar social structures. Table S11 shows the classification.

Table S11 Grouping criteria of provinces

| Grouped region | Province |
|---|---|
| Northeast | Liaoning, Jilin, Heilongjiang |
| North Coast | Beijing, Tianjin, Hebei, Shandong, |
| East Coast | Shanghai, Jiangsu, Zhejiang |
| South Coast | Fujian, Guangdong, Hainan |
| Yellow River Midstream | Shanxi, Inner Mongolia, Henan, Shaanxi |
| Yangtze River Midstream | Anhui, Jiangxi, Hubei, Hunan |
| Southwest | Guangxi, Chongqing, Sichuan, Guizhou, Yunnan |
| Northwest | Gansu, Qinghai, Ningxia, Xinjiang |

### 2.2 Construction of China's Province Domestic Extraction (DE) Database

For provinces in China, we constructed DE data for each province. Our provincial DE database followed the category system recommended by Eurostat 2013 (15). Minor adjustments in the classifications of resource categories were made. Our study includes the four main categories (biomass, fossil fuels, metal, and nonmetallic resources), 13 sub-categories and 29 specific types of resources. The detailed classification and data sources are shown in Table S12-S13.

Table S12 Resource classifications

| Category | Sub-category | Types |
|---|---|---|
| A.1 Biomass | | |
| | A.1.1 Crops (excluding fodder crops) | |
| | | A.1.1.1 Cereals |
| | | A.1.1.2 Fruits, roots, and tubers |
| | | A.1.1.3 Oil-bearing crops |
| | | A.1.1.4 Sugar crops |
| | | A.1.1.5 Cotton |
| | | A.1.1.6 Other crops n.e.c. |

| | | |
|---|---|---|
| | A.1.2 Crops residues (used), fodder crops and grazed biomass | |
| | | A.1.2.1 Crops residues (used) |
| | | A.1.2.2 Fodder crops and grazed biomass |
| | A.1.3 Wood | |
| | A.1.4 Wild fish catch | |
| A.2 Metal ores | | |
| | A.2.1 Iron | |
| | A.2.2 Non-ferrous metal | |
| | | A.2.2.1 Copper-gross ore |
| | | A.2.2.2 Nickel-gross ore |
| | | A.2.2.3 Bauxite and other aluminum-gross ore |
| | | A.2.2.4 Gold and silver-gross ore |
| | | A.2.2.5 Lead, zinc and tin-gross ore |
| | | A.2.2.6 Other n.e.c.-gross ore |
| A.3 Non-metallic minerals | | |
| | A.3.1 Non-metallic ores | |
| | | A.3.1.1 Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate) |
| | | A.3.1.2 Chalk and dolomite |
| | | A.3.1.3 Slate |
| | | A.3.1.4 Limestone and gypsum |
| | A.3.2 Soil and gravel | |
| | | A.3.2.1 Sand and gravel |
| | | A.3.2.2 Clays and kaolin |
| | A.3.3 Chemical and fertilizer minerals and other n.e.c. | |
| | | A.3.3.1 Chemical minerals and other n.e.c. |
| | | A.3.3.2 Salt |
| A.4 Fossil energy materials/carriers | | |
| | A.4.1 Coal | |
| | A.4.2 Petroleum | |
| | A.4.3 Natural gas | |
| | A.4.4 Other unconventional oil and gas | |

### 2.2.2 Data sources and estimation

There are no available government databases for provincial-level DE of all resources. We built a DE database for the resources evaluated herein following three steps:

1. Where available we used statistical data on the DE of specific resources (or used a simple conversion).
2. We estimated some gaps using the method recommended by Eurostat in its economy-wide Material Flow Analysis (EW-MFA) compilation guide (15).
3. Other gaps were filled with data from multiple projects and reports on regional circular economy developments in China (i.e. National science and technology support projects on researches and demonstrations of key technologies on regional circular economy development of China (16, 17)).

Table S10 shows the calculation/estimation method for each data type and the underlying data source.

We give further details on these three steps:

**(1) DE data based on statistics (or with simple conversion)**

Some specific resources could be directly obtained from official statistical yearbooks (or with simple conversion) (see Table S13). Because some statistical data have different units (such as cubic meter etc.), they are directly converted in mass units (ton), according to physical parameters or coefficients recommended by Eurostat(15).

**(b) Estimations based on Eurostat methods in its economy-wide Material Flow Analysis (EW-MFA) compilation guide**

For some types of biomass and non-metallic minerals, the DE cannot be directly obtained (or converted) from statistics (see Table S13). Hence, we adopted Eurostat 2013 (15) methods to estimate DE. All underlying statistical data are obtained from statistical yearbooks. The details and specifies are as followed:

Crops residues (used) (A.1.2.1)

The yield of different crop types and their harvest factors and recovery rates are used. The yield data of various crops are obtained from China Agriculture Yearbook (18). Coefficients are obtained from Eurostat (15).

Fodder crops and grazed biomass (A.1.2.2)

Fodder crops and grazed biomass can be estimated by the number of livestock and its feed intake. Livestock includes cattle, sheep, horses, donkeys, and mules. Livestock data are collected from the China Agriculture Yearbook, and the average annual feed intake is adopted from Eurostat (15).

Limestone and gypsum (A.3.1.4)

Limestone is estimated from cement production data. The cement production data are obtained from China Cement Almanac (19), and the coefficient is from Eurostat (15). Gypsum can be directly collected from the China Mining Yearbook (20).

Sand and gravel (A.3.2.1)
Sand and gravel are mainly used for concrete production and road construction as in previous studies (15). Each use case is estimated separately:

Concrete production is estimated based on cement consumption. Since the radius of delivery of sand and gravel is about 40 kilometers and local sourcing is a key criterion (21), we assume that the production of cement is highly correlated to the consumption in a province. Thus, we allocate national cement consumption to each province based on the proportion of cement production of each province. Cement data are obtained from the China Cement Almanac (19). The conversion coefficients are obtained from Eurostat (15).

Sand and gravel used for road construction contain two further categories: new roads and roads under-maintenance. According to mileage and corresponding coefficients for different types of highway, sand and gravel consumption could be estimated (15).

Clays and kaolin (A.3.2.2)
Clays and kaolin are mainly used for the production of bricks and ceramics (15). Similar to the case for sand and gravel, we have assumed that such low-cost and heavy materials will be locally sourced to avoid relatively high transportation costs. The extracted volumes are estimated by using statistics from standard brick and ceramic production data from the China Building Materials Industry Yearbook (22). The conversion coefficients are obtained from Wang et al., 2014 (11).

