VRG PROGRAM EVALUATION 2021

ACCOMPANYING RESEARCH

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Accompanying Research
VRG Program Evaluation 2021

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I. Executive Summary

This report provides results from the accompanying research to the international review panel of the WWTF Vienna Research Groups for Young Investigators (VRG) program.

Using multiple methods and data sources, namely open- and closed-ended questions in an online survey with VRG leaders, a focus group, and bibliometric analyses of VRG publications and control groups, this report aims to provide the international review panel with evidence on the program evaluation questions for their assessment, particularly with regards to the 1) attractiveness of the program for excellent young researchers, the 2) selection procedures and the program management, 3) the performance of VRG group leaders regarding publications and beyond, and 4) the embedding and career opportunities of VRG leaders in Vienna research institutions. Some results presented in this report may be outside the control of the VRG program or the WWTF but are nevertheless reported as potential determinants of the program's impact. Moreover, while some of VRG leaders' responses include suggestions or wishes for the program, the authors of this report refrain from further interpreting results or giving recommendations on the future development of the VRG grant.

The results from the qualitative and bibliometric analyses can be summarized as follows:

1) program attractiveness

— Responses by VRG leaders in the survey and focus group indicate that the grant features are **very attractive for young researchers,** particularly the **grant volume** and **duration** and the opportunity to lead one's own research group. Indeed, participants indicated that most of their expectations on the VRG program were fulfilled or exceeded, and the flexible use of resources and independence to conduct research were the most conducive factors for participants' research performance.

2) Selection procedures and program management

— VRG leaders expressed in the survey and focus group that they were **almost unconditionally satisfied with the WWTF,** its administrative procedures, and its support function. In the application phase, all steps of the application process were rated with the highest possible score by ca. 90 % of participants, including the availability of program information, the WWTF support response time, and the clarity of application guidelines.

— While VRG leaders were slightly more critical about the application evaluation phase, i.e., the transparency, speed, and quality of evaluators' feedback, **ca. 70 % of participants still gave them the highest possible rating.** Regarding the program management during the VRG project's runtime, VRG leaders were also very satisfied, particularly with the overall availability and quality of the WWTF support, where 90 % of participants gave the highest rating. In open questions and the focus group, some participants indicated that they would have wished for the WWTF to have more influence over the host institutions, and that they would have appreciated more opportunities for exchange with other VRG leaders, particularly in the earlier stages of the grant.

— Overall, the results on program management and administration compare very favourably with similar grant programs' evaluations, such as the START program by the FWF (Seus et al., 2016).

3) VRG leaders' performance

— In the survey, most VRG leaders chose highly ranked publications as the most important achievement within the VRG project. Indeed, as the bibliometric analyses of VRG leaders suggest, **publications by VRG research groups are characterised by a high citation impact** and an overall successful publication strategy mostly comparable to ERC Starting Grant recipients and better than rejected VRG applicants and the Austrian average. However, bibliometric indicators exhibit a decline in the second period (2016—2020), possibly through a shift in the research fields.

— Apart from publications, VRG leaders expressed high satisfaction with their teaching and mentoring activities.

— Moreover, most participants indicated in the survey that they could successfully expand their research network internationally and in Vienna and that **the grant was able to advance their performance and career,** particularly with regards to **high-ranking positions in academia and a long-term perspective in Vienna.**

— As the most severe challenges to their performance, VRG leader named frictions with the host institution, issues with hiring the right candidates for pre- and postdoc positions, and the teaching and administrative workload, where VRG leaders would have wished for slightly more time allocated to research, and less to administration and teaching, particularly due to the COVID19 crisis causing administrative overhead and additional time spent on implementing courses online.

4) The embedding of group leaders in the host institution

— VRG leaders expressed mixed views in the survey. While 63 % of VRG leaders indicated that to a large extent they experienced a conducive research environment at the host institution, many felt that support, particularly for teaching and hiring, was lacking. Discussions in the focus group confirmed these results and underlined that the embedding can indeed vary from institution to institution and researcher to researcher. **In this respect, some VRG leaders would have wished for a stronger influence of the WWTF and the grant agreement on the host institution** to mandate a better onboarding procedure and fewer administrative obstacles.

— With regards to the sustainability of the research group at the host institution, **13 VRG leaders from the selected candidates between 2010 and 2019 are still employed at their host institution.**

— Those who have left Vienna identified better career opportunities and funding options as the main drivers for their decision. In this respect, answers to open questions and discussions in the focus group revealed that **some VRG leaders perceived the endowment for tenure track professors in Austria as too low compared to full professorships**, which they perceived as an important cause of uncertainty about the long-term career at the host institution.

Self-Evaluation Report by WWTF Office

Report by International Review Panel

II. Introduction

2.1. Background

This report has been prepared by AIT – Austrian Institute of Technology GmbH in close collaboration with the Katholieke Universiteit Leuven. The study aims to provide evidence to the international review panel of the WWTF Vienna Research Group (VRG) program about the contribution of the WWTF VRG program towards achieving the objectives of the VRG program, specifically regarding 1) the attractiveness of the program, 2) selection procedures and program management, 3) performance of VRG group leaders, and 4) the embedding of group leaders in the host institution.

To support the evaluation process, this study provides the international review panel with the following empirical analyses:

— A qualitative assessment of VRG leaders' experiences through an online survey and a focus group with VRG leaders from different disciplines
— A comparative bibliometric analysis of the performance of the VRG group leaders
— Bibliometric screening of emerging research fields

Whereas the qualitative assessment mainly provides information on the attractiveness of the program, the efficiency of program implementation, impacts on the career prospects and framework conditions for grantees in Vienna, the bibliometric analyses of the VRG program focuses on objective performance indicators with regards to the publication and citation impact.

This background study does not provide a description of the VRG program, its objective, and participation patterns, as these are provided in-depth in the self-evaluation report of the WWTF (WWTF 2021).

[1] Two VRG leaders had to be excluded from the sampling frame as one VRG leader deceased and another VRG leader left Vienna already after half a year.

2.2 Methodological Approach

Qualitative analysis

An online survey among VRG leaders provided the main empirical basis for the qualitative analysis. The survey was performed in May 2021 and achieved to collect complete information from 19 out of 20 VRG leaders in the sampling frame[1]. Using multiple choice items, ranking tasks, and open questions, the survey addressed the following topics based on the goals of the VRG program:

1) Attractiveness of the program:
— Motivation to apply for a VRG grant
— Conducive factors for research performance
— Working time

2) Selection procedures and program management:
— Application process
— Program management

3) Performance of VRG group leaders:
— Most important achievements
— Research network
— Career impact
— Challenges for research performance

4) Embedding of group leaders in the host institution:
— Collaboration with the proponent
— Support from the host institution
— Research environment at the host institution
— Sustainability of the research group
— Change at the host institution

The results of the online survey have been validated and enriched by additional qualitative information through a group interview with seven VRG program leaders from different fields of science hosted in different institutions of the Viennese research system. The group

interview was performed online on 28/06/2021 with a focus on more detailed discussion of the strengths, weaknesses, opportunities, and threats that have been raised by the VRG grantees in the survey.

Quantitative analysis

The quantitative analysis comprises a bibliometric study on the publications of VRG projects using a set of suitable performance indicators. The identification of the relevant publication set was set up as follows: WWTF provided a list of 20 granted projects. Each of the 633 references was matched against an online version of Web of Science Core Collection (WoS). In addition to this initial matching, a search based on VRG funding acknowledgements and grant information provided in publications in the WoS Core Collection was performed. Whenever possible, additional publications were assigned to the VRG projects. The search process resulted in a matched publication output (see table 1), which formed the basis for the bibliometric analysis.

Two control groups for benchmarking the program have been chosen to compare the performance of the VRG program: 1) rejected VRG applicants and 2) Austrian ERC Starting Grant beneficiaries since 2010 in the fields of life sciences, mathematics, and ICT.

