Overview

In this appendix we report a variety of robustness checks. We filter the original dataset to include only those developers with a greater number of commits. We also rerun the network analysis of the main article focusing on those repos with relatively few contributors.

Filtering on number of commits

Here we report the results of our analysis when filtering for developers with at least 200 or 500 commits in the 2019-2020 period (vs. 100 in the primary article). Unless otherwise noted, differences in means are significant at $p < 0.001$ according to Mann-Whitney U tests. The purpose of this robustness test is to observe the consistency of the results among smaller, even more active subpopulations of the full data sample. Under both alternatives our results remain substantively unchanged compared with the results presented in the text.

At least 200 commits

In Table 1 we report the change in account location status comparing 2021 vs November 2022, filtering at the threshold of 200 commits. In Table 2 we report the destinations of leavers. In both cases we find results highly similar to the main results of the paper. Regarding differences in activity, we again find that leavers were previously more active than remainers (medians: 409 vs 346, means: 711 vs 547). Among developers locatable in November 2022, 12.6% left and account for 15% of all commits. Leavers have more collaboration network connections (mean 3.6 vs 1.4) and are more likely to be in the largest connected component of the 2019-2020 Russian collaboration network (17.7% vs 9.7%). Repeating the exercise of removing leavers versus removing random subsets of developers of the same size results in a similar Z-score for the entropy of the collaboration network connected component sizes: 5.2 (vs 5.6 in the main article).
| Country    | # of Developers | Profile Deleted (A) | Invalid/No Loc. (B) | % New Country (C) | A+B+C  |
|------------|-----------------|--------------------|---------------------|-------------------|--------|
| Russia     | 6866            | 2.9%               | 15.2%               | 12.6%             | 30.8%  |
| Belarus    | 902             | 3.9%               | 10.0%               | 20.0%             | 33.8%  |
| Ukraine    | 2918            | 3.9%               | 2.7%                | 4.7%              | 11.2%  |
| Estonia    | 270             | 1.5%               | 2.6%                | 8.1%              | 12.3%  |
| Latvia     | 162             | 1.2%               | 5.0%                | 3.1%              | 9.4%   |
| Lithuania  | 306             | 2.0%               | 2.0%                | 2.9%              | 6.9%   |
| Poland     | 4009            | 2.6%               | 2.5%                | 2.4%              | 7.5%   |
| Czechia    | 1472            | 1.8%               | 2.2%                | 3.5%              | 7.5%   |
| Slovakia   | 284             | 1.8%               | 3.6%                | 5.6%              | 11.0%  |
| Bulgaria   | 788             | 2.0%               | 1.7%                | 2.0%              | 5.7%   |
| Romania    | 790             | 2.3%               | 3.5%                | 3.4%              | 9.2%   |
| Hungary    | 751             | 1.2%               | 3.8%                | 3.9%              | 8.9%   |
| Serbia     | 413             | 2.9%               | 4.0%                | 4.6%              | 11.5%  |

Table 1: Data on developer account deletion, location removal, and emigration filtered on developers with at least 200 commits (vs 100 in primary analysis) in November 2022.

| Country          | Count | Pct. | Country          | Count | Pct. | Country          | Count | Pct. |
|------------------|-------|------|------------------|-------|------|------------------|-------|------|
| Russian Count Pct. Belarus Count Pct. Ukraine Count Pct. |       |      | United States 100 12% Poland 79 44% United States 26 19% |       |      | Germany 84 10% Georgia 18 10% Poland 16 12% |       |      | Georgia 61 7% Lithuania 14 8% Germany 13 10% |       |      | Netherlands 60 7% United States 12 7% Canada 10 7% |       |      | Armenia 51 6% Estonia 6 3% Russia 10 7% |       |      | Cyprus 47 5% Spain 5 3% Czechia 8 6% |       |      | United Arab Emirates 46 5% Germany 4 2% United Kingdom 7 5% |       |      | Türkiye 45 5% France 4 2% Netherlands 5 4% |       |      | Serbia 34 4% Norway 4 2% Sweden 4 3% |       |      | United Kingdom 30 3% United Kingdom 3 2% Spain 4 3% |       |      | Kazakhstan 23 3% Czechia 3 2% Italy 4 3% |       |      | Finland 20 2% Ukraine 3 2% Portugal 3 2% |       |      | Israel 17 2% Russia 3 2% Norway 2 1% |       |      | Poland 15 2% Latvia 3 2% Slovakia 2 1% |       |      | Czechia 14 2% Netherlands 2 1% China 2 1% |       |      | Montenegro 14 2% Portugal 2 1% Switzerland 2 1% |       |      | Canada 14 2% Armenia 1 1% France 2 1% |       |      | Indonesia 12 1% Türkiye 1 1% Finland 2 1% |       |      | Switzerland 12 1% Sweden 1 1% Ireland 2 1% |       |      | Estonia 10 1% United Arab Emirates 1 1% Türkiye 1 1% |       |      | |