**(c) Estimates based on various national reports and projects**
Statistics on metal production are provided by statistical agencies in China often include metal net content (i.e. metal volume after processing and concentration of gross ore). However, for the EE-MRIO analysis, the extraction data of metal ores are needed (i.e. the total amount of metal ores extracted before processing and concentration). Eurostat Guidelines (15) recommends that, if available, coefficients should be adopted based on local industries. Therefore, this research combine statistics and survey data to estimate actual local nonferrous metal ore production and to convert the net content of metal ore. Then, we harmonize the two sources of data and convert them into the total ore extraction. Data and coefficients are obtained from a national science and technology support project on regional circular economy development of China (16, 17) and provincial statistics.

A.2.2 Non-ferrous metal
By combining the net content of metal of ore concentrates in each province with coefficients reflecting ore grade and mining & milling technology, we estimated the quantity of gross ore mined. Then, with internal survey data from a national project (16, 17) and nonferrous metals industry association, the results are adjusted and cross-validated. Basic data on the net metal content of ore concentrates in each province and coefficients related to ore grade and mining & milling technology are from the China Nonferrous Metals Industry Yearbook (23) and the China Mining Industry Yearbook (20).

As for bauxite, we estimate the results based on the data of alumina production in each province and then cross-validated with the survey data (17) of key provinces including Shanxi, Guizhou, Henan, and Guangxi (accounting for more than 95% national extraction). Statistics come from the China Nonferrous Metals Industry Yearbook (23).

Table S13 Calculation/estimation method and sources of underlying data on material extractions.

| Types | Method | Underlying data source |
|---|---|---|
| **A.1.1.1 Cereals** | DE based on directly available statistical data per province (or with simple conversion) | China Agriculture Yearbook(18) |
| **A.1.1.2 Fruits, roots, and tubers** | | China Agriculture Yearbook(18), China Rural Statistical Yearbook(24) |
| **A.1.1.3 Oil-bearing crops** | | China Rural Statistical Yearbook(24) |
| **A.1.1.4 Sugar crops** | | China Rural Statistical Yearbook(24) |
| **A.1.1.5 Cotton** | | China Agriculture Yearbook(18), China Rural Statistical Yearbook(24) |
| **A.1.1.6 Other crops n.e.c.** | | China Rural Statistical Yearbook(24) |
| **A.1.2.1 Crops residues (used)** | Estimation based on the method recommended by Eurostat in its economy-wide Material Flow Analysis (EW-MFA) guide | China Agriculture Yearbook(18), coefficients come from EU Directive(15) |
| **A.1.2.2 Fodder crops and grazed biomass** | | China Agriculture Yearbook(18), coefficients come from EU Directive(15) |
| **A.1.3 Wood** | DE based on directly available statistical data per province (or with simple conversion) | China Forestry Yearbook, coefficients come from EU Directive(15) |
| **A.1.4 Wild fish catch** | | China Rural Statistical Yearbook(24) |
| **A.2.1 Iron** | | China Industry Economy Statistical Yearbook(25) |
| **A.2.2.1 Copper-gross ore** | Measures and estimation based on national projects | China Nonferrous Metals Industry Yearbook(23); national projects(16, 17) |
| **A.2.2.2 Nickel-gross ore** | | China Nonferrous Metals Industry Yearbook(23); national projects(16, 17) |
| **A.2.2.3 Bauxite and other aluminum-gross ore** | | China Nonferrous Metals Industry Yearbook(23), Statistical Yearbooks of provinces; national projects(16, 17) |
| **A.2.2.4 Gold and silver-gross ore** | | China Nonferrous Metals Industry Yearbook(23); national projects(16, 17) |
| **A.2.2.5 Lead, zinc and tin-gross ore** | | China Nonferrous Metals Industry Yearbook(23); national projects(16, 17) |
| **A.2.2.6 Other n.e.c.-gross ore** | | China Nonferrous Metals Industry Yearbook(23); national projects(16, 17) |

| | | |
|---|---|---|
| **A.3.1.1 Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate)** | DE based on directly available statistical data per province (or with simple conversion) | China Mining Yearbook(20) |
| **A.3.1.2 Chalk and dolomite** | | China Mining Yearbook(20) |
| **A.3.1.3 Slate** | | China Mining Yearbook(20) |
| **A.3.1.4 Limestone and gypsum** | Estimation based on the method recommended by Eurostat in its economy-wide Material Flow Analysis (EW-MFA) guide | China Cement Almanac(19), China Statistical Yearbook of the Tertiary Industry(25) |
| **A.3.2.1 Sand and gravel** | | China Cement Almanac(19), China Statistical Yearbook of the Tertiary Industry(25) |
| **A.3.2.2 Clays and kaolin** | | China Building Materials Industry Yearbook(25), coefficients from Wang et al., 2014 (11) |
| **A.3.3.1 Chemical minerals and other n.e.c.** | DE based on directly available statistical data per province (or with simple conversion) | China Industry Economy Statistical Yearbook(25), China Mining Yearbook(20) |
| **A.3.3.2 Salt** | | China Mining Yearbook(20) |
| **A.4.1 Coal** | | China Energy Statistical Yearbook(26), Statistical Yearbooks of province |
| **A.4.2 Petroleum** | | China Energy Statistical Yearbook(26) |
| **A.4.3 Natural gas** | | China Energy Statistical Yearbook(26) |
| **A.4.4 Other unconventional oil and gas** | | China Energy Statistical Yearbook(26) |

### 2.2.3 Results and comparison

Table S14 gives the DE per province (total and per type of material) for 2010. The total DE for China we obtained (25.25 Gt) deviates just 1% from the DE for China in the IRP database (25.01Gt). For the sub-categories Biomass, Fossil fuels, Metals, and Non-metallic mineral somewhat higher deviations are at stake, but numbers still are rather close (biomass: 3.48 (IRP) - 2.66(this study); Fossil energy: 3.43(IRP) - 3.70 (this study); Metals: 1.46(IRP) - 1.44(this study); Nonmetallic minerals: 16.64(IRP) - 17.45(this study); all numbers in Gt). Such small differences are quite usual when different databases for environmental extensions such as resources are used (27-29). Our study has a focus on China, and the Chinese provincial DE database almost completely uses specific Chinese statistical sources where available (see Table S13). Using such specific Chinese sources is difficult for global resource database compilers, who may not have access to such specific statistics, or may face language barriers.