The rationale to use a selection of rejected VRG applicants as a control group was to approximate the causal effect of the VRG funding on the VRG leaders.

It included 23 principal investigators whose VRG project proposal were not accepted but included in the 'Hearing' and 'Reserve list' of the last stage of the selection process across all key program areas. As the VRG program aims to fund excellent academics, this group can also be expected to consist of highly performing individuals from abroad with the intention to lead a research group in Austria. A comparison to the general population of researchers within the target group would yield biased results due to the selection of applicants. Rejected applicants represent a frequently used control group in the field of RTI evaluations as they are likely to be comparable in terms of characteristics to the successful applicants and, thus, help to ameliorate the confounding problem of the selection process.

The rationale to include the ERC starting grant holders in WWTF key areas was to include a program which has many commonalities with the VRG program and that funded a similar number of recipients in Austria. Key characteristics of the VRG program and the ERC Starting grant are provided in Table 2.

In addition to the two comparison groups outlined above, two more benchmarks were used in the bibliometric analysis:
1) bibliometric indicators were normalised based on sub-field and journal assignment and 2) the performance of Austria in the WWTF key areas was used as national benchmark.

Table 1: Matched publication output

Publication type	Output Count	WoS Matched Count
Accepted conference/workshop contribution	220	6
Book Chapter	14	4
Conference proceeding	79	21
Edited Volume	5	1
Journal paper	297	254
Monograph/Book	5	0
Other (please specify)	13	0

Table 2: Key characteristics of WWTF VRG and ERC Starting Grant

	WWTF VRG program	ERC Starting Grant
Period	2010—present	2007—present
Location of host institution	Vienna	any EU Member State and Associated Country
Level	2—8 years after PhD	2—7 years after PhD
Number of funded persons	1 PI (international) plus team members	1 PI plus team members
Max. duration	8 years	5 years
Max. funding	€ 1.6 million (€ 1.5 million before 2014)	€ 1.5 million (+ € 1 million "start-up" costs)
Funding principle	specific calls in WWTF key areas	"bottom-up" without priorities
Data availability	detailed information is available	publications and beneficiaries publicly available

III. Qualitative results

This section presents results from the responses of
VRG leaders in the online survey and in the focus group as
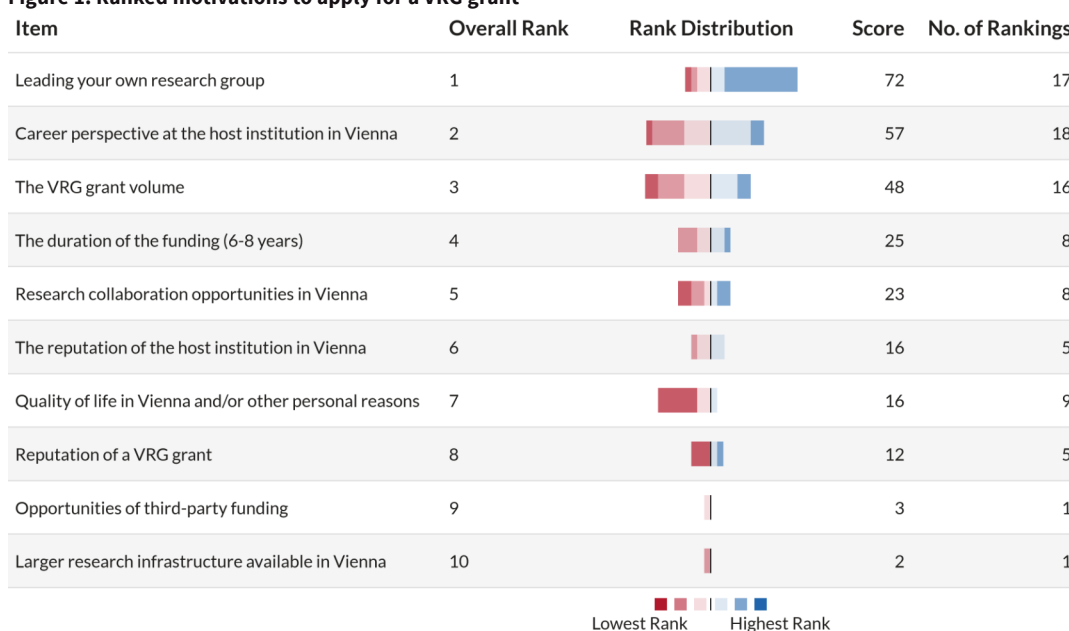described in section 1.2.

3.1. Attractiveness of the program

Motivation to apply for a VRG grant

To assess VRG leaders' motivations to apply for a VRG grant, participants were asked to rank their top five motivations to apply out of 10 options (see Figure 1). As their primary motivations, most participants selected the opportunity to lead one's own research group, followed by career perspectives at Vienna host institutions and the VRG grant volume.
The research infrastructure in Vienna and opportunities for third-party funding were considered less critical and were each selected by only one participant.

Similarly, when asked about their expectations on six potential outcomes of the VRG program (see Figure 2 on page 9, orange points), participants had the highest expectations on their independence as researchers and on their career perspective. Overall, expectations appear to have been fulfilled or exceeded (see Figure 2, blue points). However, there appears to be a slight negative mismatch between expectations and experience regarding the career perspective.

Figure 1: Ranked motivations to apply for a VRG grant

Item	Overall Rank	Rank Distribution	Score	No. of Rankings
Leading your own research group	1		72	17
Career perspective at the host institution in Vienna	2		57	18
The VRG grant volume	3		48	16
The duration of the funding (6-8 years)	4		25	8
Research collaboration opportunities in Vienna	5		23	8
The reputation of the host institution in Vienna	6		16	5
Quality of life in Vienna and/or other personal reasons	7		16	9
Reputation of a VRG grant	8		12	5
Opportunities of third-party funding	9		3	1
Larger research infrastructure available in Vienna	10		2	1

Lowest Rank　　Highest Rank

Notes: This figure shows responses to survey questions "What were your main reasons for applying for your VRG project? Please rank up to 5 key reasons according to their priority." The ranking "Score" is computed as the sum of weighted values associated with an answer category. The weighted values are inversely related to the rank, e.g. if an option is ranked first it is weighted by a factor 5 while rank 2 is weighted by a factor 4, etc.

Figure 2: Expectations on the VRG program
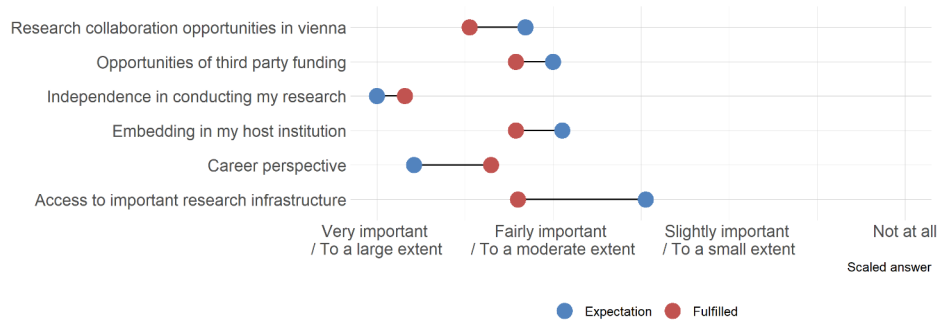
Notes: This figure shows mean responses to the questions "What were the most important expectations that you had before coming to Vienna?" (rated on a 4-point scale from *very important* to *not at all important*) and "To what extent have these expectations been fulfilled?" (rated on a 4-point scale from *to a large extent* to *not at all*).

Conducive factors for research performance

Asked to rank the five most conducive factors for their research performance out of nine options (see figure 3), most participants picked the flexibility of the use of resources and their independence in conducting their research as the most important factors. Additional resources provided by the host institution and the embedding in the host institution were perceived as least important among the presented options, being picked by only 2 and 5 participants, respectively.