Table 2: Destination countries for developers, considering only those with at least 200 commits (vs 100 in primary analysis).
| Country  | # of Developers | Profile Deleted (A) | Invalid/No Loc. (B) | % New Country (C) | A+B+C |
|----------|-----------------|---------------------|---------------------|-------------------|-------|
| Russia   | 2244            | 2.4%                | 19.2%               | 15.6%             | 37.2% |
| Romania  | 303             | 1.7%                | 2.7%                | 3.3%              | 7.7%  |
| Ukraine  | 882             | 2.4%                | 3.2%                | 5.9%              | 11.4% |
| Lithuania| 97              | 3.1%                | 1.1%                | 4.1%              | 8.3%  |
| Latvia   | 60              | 1.7%                | 6.9%                | 6.7%              | 15.2% |
| Slovakia | 103             | 1.9%                | 4.0%                | 7.8%              | 13.7% |
| Poland   | 1359            | 2.1%                | 2.4%                | 2.7%              | 7.2%  |
| Czechia  | 697             | 1.7%                | 2.5%                | 3.0%              | 7.2%  |
| Estonia  | 97              | 0.0%                | 3.1%                | 5.2%              | 8.2%  |
| Hungary  | 274             | 0.7%                | 3.7%                | 4.0%              | 8.5%  |
| Bulgaria | 301             | 3.0%                | 2.8%                | 2.7%              | 8.4%  |
| Belarus  | 264             | 3.4%                | 11.5%               | 25.8%             | 40.6% |
| Serbia   | 109             | 2.8%                | 5.7%                | 1.8%              | 10.3% |

Table 3: Data on developer account deletion, location removal, and emigration filtered on developers with at least 500 commits (vs 100 in primary analysis) in November 2022.

At least 500 commits  
In Table 3 we report the change in account location status comparing 2021 vs November 2022, filtering at the threshold of 500 commits. In Table 4 we report the destinations of leavers. In both cases we find results highly similar to the main results of the paper. Regarding differences in activity, we again find that leavers were previously more active than remainers (medians: 861 vs 782, means: 1,295 vs 1,124). Among developers locatable in November 2022, 15.6% left and account for 16.9% of all commits. Leavers have more collaboration network connections (mean 3.2 vs 1.1) and are more likely to be in the largest connected component of the 2019-2020 Russian collaboration network (16.3% vs 9.2%). Repeating the exercise of removing leavers versus removing random subsets of developers of the same size results in a smaller but still statistically significant ($p < .05$) Z-score for the entropy of the collaboration network connected component sizes: 2.2 (vs 5.6 in the main article).
| Russian Count Pct. | Belarus Count Pct. | Ukraine Count Pct. |
|-------------------|-------------------|--------------------|
| United States     | 36                | 10%                |
| Poland            | 31.0              | 46%                |
| United States     | 12                | 23%                |
| Germany           | 33, 9%            |                    |
| Lithuania         | 6.0, 9%           |                    |
| United Kingdom    | 5                 | 10%                |
| Poland            | 33, 9%            |                    |
| Georgia           | 5.0, 7%           |                    |
| Poland            | 5                 | 10%                |
| Cyprus            | 24, 7%            |                    |
| United States     | 4.0, 6%           |                    |
| Germany           | 4                 | 8%                 |
| United Arab Emirates | 23, 7%          |                    |
| Germany           | 4.0, 6%           |                    |
| Czechia           | 5                 | 6%                 |
| Lithuania         | 6.0, 9%           |                    |
| United States     | 6                 | 10%                |
| Germany           | 5                 | 10%                |
| Armenia           | 19, 5%            |                    |
| Estonia           | 3.0, 4%           |                    |
| Poland            | 3                 | 6%                 |
| Türkiye           | 19, 5%            |                    |
| Latvia            | 2.0, 3%           |                    |
| Italy             | 2                 | 4%                 |
| Serbia            | 12, 3%            |                    |
| Norway            | 2.0, 3%           |                    |
| Portugal          | 2                 | 4%                 |
| Georgia           | 11, 3%            |                    |
| United Kingdom    | 2.0, 3%           |                    |
| Russia            | 2                 | 4%                 |
| Kazakhstan        | 11, 3%            |                    |
| Ukraine           | 1.0, 1%           |                    |
| Slovakia          | 2                 | 4%                 |
| United Kingdom    | 10, 3%            |                    |
| Spain             | 1.0, 1%           |                    |
| Sweden            | 2                 | 4%                 |
| Switzerland       | 9, 3%             |                    |
| Armenia           | 1.0, 1%           |                    |
| Indonesia         | 1                 | 2%                 |
| Malaysia          | 8, 2%             |                    |
| Latvia            | 1.0, 1%           |                    |
| Finland           | 8                 | 2%                 |
| Kazakhstan        | 1.0, 1%           |                    |
| Malta             | 2                 | 2%                 |
| Canada            | 7, 2%             |                    |
| Czechia           | 1.0, 1%           |                    |
| Georgia           | 1                 | 2%                 |
| Indonesia         | 7, 2%             |                    |
| Cyprus            | 1.0, 1%           |                    |
| France            | 2                 | 2%                 |
| Thailand          | 6, 2%             |                    |
| Canada            | 1.0, 1%           |                    |
| Spain             | 2                 | 2%                 |
| Israel            | 6, 2%             |                    |
| Uzbekistan        | 1.0, 1%           |                    |
| Switzerland       | 2                 | 2%                 |
| Lithuania         | 5, 1%             |                    |
| Estonia           | 1                 | 2%                 |
| Finland           | 4                 | 2%                 |

Table 4: Destination countries for developers, considering only those with at least 500 commits (vs 100 in primary analysis).
Network Analysis: Excluding repos with many contributors

Here we report the results of our network analysis rerun after excluding repos with more than 10 contributors, considered globally (i.e. not restricted to Russia-based developers). The purpose of this analysis is to consider situations which can more confidently be considered as collaborations: in this subset of repos developers are much more likely to directly interact with one another. When considering those repos with at most 10 contributors, we find that Russia leavers have more connections than remainers (mean: 0.71 vs 0.51; stdev: 1.48 vs 1.21). Leavers are also more likely to be in the largest connected component (5.4% are in the LCC vs 3.3% of remainers).