Table S14 DE per province (total and per type of material) for 2010 and comparison to IRP's global material database (30) (million ton)

| Resource type /Province | Biomass | Fossil | Metal | Nonmetal | **Total DE** |
|---|---|---|---|---|---|
| Beijing | 7 | 5 | 20 | 82 | **114** |
| Tianjin | 9 | 35 | 0 | 77 | **121** |
| Hebei | 163 | 107 | 451 | 1,069 | **1,790** |
| Shanxi | 40 | 728 | 66 | 346 | **1,180** |
| Inner Mongolia | 125 | 775 | 111 | 559 | **1,570** |
| Liaoning | 91 | 75 | 150 | 457 | **774** |
| Jilin | 97 | 59 | 25 | 319 | **500** |
| Heilongjiang | 142 | 133 | 3 | 371 | **649** |
| Shanghai | 7 | 0 | 0 | 75 | **83** |
| Jiangsu | 115 | 23 | 4 | 1,262 | **1,403** |
| Zhejiang | 42 | 0 | 2 | 1,191 | **1,235** |
| Anhui | 100 | 128 | 42 | 680 | **951** |
| Fujian | 38 | 24 | 44 | 572 | **679** |
| Jiangxi | 66 | 28 | 54 | 670 | **817** |
| Shandong | 226 | 182 | 58 | 1,319 | **1,785** |
| Henan | 246 | 215 | 46 | 1,016 | **1,524** |
| Hubei | 103 | 14 | 22 | 915 | **1,053** |
| Hunan | 118 | 75 | 21 | 922 | **1,136** |
| Guangdong | 88 | 18 | 22 | 1,080 | **1,208** |
| Guangxi | 186 | 7 | 28 | 628 | **850** |
| Hainan | 20 | 0 | 5 | 135 | **160** |
| Chongqing | 41 | 45 | 2 | 397 | **484** |
| Sichuan | 156 | 124 | 107 | 1,224 | **1,610** |
| Guizhou | 65 | 124 | 5 | 346 | **540** |
| Yunnan | 114 | 96 | 60 | 629 | **899** |
| Shaanxi | 50 | 401 | 28 | 99 | **578** |
| Gansu | 64 | 45 | 28 | 470 | **607** |
| Qinghai | 33 | 24 | 8 | 262 | **327** |
| Ningxia | 19 | 65 | 0 | 77 | **161** |
| Xinjiang | 90 | 141 | 28 | 199 | **458** |
| **Total** | **2,661** | **3,699** | **1,441** | **17,447** | **25,248** |
| IRP's national results | 3,479 | 3,431 | 1,458 | 16,642 | 25,009 |

## 2.3 EXIOBASE material extensions

For countries and regions other than China, we used material extensions (Domestic Extraction, DE) directly from EXIOBASE v3.4. We aggregate 163 sectors in EXIOBASE for each country or region to 48 which are consistent to 48 Chinese sectors. The latest version of the EXIOBASE material extensions delivered February 2018 is fully consistent with the IRP database. Although the EXIOBASE extensions cover more disaggregation in the biomass material categories when compared to IRP data the aggregated totals are the same. These more detailed extensions in EXIOBASE were compiled by EXIOBASE partner WU (31), who was also partner in the development of the IRP database.

## 2.4 Linking the Chinese MRIO to GMRIO

In order to trace how each sector in each province trades with other nations globally, we link the Chinese Multi-Regional Input-Output Table (MRIO) (32, 33) to the global MRIO EXIOBASE (31, 34-36). The original Chinese MRIO is limited in sectoral resolution, with only 30 sectors in each province. In particular, only five sectors are related to resource extractions. Research shows different physical characteristics are aggregated into the same group via monetary units can lead to discrepancies when the provincial material footprint is calculated (1). Therefore, we improved the resolution in upstream sectors (where most raw materials first enter the system). We disaggregated the 5 upstream sectors into 23 detailed sectors by assuming the input-output relations of those disaggregated sectors in a province having the same proportion as China's national-level MRIO for those sectors. Other sectors are not altered. Consequently, the 30 original sectors in the Chinese provincial MRIO are disaggregated to 48 sectors. The category of inventory in the final demand is combined into capital formation category as Chinese provincial MRIO in 2010 structured. EXIOBASEv3.4 contains 163 sectors. We harmonized these 163 sectors to the 48 in the provincial Chinese MRIO (See Table S15 and S16 for details).

With two input-output tables having harmonized sectors, we link the two tables by disaggregating national imports and exports matrices for China (the national level) derived from EXIOBASE. We disaggregated Chinese national imports and exports matrices into each sector in each province based on the proportion derived from international trade data at the provincial level. The provincial-level international trade datasets provide information for each international trade including the originating country with details such as destination country/province, HS code (Harmonized Commodity Description and Coding Systems) of products, transaction values, physical amounts, and company codes, etc. We derived the distribution proportion for every sector in each province in the Chinese regional imports and exports matrices by considering every province as a virtual 'country' (37, 38). Finally, we adjust the overall volume to match the corresponding parts in the EXIOBASE. Bi-proportional adjustment is employed to balance the input-output table. The linked China-GMRIO includes 78 regions (original 48 counties and regions in EXIOBASE and 30 Chinese provinces/cities) with 48 economic sectors.