Figure 3: Ranking of most conducive factors for the research performance of VRG leaders

Item	Overall Rank	Rank Distribution	Score	No. of Rankings
Independence of conducting my research including selecting my group members	1		60	15
Flexibility of the use of resources of the VRG grant	2		60	16
The VRG grant size	3		49	14
The duration of the funding (6-8 years)	4		25	10
Adequate balance between administrative / teaching tasks and research	5		22	8
Career perspective	6		20	6
Research collaboration opportunities in Vienna	7		18	7
Embedding in my host institution i.e. teaching, platforms, doctoral schools, support, etc	8		6	5
Additional resources provided by my host institution	9		2	2

Lowest Rank Highest Rank

Notes: This figure shows responses to the survey question "Which of the following characteristics of the VRG grant have been most conducive for your research performance? Please rank up to 5 key aspects according to your priority." The ranking "Score" is computed as the sum of weighted values associated with an answer category. The weighted values are inversely related to the rank, e.g., if an option is ranked first it is weighted by the factor 5, rank 2 is weighted by the factor 4, etc.

Working time

Participants were asked to indicate the actual percentage of their working time spent on research, teaching and supervision, and administration as well as the ideal distribution of their work time on the same three categories. As shown in Figure 4, on average, VRG leaders would wish for slightly less workload in administration (6 instead of 16 %) and teaching (32 instead of 38 %) and focus more on research (62 instead of 45 %).

These results are also mirror results in Figure 10 in Section 3.3, which shows that 7 out of 19 respondents perceived the teaching and administrative load as one of the three main barriers for their research performance. As indicated in responses to open questions by some participants, the COVID19 crisis also appears to have led to an increased burden on translating courses to an online mode and shift administrative process to accommodate remote work.

## 3.2 Selection procedures and program management

Application process

Participants were asked to rate 11 aspects of the quality of WWTF services and support in the VRG application phase on a 5-point scale from very good to unsatisfactory (see Figure 5). Overall, VRG leaders were remarkably satisfied with the application process, with the response time of the WWTF and the hearing format and process receiving the highest scores. On average, participants were most critical about the evaluation phase, whose transparency, speed, and feedback quality were rated less than very good by ca. 30 % of participants.

Figure 4: Ranking of most conducive factors for the research performance of VRG leaders
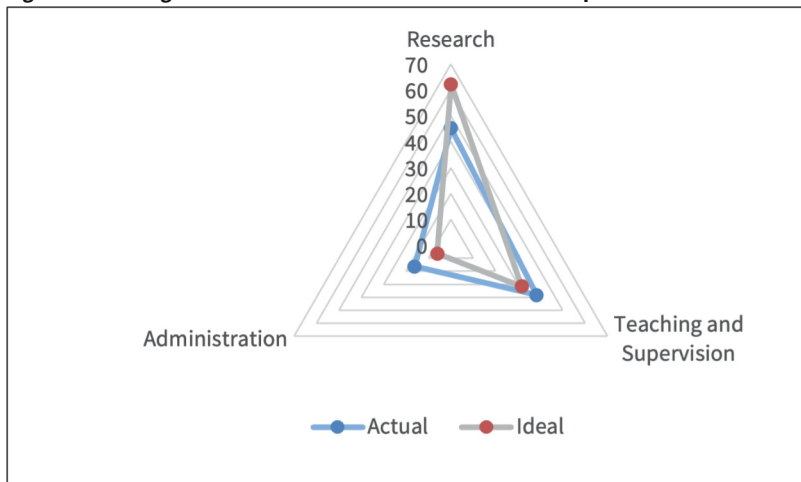
Figure 5: Quality of the administrative procedures in the application phase
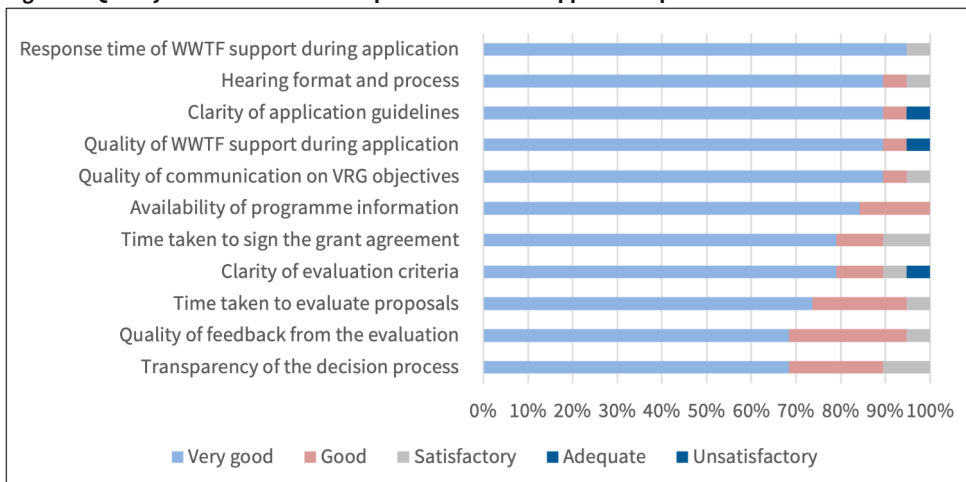
Notes: This figure shows responses to the survey question "Please rate the quality of WWTF services and support in the VRG application phase." Bar colours represent the proportion of the respective answer category.

Program management

With regards to administrative procedures by the WWTF during the runtime of the project, participants appeared to be highly satisfied (see Figure 6): With few exceptions, participants indicated a very good quality and availability of WWTF support, and highly appropriate reporting requirements. Moreover, all of the 18 comments entered into the textboxes were positive. Most comments pointed out that the WWTF was always quick and helpful in clarifying administrative questions, and very supportive with issues that arose with the host institution. Suggestions for improvement focused mainly on issues with Austrian (host) institutions, where some participants would wish that the WWTF could exert more influence on the host institutions.

These results were discussed in more detail in the focus group, where all participants agreed that the support from and interactions with the WWTF were excellent in all regards, with little administrative overhead and helpful personal contact with WWTF representatives.

Regarding social activities, some participants appear to have wished for more social and networking activities particularly in the early stages of the grant. In the focus group, one VRG leader suggested establishing a VRG wide "junior platform", in which new VRG leaders can profit from the experience of others.

3.3 Performance of the VRG group leaders
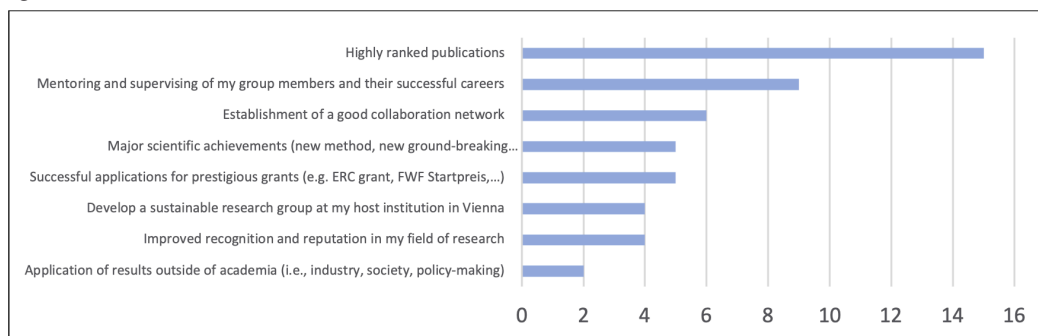
Most important achievements

In the online survey, VRG leaders were asked to choose their top three most important achievements out of 8 options (see Figure 7) and mention additional examples. Highly ranked publications were chosen as a main achievement by 15 respondents. Examples provided by the participants include a publication in Nat. Microbiology, the release of a book on Knowledge Graphs, and influential contributions to conferences. The performance of VRG group leaders as measured by the quality and impact of their scientific publications is captured in the accompanying bibliometric reports.