Table S15 Sector classification for EXIOBASE to China-GMRIO

| No. | Origin Sector Name of EXIOBASE | Number of Disaggregated Sector of China-GMRIO |
|---|---|---|
| 1 | Cultivation of paddy rice | 1 |
| 2 | Cultivation of wheat | 1 |
| 3 | Cultivation of cereal grains nec. | 1 |
| 4 | Cultivation of vegetables, fruit, nuts | 2 |
| 5 | Cultivation of oilseeds | 3 |
| 6 | Cultivation of sugar cane, sugar beet | 4 |
| 7 | Cultivation of plant-based fibers | 5 |
| 8 | Cultivation of crops nec. | 6 |
| 9 | Cattle farming | 7 |
| 10 | Pigs farming | 7 |
| 11 | Poultry farming | 7 |
| 12 | Meat animals nec. | 7 |
| 13 | Animal products nec. | 7 |
| 14 | Raw milk | 7 |
| 15 | Wool, silk-worm cocoons | 7 |
| 16 | Manure treatment (conventional), storage and land application | 7 |
| 17 | Manure treatment (biogas), storage and land application | 7 |
| 18 | Forestry, logging, and related service activities | 8 |
| 19 | Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing | 9 |
| 20 | Mining of coal and lignite; extraction of peat | 10 |
| 21 | Extraction of crude petroleum and services related to crude oil extraction, excluding surveying | 11 |
| 22 | Extraction of natural gas and services related to natural gas extraction, excluding surveying | 12 |
| 23 | Extraction, liquefaction, and regasification of other petroleum and gaseous materials | 13 |
| 24 | Mining of uranium and thorium ores | 20 |
| 25 | Mining of iron ores | 14 |
| 26 | Mining of copper ores and concentrates | 15 |
| 27 | Mining of nickel ores and concentrates | 16 |
| 28 | Mining of aluminum ores and concentrates | 17 |
| 29 | Mining of precious metal ores and concentrates | 18 |
| 30 | Mining of lead, zinc and tin ores and concentrates | 19 |
| 31 | Mining of other non-ferrous metal ores and concentrates | 20 |
| 32 | Quarrying of stone | 21 |
| 33 | Quarrying of sand and clay | 22 |
| 34 | Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying nec. | 23 |

| | | |
|---|---|---|
| 35 | Processing of meat cattle | 24 |
| 36 | Processing of meat pigs | 24 |
| 37 | Processing of meat poultry | 24 |
| 38 | Production of meat products nec. | 24 |
| 39 | Processing vegetable oils and fats | 24 |
| 40 | Processing of dairy products | 24 |
| 41 | Processed rice | 24 |
| 42 | Sugar refining | 24 |
| 43 | Processing of Food products nec. | 24 |
| 44 | Manufacture of beverages | 24 |
| 45 | Manufacture of fish products | 24 |
| 46 | Manufacture of tobacco products | 24 |
| 47 | Manufacture of textiles | 25 |
| 48 | Manufacture of wearing apparel; dressing and dyeing of fur | 26 |
| 49 | Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness, and footwear | 26 |
| 50 | Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials | 27 |
| 51 | Re-processing of secondary wood material into new wood material | 27 |
| 52 | Pulp | 28 |
| 53 | Re-processing of secondary paper into new pulp | 28 |
| 54 | Paper | 28 |
| 55 | Publishing, printing and reproduction of recorded media | 28 |
| 56 | Manufacture of coke oven products | 29 |
| 57 | Petroleum Refinery | 29 |
| 58 | Processing of nuclear fuel | 29 |
| 59 | Plastics, basic | 30 |
| 60 | Re-processing of secondary plastic into new plastic | 30 |
| 61 | N-fertilizer | 30 |
| 62 | P- and other fertilizer | 30 |
| 63 | Chemicals nec. | 30 |
| 64 | Manufacture of rubber and plastic products | 30 |
| 65 | Manufacture of glass and glass products | 31 |
| 66 | Re-processing of secondary glass into new glass | 31 |
| 67 | Manufacture of ceramic goods | 31 |
| 68 | Manufacture of bricks, tiles and construction products, in baked clay | 31 |
| 69 | Manufacture of cement, lime and plaster | 31 |

| | | |
|---|---|---|
| 70 | Re-processing of ash into clinker | 31 |
| 71 | Manufacture of other non-metallic mineral products nec. | 31 |
| 72 | Manufacture of basic iron and steel and of Ferro-alloys and first products thereof | 32 |
| 73 | Re-processing of secondary steel into new steel | 32 |
| 74 | Precious metals production | 32 |
| 75 | Re-processing of secondary precious metals into new precious metals | 32 |
| 76 | Aluminum production | 32 |
| 77 | Re-processing of secondary aluminum into new aluminum | 32 |
| 78 | Lead, zinc and tin production | 32 |
| 79 | Re-processing of secondary lead into new lead | 32 |
| 80 | Copper production | 32 |
| 81 | Re-processing of secondary copper into new copper | 32 |
| 82 | Other non-ferrous metal production | 32 |
| 83 | Re-processing of secondary other non-ferrous metals into new other non-ferrous metals | 32 |
| 84 | Casting of metals | 32 |
| 85 | Manufacture of fabricated metal products, except machinery and equipment | 33 |
| 86 | Manufacture of machinery and equipment nec. | 34 |
| 87 | Manufacture of office machinery and computers | 38 |
| 88 | Manufacture of electrical machinery and apparatus nec. | 36 |
| 89 | Manufacture of radio, television and communication equipment and apparatus | 37 |
| 90 | Manufacture of medical, precision and optical instruments, watches and clocks | 38 |
| 91 | Manufacture of motor vehicles, trailers and semi-trailers | 35 |
| 92 | Manufacture of other transport equipment | 35 |
| 93 | Manufacture of furniture; manufacturing nec. | 27 |
| 94 | Recycling of waste and scrap | 39 |
| 95 | Recycling of bottles by direct reuse | 39 |
| 96 | Production of electricity by coal | 40 |
| 97 | Production of electricity by gas | 40 |
| 98 | Production of electricity by nuclear | 40 |
| 99 | Production of electricity by hydro | 40 |
| 100 | Production of electricity by wind | 40 |
| 101 | Production of electricity by petroleum and other oil derivatives | 40 |
| 102 | Production of electricity by biomass and waste | 40 |
| 103 | Production of electricity by solar photovoltaic | 40 |
| 104 | Production of electricity by solar thermal | 40 |