Figure 6: Quality of the administrative procedures during the project runtime
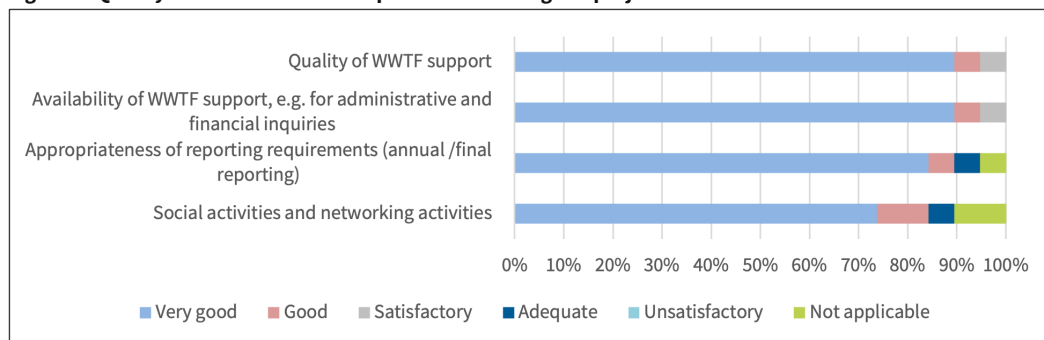
Notes: This figure shows responses to the survey question "How satisfied are you with the administrative procedures of WWTF during the runtime of the project?" Bar colours represent the proportion of the respective answer category.

Figure 7: Most important achievements by VRG leaders

Notes: This figure shows selection frequencies of the answer options to the survey question "From your point of view, what were your most important achievements within the VRG project as of today (three options possible)?"

The second most frequently mentioned achievement was mentoring and supervising group members. In the open-format answers, several VRG leaders emphasized that the success of the team members became one of the main success criteria.

Another frequently mentioned dimension was the extension of the research network. Asked about the extent that the programme enabled the VRG leader to increase their research network, respondents highlighted the larger scientific network in Vienna and internationally (see Figure 8).

An important aspect of the research network mentioned during interviews and in the open survey questions was the supervision of PhD candidates and postdocs, who would expand the network after leaving the VRG group. A more divided picture emerges regarding recognition in the public sphere.

VRG leaders report on their public outreach activities on an annual basis.

The statistic shows that among the 164 reported publication outreach activities, covering media co-operations, public events, and exhibitions, a major share falls on few VRGs with a strong focus on public communication.

The findings from the survey are reflected in the annual reports of the VRG leaders showing large numbers of academic co-operations within Vienna (52) and internationally (124), as shown in Table 3. Applications of results outside academia play a more limited role overall. However, in open answers, two VRG projects mentioned success stories regarding their impact outside of academia, namely successful collaborations with industrial research labs, and two patents.

Figure 8: Extension of the research network and recognition
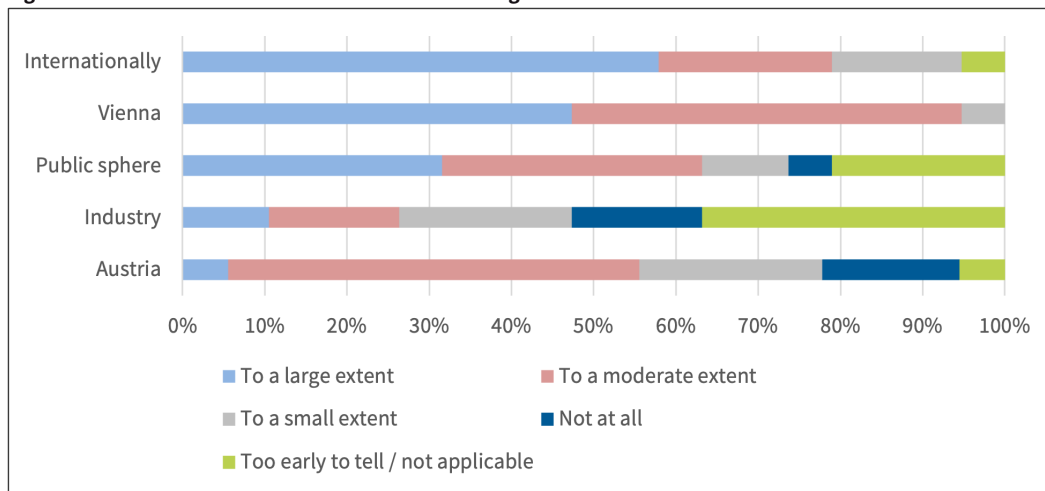
Notes: This figure presents responses to the survey question "To which extent has the VRG enabled you to increase your research network?" Bar colours represent the proportion of the respective answer category.

Table 3: New academic co-operation

	International	National	Within Vienna	Total
Consulting /Advice	3		2	5
Exchange of data and/or materials	15		5	20
Other	2		1	3
Research project	99	7	43	149
Technical cooperation/ support	5		1	6
Total	124	7	52	183

Source: Annual WWTF reporting.

Career Impact

Structural career effects such as academic career progression and the acquisition of prestigious additional grants is discussed in the Self-Evaluation Report of the WWTF. This sub-section focusses on the results of the qualitative data collection and subjective assessment of career effects by the VRG leaders.

Figure 9 highlights that the major subjective career effects are related to high-ranking positions in academia, long-term career perspectives at the host institution and roles as speakers at conferences. To a lesser degree, the access to research infrastructure and other career aspects were enabled by the programme.

A VRG leader responded that, compared to other countries, the research landscape in Austria is relatively small. The VRG grant provided them with access to the sphere of scientific leaders, for example through invitations to dinners, presentations, award ceremonies etc. Others mentioned the importance of the long-term perspective on their personal life and dual career, the confidence it gave them to apply for additional grants, and the increased research network.

Evidence from the focus group discussion and open responses to the question how the VRG grant helped to progress in their career elucidate additional aspects mostly relating to the career perspective at the host institution which is presented in section 3.4.

Challenges for research performance

In the survey, VRG leaders were asked to list their three main challenges and barriers for research performance. The open answers were categorised by the study team and highlighted three central aspects, namely hiring talented pre- and postdocs, frictions with the host institution, and teaching and administrative load (see Figure 10).

Regarding hiring, respondents mentioned the recruiting, onboarding, and career development of their research group members as challenging. However, opinions in the focus interviews showed a more differentiated picture. In particular, VRG leaders that could leverage the connection to an existing doctoral school were successful in jointly recruiting candidates and applying for doctoral school grants such as the FWF Doktoratskolleg. While the COVID19 crisis made physical collaborations more difficult and increased overhead costs, some VRG

Figure 9: Career advancement through the VRG grant
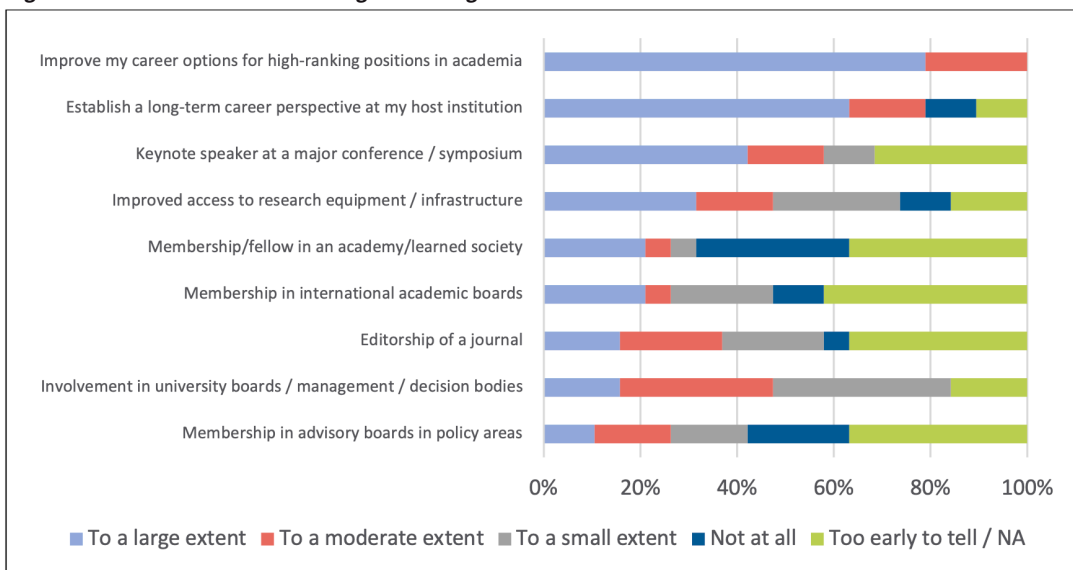
Notes: This figure presents responses to the survey question "To which extent has the VRG grant enabled you to advance your career?" Bar colours represent the proportion of the respective answer category.

leaders saw some benefits in the increased trend towards working remotely as it made it possible to recruit more widely.