| | | |
|---|---|---|
| 105 | Production of electricity by tide, wave, ocean | 40 |
| 106 | Production of electricity by Geothermal | 40 |
| 107 | Production of electricity nec. | 40 |
| 108 | Transmission of electricity | 40 |
| 109 | Distribution and trade of electricity | 40 |
| 110 | Manufacture of gas; distribution of gaseous fuels through mains | 41 |
| 111 | Steam and hot water supply | 41 |
| 112 | Collection, purification and distribution of water | 41 |
| 113 | Construction | 42 |
| 114 | Re-processing of secondary construction material into aggregates | 42 |
| 115 | Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motorcycle parts and accessories | 48 |
| 116 | Retail sale of automotive fuel | 44 |
| 117 | Wholesale trade and commission trade, except motor vehicles and motorcycles | 44 |
| 118 | Retail trade, except motor vehicles and motorcycles; repair of personal and household goods | 44 |
| 119 | Hotels and restaurants | 45 |
| 120 | Transport via railways | 43 |
| 121 | Other land transport | 43 |
| 122 | Transport via pipelines | 43 |
| 123 | Sea and coastal water transport | 43 |
| 124 | Inland water transport | 43 |
| 125 | Air transport | 43 |
| 126 | Supporting and auxiliary transport activities; activities of travel agencies | 43 |
| 127 | Post and telecommunications | 48 |
| 128 | Financial intermediation, except insurance and pension funding | 48 |
| 129 | Insurance and pension funding, except compulsory social security | 48 |
| 130 | Activities auxiliary to financial intermediation | 48 |
| 131 | Real estate activities | 48 |
| 132 | Renting of machinery and equipment without operator and of personal and household goods | 46 |
| 133 | Computer and related activities | 48 |
| 134 | Research and development | 47 |
| 135 | Other business activities | 48 |
| 136 | Public administration and defense; compulsory social security | 48 |
| 137 | Education | 48 |
| 138 | Health and social work | 48 |

| | | |
|---|---|---|
| 139 | Incineration of waste: Food | 48 |
| 140 | Incineration of waste: Paper | 48 |
| 141 | Incineration of waste: Plastic | 48 |
| 142 | Incineration of waste: Metals and Inert materials | 48 |
| 143 | Incineration of waste: Textiles | 48 |
| 144 | Incineration of waste: Wood | 48 |
| 145 | Incineration of waste: Oil/Hazardous waste | 48 |
| 146 | Biogasification of food waste, incl. land application | 48 |
| 147 | Biogasification of paper, incl. land application | 48 |
| 148 | Biogasification of sewage sludge, incl. land application | 48 |
| 149 | Composting of food waste, incl. land application | 48 |
| 150 | Composting of paper and wood, incl. land application | 48 |
| 151 | Wastewater treatment, food | 48 |
| 152 | Wastewater treatment, other | 48 |
| 153 | Landfill of waste: Food | 48 |
| 154 | Landfill of waste: Paper | 48 |
| 155 | Landfill of waste: Plastic | 48 |
| 156 | Landfill of waste: Inert/metal/hazardous | 48 |
| 157 | Landfill of waste: Textiles | 48 |
| 158 | Landfill of waste: Wood | 48 |
| 159 | Activities of membership organization nec. | 48 |
| 160 | Recreational, cultural and sporting activities | 48 |
| 161 | Other service activities | 48 |
| 162 | Private households with employed persons | 48 |
| 163 | Extra-territorial organizations and bodies | 48 |

468 Table S16 Sector classification for original China's MRIO

| No. | Disaggregated Sector of China-GMRIO | No. | Original Sector Name of CMRIO |
|---|---|---|---|
| 1 | Cereal | | |
| 2 | Nuts, vegetables, fruits | | |
| 3 | Oil-bearing crops | | |
| 4 | Sugar crops | | |
| 5 | Fibers | 1 | Agriculture, forestry, animal husbandry & fishery |
| 6 | Other crops | | |
| 7 | Animal husbandry | | |
| 8 | Forestry | | |
| 9 | Fishery | | |
| 10 | Coal | 2 | Mining and washing of coal |
| 11 | Oil | | |
| 12 | Natural gas | 3 | Extraction of petroleum and natural gas |
| 13 | Other petroleum and gaseous materials | | |
| 14 | Iron ores | | |
| 15 | Copper | | |
| 16 | Nickel | | |
| 17 | Bauxite | 4 | Mining of metal ores |
| 18 | Precious metal | | |
| 19 | Lead, zinc, tin | | |
| 20 | Other non-ferrous metal | | |
| 21 | Stone | | |
| 22 | Quarrying of sand and clay | 5 | Mining and processing of nonmetal ores and other ores |
| 23 | Chemical, fertilizer and salt, other quarrying | | |
| 24 | Manufacture of foods and tobacco | 6 | Manufacture of foods and tobacco |
| 25 | Manufacture of textiles | 7 | Manufacture of textiles |
| 26 | Manufacture of textile wearing apparel, footwear, caps, leather, fur, feather(down) and its product | 8 | Manufacture of textile wearing apparel, footwear, caps, leather, fur, feather(down) and its product |
| 27 | Processing of timbers and manufacture of furniture | 9 | Processing of timbers and manufacture of furniture |
| 28 | Papermaking, printing, and manufacture of articles for culture, education and sports activities | 10 | Papermaking, printing, and manufacture of articles for culture, education and sports activities |
| 29 | Processing of petroleum, coking, processing of nuclear fuel | 11 | Processing of petroleum, coking, processing of nuclear fuel |
| 30 | Chemical industry | 12 | Chemical industry |
| 31 | Manufacture of nonmetallic mineral products | 13 | Manufacture of nonmetallic mineral products |
| 32 | Smelting and rolling of metals | 14 | Smelting and rolling of metals |

| | | | |
|---|---|---|---|
| 33 | Manufacture of metal products | 15 | Manufacture of metal products |
| 34 | Manufacture of general-purpose and special-purpose machinery | 16 | Manufacture of general-purpose and special-purpose machinery |
| 35 | Manufacture of transport equipment | 17 | Manufacture of transport equipment |
| 36 | Manufacture of electrical machinery and equipment | 18 | Manufacture of electrical machinery and equipment |
| 37 | Manufacture of communication equipment, computer, and other electronic equipment | 19 | Manufacture of communication equipment, computer, and other electronic equipment |
| 38 | Manufacture of measuring instrument and machinery for cultural activity & office work | 20 | Manufacture of measuring instrument and machinery for cultural activity & office work |
| 39 | Other manufacture | 21 | Other manufacture |
| 40 | Production and supply of electric power and heat power | 22 | Production and supply of electric power and heat power |
| 41 | Production and distribution of gas and water | 23 | Production and distribution of gas and water |
| 42 | Construction | 24 | Construction |
| 43 | Traffic, transport, and storage | 25 | Traffic, transport, and storage |
| 44 | Wholesale and retail trades | 26 | Wholesale and retail trades |
| 45 | Hotels and catering services | 27 | Hotels and catering services |
| 46 | Leasing and business services | 28 | Leasing and business services |
| 47 | Research and experimental development | 29 | Research and experimental development |
| 48 | Other services | 30 | Other services |

In this study, we include 48 regions and countries and 30 provinces in China (including four direct-administered municipalities: Beijing, Shanghai, Tianjin, and Chongqing) as shown in Table S17. Tibet, Hong Kong, Macao and Taiwan are not included for analysis yet given to data availability and methodological consistency.

Table S17 Regions included in China-GMRIO

| No. | Country and region | No. | Provinces in China |
|---|---|---|---|
| 1 | Austria | 49 | Beijing |
| 2 | Belgium | 50 | Tianjin |
| 3 | Bulgaria | 51 | Hebei |
| 4 | Cyprus | 52 | Shanxi |
| 5 | Czech Republic | 53 | Inner Mongolia |
| 6 | Germany | 54 | Liaoning |
| 7 | Denmark | 55 | Jilin |
| 8 | Estonia | 56 | Heilongjiang |
| 9 | Spain | 57 | Shanghai |
| 10 | Finland | 58 | Jiangsu |
| 11 | France | 59 | Zhejiang |

| | | | |
|---|---|---|---|
| 12 | Greece | 60 | Anhui |
| 13 | Croatia | 61 | Fujian |
| 14 | Hungary | 62 | Jiangxi |
| 15 | Ireland | 63 | Shandong |
| 16 | Italy | 64 | Henan |
| 17 | Lithuania | 65 | Hubei |
| 18 | Luxembourg | 66 | Hunan |
| 19 | Latvia | 67 | Guangdong |
| 20 | Malta | 68 | Guangxi |
| 21 | Netherlands | 69 | Hainan |
| 22 | Poland | 70 | Chongqing |
| 23 | Portugal | 71 | Sichuan |
| 24 | Romania | 72 | Guizhou |
| 25 | Sweden | 73 | Yunnan |
| 26 | Slovenia | 74 | Shaanxi |
| 27 | Slovak Republic | 75 | Gansu |
| 28 | United Kingdom | 76 | Qinghai |
| 29 | United States | 77 | Ningxia |
| 30 | Japan | 78 | Xinjiang |
| 31 | Canada | | |
| 32 | South Korea | | |
| 33 | Brazil | | |
| 34 | India | | |
| 35 | Mexico | | |
| 36 | Russian Federation | | |
| 37 | Australia | | |
| 38 | Switzerland | | |
| 39 | Turkey | | |
| 40 | Taiwan, China | | |
| 41 | Norway | | |
| 42 | Indonesia | | |
| 43 | South Africa | | |
| 44 | RoW Asia and Pacific | | |
| 45 | RoW America | | |
| 46 | RoW Europe | | |
| 47 | RoW Africa | | |
| 48 | RoW Middle East | | |

476

Table S18 Classification for sector aggregation for analysis

| No | Sectors in Chinese-GMRIO | Aggregated sector for analysis |
|---|---|---|
| 1 | Cereal | Agriculture & Food |
| 2 | Nuts, vegetables, fruits | Agriculture & Food |
| 3 | Oil-bearing crops | Agriculture & Food |
| 4 | Sugar crops | Agriculture & Food |
| 5 | Fibers | Agriculture & Food |
| 6 | Other crops | Agriculture & Food |
| 7 | Animal husbandry | Agriculture & Food |
| 8 | Forestry | Agriculture & Food |
| 9 | Fishery | Agriculture & Food |
| 10 | Coal | Extraction & Mining |
| 11 | Oil | Extraction & Mining |
| 12 | Natural gas | Extraction & Mining |
| 13 | Other petroleum and gaseous materials | Extraction & Mining |
| 14 | Iron ores | Extraction & Mining |
| 15 | Copper | Extraction & Mining |
| 16 | Nickel | Extraction & Mining |
| 17 | Bauxite | Extraction & Mining |
| 18 | Precious metal | Extraction & Mining |
| 19 | Lead, zinc, tin | Extraction & Mining |
| 20 | Other non-ferrous metal | Extraction & Mining |
| 21 | Stone | Extraction & Mining |
| 22 | Quarrying of sand and clay | Extraction & Mining |
| 23 | Chemical, fertilizer and salt, other quarrying | Extraction & Mining |
| 24 | Manufacture of foods and tobacco | Manufacturing |
| 25 | Manufacture of textiles | Manufacturing |
| 26 | Manufacture of textile wearing apparel, footwear, caps, leather, fur, feather(down) and its product | Manufacturing |
| 27 | Processing of timbers and manufacture of furniture | Manufacturing |
| 28 | Papermaking, printing and manufacture of articles for culture, education and sports activities | Manufacturing |
| 29 | Processing of petroleum, coking, processing of nuclear fuel | Manufacturing |
| 30 | Chemical industry | Manufacturing |
| 31 | Manufacture of nonmetallic mineral products | Manufacturing |
| 32 | Smelting and rolling of metals | Manufacturing |
| 33 | Manufacture of metal products | Manufacturing |
| 34 | Manufacture of general-purpose and special-purpose machinery | Manufacturing |
| 35 | Manufacture of transport equipment | Manufacturing |
| 36 | Manufacture of electrical machinery and equipment | Manufacturing |

| | | |
|---|---|---|
| 37 | Manufacture of communication equipment, computer, and other electronic equipment | Manufacturing |
| 38 | Manufacture of measuring instrument and machinery for cultural activity & office work | Manufacturing |
| 39 | Other manufacture | Manufacturing |
| 40 | Production and supply of electric power and heat power | Services |
| 41 | Production and distribution of gas and water | Services |
| 42 | Construction | Construction |
| 43 | Traffic, transport and storage | Services |
| 44 | Wholesale and retail trades | Services |
| 45 | Hotels and catering services | Services |
| 46 | Leasing and business services | Services |
| 47 | Research and experimental development | Services |
| 48 | Other services | Services |

## 2.5 Allocation of material extensions to CN-GMRIO sectors

For the countries and regions except for China, we use the material extensions directly from EXIOBASE v3.4 (31). As the sectors are aggregated into 48, the corresponding material extensions are allocated accordingly. For the provinces in China, the allocation of extensions to China's sectors is straightforward regarding most of the material items from the extraction (agriculture for biomass) industries. Therefore, the allocation of material extraction (agriculture for biomass) to the sector is a one-to-one exercise (31). Specifics and details are described in Table S19.