Frictions with the host institutions included lacking research infrastructure, limited long-term perspective and, in one case, the failure of the host institution to provide promised in-kind contributions. Nevertheless, 63 % of respondents indicated that the research environment at their host institution was to a large extent conducive for pursuing the planned activities of the VRG grant. Further aspects are discussed in the following section 'Embedding of group leaders in the host institution'.

3.4 Embedding of group leaders in the host institution

Collaboration with the proponent

The proponent from the Viennese host institution applies in tandem with the VRG candidate to the WWTF. Beyond the application and starting phase, the VRG programme does not foresee an explicit role or obligation of the proponent as the independence of the group leader is the priority. Some universities offer mentorship programmes, and several qualifying agreements include explicit mentorship roles. In some cases, the role of the mentor and the role of the proponent coincide. Hence, the role of the proponent varies between VRG projects.

20 % of VRG leaders collaborated with their proponent before applying for the VRG grant and almost all VRG leaders characterize the cooperation with the proponent in the application and starting phase as excellent and very supportive. In many cases the proponent initiated the idea to apply for the VRG grant.

Research environment at the host institution

Overall, respondents' view on the research environment at the host institutions is relatively positive, but responses include several distinctly negative experiences. 63% of VRG leaders indicated that the research environment at the host institution was to a large extent conducive for pursuing their planned activities, 16 % responded to a moderate extent, and 11 % each responded to a small extent or too early to say. Several VRG leaders highlighted that the support in recruitment was essential, synergies at the host institution were conducive, and the infrastructure was excellent.

As to the most negative experiences, one VRG leader commented that the institution lacked the understanding how to foster excellent research, and one remarked that they experienced discriminatory treatment and were not provided with the promised equipment.

Figure 10: Greatest challenges during the VRG grant
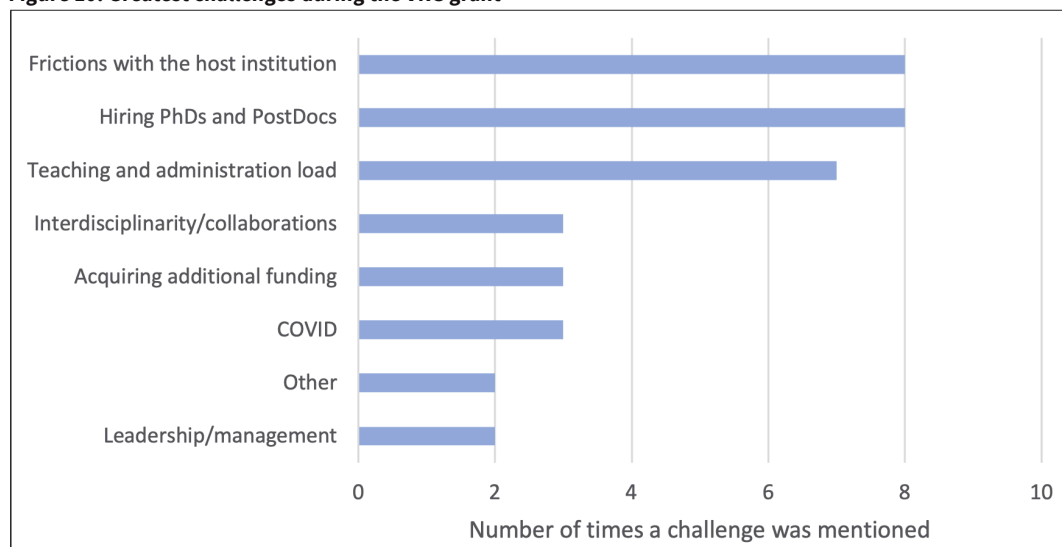
Notes: This figure shows the frequency of open answers to the survey question "What were the three greatest challenges during your VRG grant?" as categorized by the study team.

Discussion in the focus group confirmed these heterogenous experiences by the VRG leaders. While some participants were completely satisfied with their host institutions, others reported being completely left out of decisions and receiving little support.

With respect to different aspects of host institutions' support, responses show a mixed picture (see Figure 11). For example, more than half of all VRG leaders indicated receiving only limited support regarding teaching or hiring.

Sustainability of the research group

As listed in the Self-Evaluation report of the WWTF, 13 of the 21 selected candidates between 2010-2019 are still at the host institution with which they applied for the VRG programme and, and 14 are still in Vienna.

While two VRG research groups grew or remained the same size , others decreased in size.

For those group leaders moving away from Vienna, better career prospects, more generous or easily accessible funding opportunities, and basic funding for the research group by the host institution were the main reasons for moving to a new location outside Vienna (see Figure 12 on page 16).

One of the main aspects, which was also highlighted in the focus group discussion, related to the endowment of professors in the tenure track model. Several VRG leaders saw the tenure track professorship as less attractive than externally recruited full professorships due to lower endowment leading to high insecurity about the period after the end of the VRG grant.

Figure 11: Support from the host institution
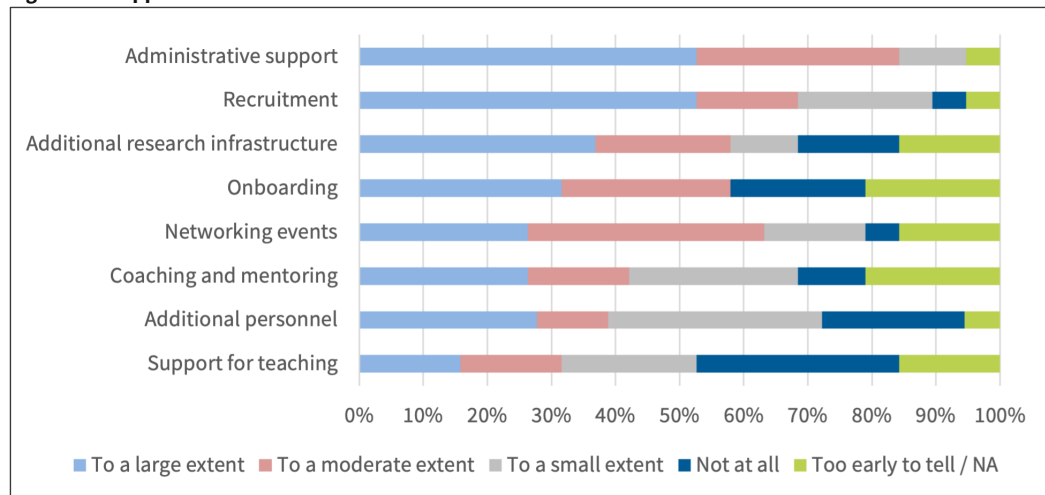
Notes: This figure shows answers to the survey question "To which extent have you received support from your host institution regarding the following aspects?" Bar colours represent the proportion of the respective answer category.

Figure 13 shows the average distribution of funding sources for all VRG projects and whether they were able to maintain or expand their research group (only for 11 VRGs in the second phase of the VRG project). All VRG leaders who moved away continued their collaborations with researchers in Vienna.

Change at the host institution

VRG leaders were asked to provide concrete examples how the VRG project contributed to structural or cultural changes of the host institution.

While many respondents indicated that institutional change was often slow, success stories included that

— the institution has become world-leading group in a specialised field, including the establishment of new teaching disciplines,
— the joint supervision of PhD candidates and postdocs across departments increased the interdisciplinary exchange,
— the first female PI was awarded with a tenure-track position at the institution,
— proven real-world impact of foundational research was achieved,
— a new tenure-track model was established.

Figure 12: Main reasons for moving to a new location outside Vienna
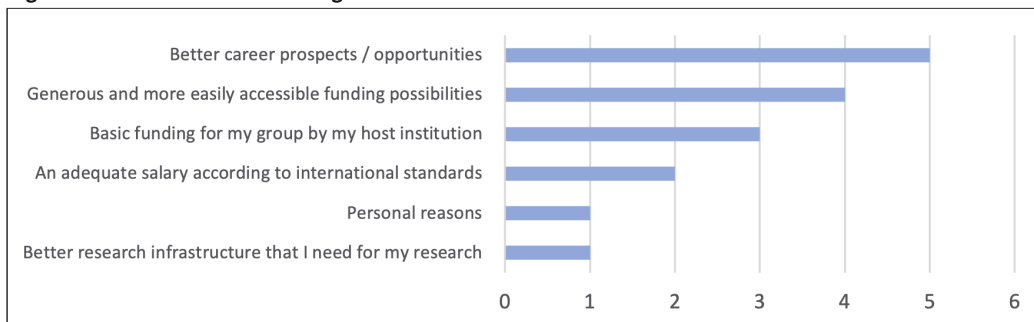
Notes: This figure displays selection frequencies for the survey question "What were the main reasons for moving to a new location outside Vienna? Please tick all that apply."

Figure 13: Funding sources and opportunities to maintain the research group
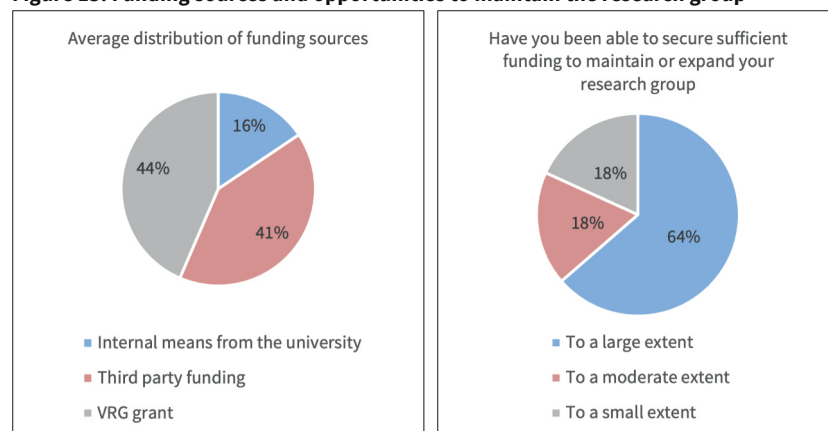
IV. Comparative bibliometric analysis

The objective of this comparative bibliometric analysis of the Vienna Research Group Program is to monitor, screen and analyse the scientific output and impact of this funding program initiated by the WWTF.

The study is based on the Web of Science indexed publication output of granted VRG projects. It concerns the publication data that are indexed in the 2011–2020 volumes of Clarivate Analytics Web of Science Core Collection (WoS) restricted to the three journal databases Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI) and the indexed conference proceedings.

The **bibliometric analysis presents a three-dimensional perspective** on the research activities and impact where the results are gauged against relevant benchmarks and control groups whenever relevant and appropriate:

> **Research productivity**

> **Publication strategy**

> **Citation impact**

(1) The first dimension reflects the **research productivity** and is primarily based on the publication counts. This section analyses the publication output, the research profiles, and the evolutionary aspect.
In the section, special attention is also devoted on (international) collaboration in the mirror of co-authorship.

(2) In addition to the publication activity, the report focusses on the **publication strategy** by investigating the journals in which the researchers have published.

(3) The last dimension is devoted to the **citation impact**. This analysis already reflects the international reception of granted VRG research output with respect to the standard world citation scores allowing national and international comparison.

As mentioned above, the main analyses are based on the publication output of granted VRG projects. Using an alternative approach of retrieving publications, some analyses were also repeated considering all publications of VRG leaders in the relevant time frame, irrespective of whether publications are directly associated with a VRG project or not. Results of these alternative analyses are presented in the Annex. The alternative approach identified 51 additional publications by VRG leaders, including several high-level publications.

Overall, including the additional publications into the analysis, results in similar or better performance metrics of VRG leaders, which were mostly caused by a few highly cited papers in biochemistry.

4.1 Data source and retrieval

Publications are extracted from WoS-indexed journal articles based on publication lists of the projects and on information in the funding acknowledgement section of the papers. The publication and citation study are based on bibliographic data indexed in the Web of Science Core Collection (WoS) of Clarivate Analytics. Given the publication data available at ECOOM, the complete publication period was split into two sub-periods, namely 2011—2015 and 2016—2020. The research productivity analysis is conducted for the entire period 2011—2020, the two sub-periods, and the annual patterns.

The assignment of publications to field and subfield is based on the extended WoS-based Leuven-Budapest classification scheme (cf. Glänzel & Schubert, 2003; Glänzel et al., 2016) which is a cognitive-logical grouping of the approximately 250 subject categories in the Web of Science Subject Category System. In this hierarchical system, journals are assigned to one or more of the subject categories and then to the aggregated 74 subfields or disciplines and 16 fields. At each level, an assignment to one or more classes is possible. There is no concordance table to map the VRG Key Areas to the applied 74 subfields or 16 fields.

Since the citation analysis for publications, journals and subfields is based on three-year citation windows (publication year and the two subsequent years), citation analysis is limited to the period 2011—2018. These publication sets, which were indexed in the Web of Science Core Collection (WoS), were delivered as yearly updates and have already undergone careful cleaning and data processing at ECOOM. The source of data collection for this report was therefore the ECOOM database. Publication data indexed in year x is always delivered to ECOOM in the subsequent year (x+1); data for 2021 are therefore not yet available. Citation data are therefore only complete for publications indexed in 2018 with a citation window up to 2020.

All data is based on data retrieved and extracted from the above-mentioned databases. One important feature of this database is that all authors, institutional addresses, funding acknowledgements and references for all indexed publications over an extended time window are recorded and available. Only 'citable' document types are taken into account (articles, letters, notes and reviews). Bibliographic data are cleaned and processed to bibliometric indicators according to the standard rules in the field (see, e.g., Glänzel et al., 2009).

4.2 Benchmarks and control groups

In order to assess the obtained bibliometric results for the VRG funded projects, the report presents three different control groups in combination with sub-field and journal normalized indicators who represent the overall international situation.

— Research output of a selection of 23 Principal Investigators who applied for a VRG grant which was rejected. The selection is based on a fair distribution of PI's over Key Areas and across the last stage that was reached by the applicant ('Hearing' or 'Reserve List'). For these researchers, the complete output between 2011 and 2020 is considered.

— Research output of 20 Austrian ERC Starting Grant holders in the according Key Areas where the granted project ended between 2015 and 2018. As publications can be attributed to specific projects through the acknowledgement information, the output of the grant holders is restricted to those publications that can be linked to the specific funded ERC-project to reflect to selection procedure for the VRG research output as close as possible.

— Research output of Austria in the considered time period across all fields in natural, life, technical, social sciences and humanities.

4.3 Citation Indicators

The indicators for the second and third dimension mentioned before form an **indicator triplet that should best be considered and interpreted together.** Their mathematical relation reveals details about **publication strategy and factual impact** with respect to what should be expected on the basis of the publications' subject.