Table S19 Allocation of material extensions

| Types | Sector No. | Allocated sector |
|---|---|---|
| A.1.1.1 Cereals | 1 | Cereal |
| A.1.1.2 Fruits, roots, and tubers | 2 | Nuts, vegetables, fruits |
| A.1.1.3 Oil-bearing crops | 3 | Oil-bearing crops |
| A.1.1.4 Sugar crops | 4 | Sugar crops |
| A.1.1.5 Cotton | 5 | Fibers |
| A.1.1.6 Other crops n.e.c. | 6 | Other crops |
| A.1.2.1 Crops residues (used) | 6 | Other crops |
| A.1.2.2 Fodder crops and grazed biomass | 7 | Animal husbandry |
| A.1.3 Wood | 8 | Forestry |
| A.1.4 Wild fish catch | 9 | Fishery |
| A.2.1 Iron | 14 | Iron ores |
| A.2.2.1 Copper-gross ore | 15 | Copper |
| A.2.2.2 Nickel-gross ore | 16 | Nickel |
| A.2.2.3 Bauxite and other aluminum-gross ore | 17 | Bauxite |
| A.2.2.4 Gold and silver-gross ore | 18 | Precious metal |
| A.2.2.5 Lead, zinc and tin-gross ore | 19 | Lead, zinc, tin |

| | | |
|---|---|---|
| A.2.2.6 Other n.e.c.-gross ore | 20 | Other non-ferrous metal |
| A.3.1.1 Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate) | 21 | Stone |
| A.3.1.2 Chalk and dolomite | 21 | Stone |
| A.3.1.3 Slate | 21 | Stone |
| A.3.1.4 Limestone and gypsum | 21 | Stone |
| A.3.2.1 Sand and gravel | 22 | Quarrying of sand and clay |
| A.3.2.2 Clays and kaolin | 22 | Quarrying of sand and clay |
| A.3.3.1 Chemical minerals and other n.e.c. | 23 | Chemical, fertilizer and salt, other quarrying |
| A.3.3.2 Salt | 23 | Chemical, fertilizer and salt, other quarrying |
| A.4.1 Coal | 10 | Coal |
| A.4.2 Petroleum | 11 | Oil |
| A.4.3 Natural gas | 12 | Natural gas |
| A.4.4 Other unconventional oil and gas | 13 | Other petroleum and gaseous materials |

## 2.6 Data Availability

EXIOBASE is available at https://www.exiobase.eu.

China's Provincial MRIO is available two ways, either:

- from the data on the CD attached to the official statistical books: "W. Liu, Z. Tang, J. Chen, B. Yang (2014) China's interregional input-output tables between 30 provinces in 2010. (China Statistics Press, Beijing)"; and "W. Liu et al. (2012) Theories and practice of constructing China's interregional input-output tables between 30 provinces in 2007. (China Statistics Press, Beijing)";
- or, upon request to The Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (mriochina@igsnrr.ac.cn)

All the data sources used in the material extensions are indicated in SI Sections 2.2 and 2.3 and are openly available to researchers.

China's customs data are commercial datasets and can be requested from the authors for replication purposes only.

## 2.7 Region aggregation effects

EXIOBASE contains 43 major economies and 5 aggregated regions (i.e. Rest of Asia and Pacific, Rest of America, Rest of Europe, Rest of Africa and Rest of Middle East). The aggregation of countries to these 5 regions may have some very limited influence on the results of resources embodied in trade. The reason is that the 43 major economies in EXIOBASE which are explicitly specified account for around 90% of global gross domestic product (GDP)(31). The overall uncertainties driven by MF estimates in the 5 aggregated regions are very small since they are such a small part of the global economy. De Koning et al. (39) for instance performed an aggregation exercise, in which the 48

EXIOBASE countries and regions were further aggregated into 4 economic blocks. This changed the material footprint of the EU by just 2%, so the potential error of having 5 aggregated regions in EXIOBASE, which together count for just 10% or less of the global economy, is likely to be a fraction of this. Furthermore, the MF of Chinese provinces is dominated by extraction in China and imports from countries specifically modeled in EXIOBASE. Most provinces (26 out of 30) take less than 5% of their material demands via the embodied imports from the aggregated regions as shown in Fig. S27. There are four provinces whose MF is caused for a slightly higher part (6%-14%) by the aggregated EXIOBASE regions. Yet, even if aggregation would lead to errors of 10%, we talk about an overall error in the MF of a province of about 1%. In view of the results of de Koning et al.(39), we would expect the error introduced by geographical aggregations to be much, much lower than 10%.

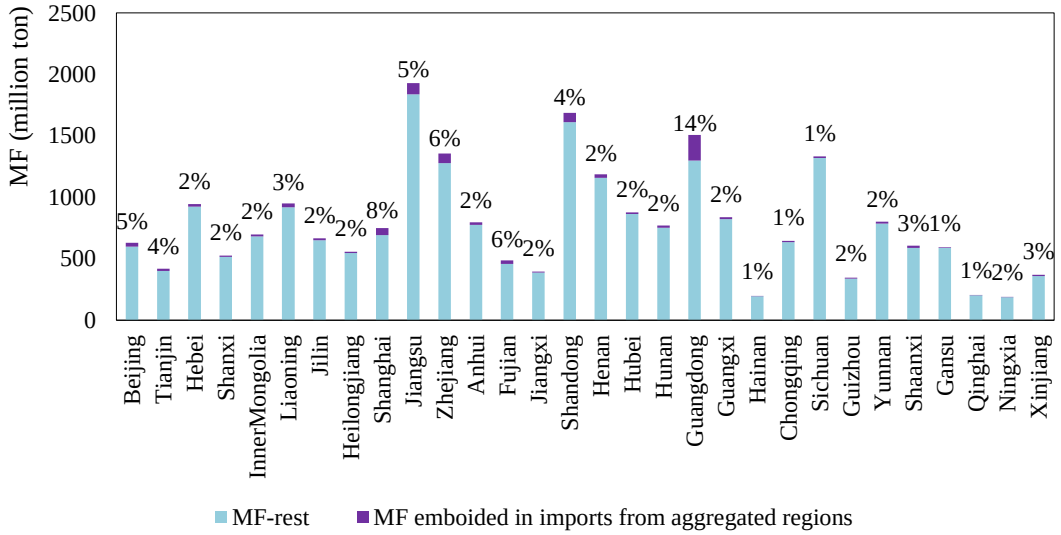



Figure S27 The proportion of MF caused by embodied imports from the five aggregated regions in the total MF (shown in percentage). All data are for 2010.