(1) The first indicator is the **Mean Observed Citation Rate (MOCR)**. MOCR is the average number of citations per publication. It is calculated as the ratio of citation count (i.e., in a three-year citation window) to publication count. It reflects the factual citation impact of a country, region, institution, research group etc.

(2) The second indicator is the the **Mean Expected Citation Rate (MECR).** The expected citation rate of a single paper is defined as the average citation rate of all papers published in the same journal in the same year. Instead of the one-year citation window to publications of the two preceding years as used in the Journal Citation Report (JCR), a three-year citation window to one source year is used, as indicated above. For a set of papers assigned to a given country, region or institution in a given field or subfield, the indicator is the average of the individual expected citation rates over the whole set. This indicator is used as an auxiliary measure.

The ratio of the two previous indicators, that is, RCR = MOCR/MECR is called **Relative Citation Rate (RCR).** The RCR relates a publication's citation rate to the average citation rates of the journal in which it appeared. This indicator measures whether the publications of a country or institution attract citations than expected on the basis of the impact measures.

Since the citation rates of the papers are gauged against the standards set by the specific journals, it is largely insensitive to the big differences between the citation practices of the different science fields and subfields.

It should be stressed again that in this study, a 3-year citation window to one source year is used for the calculation of both the enumerator and denominator of RCR.

RCR = 0 corresponds to uncitedness, RCR < 1 means lower-than-average, RCR > 1 higher-than-average citation rate, RCR = 1 if the set of papers in question attracts just the number of citations expected based on the average citation rate of the publishing journals. RCR has been introduced by Schubert & Braun (1986) and largely been applied to comparative macro and meso studies since (e.g., Braun et al., 1985).

(3) The next indicator is the **Normalised Mean Citation Rate (NMCR).** In contrast to the RCR, NMCR gauges citation rates of the papers against the standards set by the specific subfields. NMCR is calculated analogously to the RCR as the ratio of the Mean Observed Citation Rate to the weighted average of the mean citation rates called **_Field Expected Citation Rate_ (FECR)**. Since subject assignment is not unique, it has to be fractionated for each publication. This procedure guarantees additivity over subjects. Its neutral value is 1 and NMCR > (<) 1 indicates higher (lower)-than-average citation rate than expected on the basis of the average citation rate of the subfield.

The NMCR indicator has been introduced by Braun and Glänzel (1990) in the context of measuring national publication strategy and been used along with RCR in quantitative studies of national, regional and institutional research assessment (Glänzel et al., 2009).

Versions of these indicators are used also at CWTS in Leiden. In particular, MOCR coincides with _Citations per Paper_ (CPP), a version of MECR is _Mean Journal Citation Score_ (JCSm), a version of RCR is called CPP/FCSm at CWTS, _Mean Field Citation Score_ (FCSm) is a version of $MECR|_s$ and CPP/FCSm is a version of NMCR (cf. Moed et al, 1995).

As has been mentioned above, these indicators should best be considered and interpreted together.

Several "constellations" are possible here, for instance, MOCR > MECR > FECR, which reflects the most favourable situation, means that the author publishes on average in journals with a higher-than-discipline standard and receives even more citations (on average) than the standard set by the journals in which the papers are published.

MECR > MOCR > FECR means that the latter standard is not reached and, for instance, FECR > MOCR > MECR means that the researcher achieved a higher citation impact than expected on the basis of the journals in which he/she has published but these journals do, on an average, not belong to the top journals in their discipline.

All these constellations could be observed in the study. The least favourable situation, namely, FECR > MECR > MOCR, did not occur.

4.4 Research Productivity

Publication activity

All bibliometric data used in this study are based on first-order bibliographic data extracted from the 2011—2020 cumulative data files of the as recorded in the ECOOM-database. Only so-called citable papers, that is, documents recorded in the annual volumes of the two databases as *article*, *letter*, *note, proceedings paper* and *review* were taken into consideration. Proceedings papers published in regular periodicals, journals or serials were considered as journal literature.

Two sources were used for the retrieval of the relevant publication set. First, the publication list as provided by WWTF based on the reported output by the projects was used.

Table 4 indicates count of entries in this list by the publication type. These entries were, when possible, matched with the WOS database hosted by ECOOM.

The publication sets resulting from the matching of the reported list with the ECOOM database was extended by additional retrieval using funding information as present and recorded in the funding acknowledgement section of the papers. This resulted in a final publication set of 260 journal papers and 41 additional conference proceedings. Table 5 presents the annual and total count for journal and conference contributions. Table 18 in the Annex shows the counts using the alternative method of publication retrieval, including publications by VRG leaders not directly associated to a VRG project.

Table 4: Number of reported and matched publications

Publication type	Output count	WoS matched count
Accepted conference / workshop contribution	220	6
Book Chapter	14	4
Conference proceeding	79	21
Edited Volume	5	1
Journal paper	297	254
Monograph/Book	5	0
Other	13	0

Table 5: Annual rate of retrieved publications in Journals and Proceedings

Year	Journal literature	Conference Proceedings
2011	6	0
2012	9	0
2013	15	0
2014	19	5
2015	20	2
2016	18	4
2017	34	7
2018	38	3
2019	41	12
2020	60	8
Total	**260**	**41**

A strict full-counting scheme has been applied to publications and citations. This applies to both subject matter and affiliation. The papers were assigned to all countries based on the corporate address given in the by-line of the publication. All countries indicated in the address field were thus taken into account; publication counts have thus *not* been fractionated according to addresses. This is necessary to analyse collaboration patterns, but this approach does not allow summing up publication counts from a lower level of aggregation to a higher one. The bibliometric analysis has therefore to be conducted at each level of aggregation separately[2].

— The analysis of the publication data is based on the following basic indicators: Distribution of publications over the ECOOM-Subfields.

— Share of "international" publications, i.e. publications with at least two distinct countries mentioned in the by-line of the paper. The distribution of publications over those countries with which VRG projects has co-published is also presented.

[2] As a consequence of the full counting scheme percentages given in the following tables might sum up to more than 100%.

The publication profile

The assignment of papers is based on the ECOOM-classification system. In this system, journals are assigned to and grouped into cognitive-logical disciplines. This scheme comprises of 74 disciplines for the natural and life sciences, social and behavioural science and arts and humanities. The assignment of an individual paper to a subfield is made through the journal where this paper has appeared. Thus, a paper can be assigned to more than one discipline.

Table 6 gives their distribution by ECOOM disciplines. This table is complemented by Figure 14 which gives the share of publications of VRG projects across the 15 broader fields of science and the multidisciplinary journals together with the share for Austrian publications in the same period.

Table 19 in the Annex shows shares across fields using the alternative method of publication retrieval, including publications by VRG leaders not directly associated to a VRG project.

Table 6: Distribution of publications over ECOOM subfields

Sub-Field	Description	Publications	Share
E1	computer science/information technology	67	25.8 %
B1	biochemistry/biophysics/molecular biology	47	18.1 %
B2	cell biology	34	13.1 %
H1	applied mathematics	33	12.7 %
X0	multidisciplinary sciences	25	9.6 %
Z3	microbiology	23	8.8 %
N1	neurosciences & psychopharmacology	19	7.3 %
Z4	plant sciences	19	7.3 %
N2	psychology & behavioral sciences	15	5.8 %
M6	psychiatry & neurology	14	5.4 %
B0	multidisciplinary biology	13	5.0 %

Both table and figure confirm that the research conducted within the framework of the VRG program has an own, distinctive profile with strong emphasis on three pillars: Engineering and Applied Mathematics (36 % and 42 %) at one side and Biosciences and Biology (microbiology) (51 % and 30 %) at the other side in the first and second period.

From 2016 the share of Neuro- and Behavioral sciences combined with Psychiatry and Neurology is increasing (4 % and 17 %). These three pillars account for almost 9 out of ten publications in the VRG output (88 % and 85 % in first and second period) as there is a small overlap between Bioscience and the Neurology overlap as a small number of papers is assigned to both domains.