**Figure Index**

**Table Index**

## Reference


1. A. Tukker *et al.*, Environmental and resource footprints in a global context: Europe's structural deficit in resource endowments. *Glob. Environ. Change-Human Policy Dimens.* **40**, 171-181 (2016).
2. National Bureau of Statistics of China, "China statistical yearbook 2011" (National Bureau of Statistics of China, Beijing, 2011)
3. B. W. Ang, The LMDI approach to decomposition analysis: a practical guide. *Energy policy* **33**, 867-871 (2005).
4. National Development and Reform Commission of China, "The Eleventh Five-Year Plan for the Development of the Western Region" (National Development and Reform Commission of China, Beijing, 2007)
5. J. Teixidó-Figueras *et al.*, International inequality of environmental pressures: Decomposition and comparative analysis. *Ecol. Indic.* **62**, 163-173 (2016).
6. T. J. White, Sharing resources: The global distribution of the Ecological Footprint. *Ecol. Econ.* **64**, 402-410 (2007).
7. T. Wiedmann *et al.*, A carbon footprint time series of the UK–results from a multi-region input–output model. *Econ. Syst. Res.* **22**, 19-42 (2010).
8. S. Giljum, M. Bruckner, A. Martinez, Material footprint assessment in a global input‐output framework. *J. Ind. Ecol.* **19**, 792-804 (2015).
9. R. Wu, Y. Geng, W. Liu, Trends of natural resource footprints in the BRIC (Brazil, Russia, India and China) countries. *J. Clean Prod.* **142**, 775-782 (2017).
10. X. Tian, R. Wu, Y. Geng, R. Bleischwitz, Y. Chen, Environmental and resources footprints between China and EU countries. *J. Clean Prod.* **168**, 322-330 (2017).
11. H. Wang *et al.*, Exploring China's materialization process with economic transition: analysis of raw material consumption and its socioeconomic drivers. *Environ. Sci. Technol.* **48**, 5025-5032 (2014).
12. International Resource Panel, Data from "Global Material Flows Database". Available at https://www.resourcepanel.org/global-material-flows-database. Accessed 4 February, 2019.
13. F. Ma *et al.*, Material footprint of a fast-industrializing region in China, Part 1: Exploring the materialization process of Liaoning Province. *Resour. Conserv. Recycl.* **134**, 228-238 (2018).
14. Division of Development Strategy and Regional Economy of Development Research Center of China's State Council, "Social and economic analysis of mainland China" (Development Research Center of China's State Council, Beijing, 2003)
15. Eurostat, "Economy-wide material flow accounts (EW-MFA): Compilation guide 2013" (Eurostat, Luxembourg, 2013)
16. National Bureau of Statistics of China, "Training manual for resource productivity pilot survey" (National Bureau of Statistics of China, Beijing, 2012)
17. Institute for Circular Economy of Tsinghua University, "Progress report of National science and technology support project on Researches and demonstrations of key

technologies on regional circular economy development of China" (Institute for Circular Economy of Tsinghua University, Beijing, 2016)

18. China Agriculture Press, "China Agriculture Yearbook" (China Agriculture Press, Beijing, 2011)

19. China Cement Association, "China Cement Almanac" (China Building Materials Press, Beijing, 2011)

20. Editorial Office of China Mining Yearbook, "China Mining Yearbook" (Seismological press, Beijing, 2011)

21. European Aggregates Association, "Sustainable Development in the European aggregates industry for the benefits of future generations" (European Aggregates Association, Belgium, 2006)

22. China Building Material Federation, "Almanac of China Building Materials Industry" (China Building Material Federation, Beijing, 2011)

23. China Nonferrous Metals Industry Association, "China Nonferrous Metals Industry Yearbook" (China Nonferrous Metals Industry Association, Beijing, 2011)

24. National Bureau of Statistics of China, "China Rural Statistical Yearbook" (China Statistics Press, Beijing, 2011)

25. National Bureau of Statistics of China, "China Industry Economy Statistical Yearbook" (China Statistics Press, Beijing, 2011)

26. National Bureau of Statistics of China, "China Energy Statistics Yearbook" (National Statistics Press, Beijing, 2011)

27. N. Eisenmenger *et al.*, Consumption-based material flow indicators — Comparing six ways of calculating the Austrian raw material consumption providing six results. *Ecol. Econ.* **128**, 177-186 (2016).

28. A. E. Owen, Techniques for evaluating the differences in consumption-based accounts: a comparative evaluation of Eora, GTAP and WIOD (Springer, Cham, Switzerland, 2015).

29. A. Tukker *et al.*, Towards Robust, Authoritative Assessments of Environmental Impacts Embodied in Trade: Current State and Recommendations. *J. Ind. Ecol.* **22**, 585-598 (2018).

30. International Resource Panel, "Global material flows and resource productivity. An assessment study of the UNEP International Resource Panel" (United Nations Environment Programme, Paris, 2016)

31. K. Stadler *et al.*, EXIOBASE 3: Developing a time series of detailed environmentally extended multi‐regional input‐output tables. *J. Ind. Ecol.* **22**, 502-515 (2018).

32. W. Liu, Z. Tang, J. Chen, B. Yang, "China's interregional input-output tables between 30 provinces in 2010" (China Statistics Press, Beijing, 2014)

33. W. Liu *et al.*, "Theories and practice of constructing China's interregional input-output tables between 30 provinces in 2007" (China Statistics Press, Beijing, 2012)

34. A. Tukker *et al.*, Towards a global multi-regional environmentally extended input–output database. *Ecol. Econ.* **68**, 1928-1937 (2009).

35. A. Tukker *et al.*, EXIOPOL–development and illustrative analyses of a detailed global MR EE SUT/IOT. *Econ. Syst. Res.* **25**, 50-70 (2013).

36. R. Wood *et al.*, Global sustainability accounting—developing EXIOBASE for multi-regional footprint analysis. *Sustainability* **7**, 138-163 (2015).

37. A. Tukker, A. de Koning, R. Wood, S. Moll, M. C. Bouwmeester, Price corrected domestic technology assumption. A method to assess pollution embodied in trade using primary official statistics only. *Environ. Sci. Technol.* **47**, 1775-1783 (2013).

38. R. Wood *et al.*, Global sustainability accounting—developing EXIOBASE for multi-regional footprint analysis. *Sustainability* **7**, 138-163 (2014).

39. A. de Koning *et al.*, Effect of aggregation and disaggregation on embodied material use of products in input–output analysis. *Ecol. Econ.* **116**, 289-299 (2015).