Figure 14: Share of publications across fields for VRG granted projects and Austria
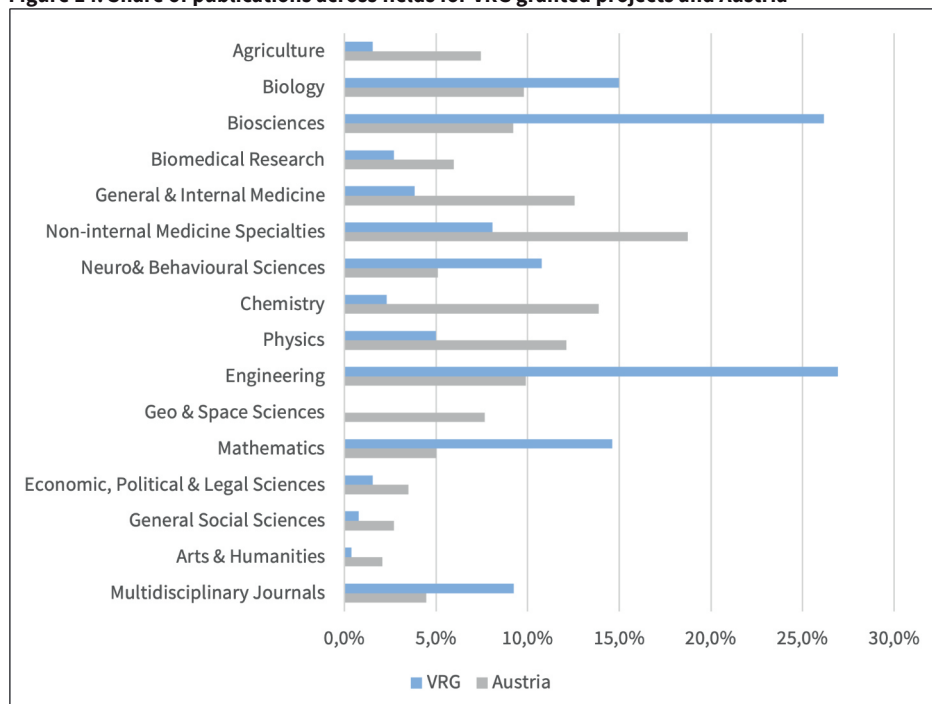
International collaboration patterns

A link between two countries is established whenever the two given countries co-occurred in the corporate addresses in the by-line of a publication. Consequently, institutional affiliation is decisive, not the nationality of authors. Papers that have been published in co-operation of at least two different countries will be called international papers.

Furthermore, an integer-counting scheme has been applied, that is, all countries occurring in the address list of the publication have been counted once. Papers are not fractionated according to countries.

Each paper is thus assigned to all countries involved as a full publication.

On the other hand, if an author has two corporate addresses in two different countries, his/her paper is considered as an international publication. The number and share of international papers according to the WoS can be found in table 7. Table 20 in the Annex shows international co-publications using the alternative method of retrieving VRG leaders' publications, including papers not directly associated to a VRG project.

Table 7: Count and share of international co-publications in the period 2011−2020

	2011−2015	**2016−2020**	**2011−2020**
International VRG publications	53	153	206
Granted VRG	76.8 %	80.1 %	79.2 %
Rejected	51.4 %	47.8 %	49.5 %
ERC Starting Grant	72.4 %	74.1 %	73.3 %
Austria	65.7 %	72.7 %	69.7 %

Table 8: Share of international co-publications with partner countries

	2011−2015	**2016−2020**	**2011−2020**
Germany	20.8 %	32.7 %	29.6 %
USA	18.9 %	30.1 %	27.2 %
UK	13.2 %	24.2 %	21.4 %
France	11.3 %	14.4 %	13.6 %
Netherlands	3.8 %	13.7 %	11.2 %
Norway	17.0 %	7.8 %	10.2 %
Belgium	28.3 %	3.3 %	9.7 %
Czech Republic	15.1 %	7.2 %	9.2 %
Canada	0.0 %	11.1 %	8.3 %
Sweden	9.4 %	6.5 %	7.3 %
Switzerland	11.3 %	5.2 %	6.8 %
Peoples Rep. of China	0.0 %	7.2 %	5.3 %
Intl co-publications	100 %	100 %	100 %

The share of international papers in all VRG publications has slightly increased up to four out of five publications in the most recent years.

Table 8 (on page 23) gives the share of co-publications with other the most important international partner countries. The share is calculated with respect to all co-publications, that is, a share of 50 % means that this percentage of papers has co-authors from this country/world region in all international co-publications. According to the shares in this table, there are several patterns that can be observed. The collaboration with some countries is intensified (Germany, USA, UK, France and The Netherlands) while other countries show a decreasing share (Norway, Belgium, Czech Republic, Switzerland). Canada and China pop up as new partners. These dynamics in the collaboration patterns are not surprising as both time frames can cover different and clearly distinct projects.

4.5 Publication Strategy

The ratio between the *Mean Expected Citation Rate* (MECR) and the *Field Expected Citation Rate* (FECR) provides insight into the general publication strategy for a set of publications. As mentioned in the introduction, values above 1.0 indicate that these publications have been published in journals that can attract more citations in the three year window than the expected rate that is set for the fields to which these journals have been assigned. Table 9 provides the ratio between these two normalised indicators.

Although we can observe some fluctuations in the obtained scores due to small size publication sets for VRG and the two control groups, it is clear that the research output of the granted VRG projects is published in higher profile journals compared to the output that can be linked to the researchers of the rejected projects and to the overall Austrian output. In contrast, the scores for the Austrian ERC Starting Grant holders are remarkably higher and even increasing towards the second period.

Interesting in the context of publication strategy is the share of publications in multidisciplinary journals (see Table 10). These journals are often high impact journals and are considered to be favourable to publish in. All three groups have a higher share of publications in these multidisciplinary journals than the Austrian share. However, the granted VRG project have a lower share than the two control groups.

Table 9: Ratio between MECR and FECR for VRG granted projects and control groups

	2011—2015	2016—2018	2011—2018
Granted VRG	2.07	1.54	1.75
Rejected	1.30	1.46	1.37
ERC Starting Grant	1.99	2.33	2.15
Austria	1.19	1.20	1.20

Table 10: Share of publications in multidisciplinary journals

	2011—2020
Granted VRG	9.2 %
Rejected	12.8 %
ERC Starting Grant	20.6 %
Austria	4.5 %

4.6 Citation Impact

The citation-based indicators for the four publication sets are presented in Table 8. It should be stressed again that citations are based on three-year citation periods. The analysis is therefore restricted to the period 2011–2018.

According to Table 11, the factual citation impact of VRG papers is in line with the journal expectation and that, in turn, is distinctly above the field-based expectation. However, the scores are decreasing but show a clear pattern with respect to the two control groups and Austria. **In other words, the granted researchers publish on average in high impact journals (with respect to their field) and receive more citations than expected for these fields.**

Table 12 (on page 26) shows the effect of international collaboration on the citation impact. If one compares the share of international co-publications with the share of citations that are attracted by those, one can conclude that collaboration has a clear positive effect as the values of all relative citation indicators are distinctly higher than the domestic standard. The favourable situation is also here clearly apparent: MOCR = 14.0 *and* RCR > 1.0 *and* NMCR > RCR for 2011–2018.

The citation analysis using the characteristic scores and scales (CSS) is the most complex, but gives more details about the distribution of citations than mean values can do. CSS-scores are obtained from iteratively truncating samples at their mean value and recalculating the mean of the truncated sample until the procedure is stopped or no new scores are generated.

Table 11: Citation-impact indicators for VRG and control groups, 2011–2018

Period	Publication Set	MOCR	RCR	NMCR
2011—2015	Granted VRG	16.29	1.15	2.39
	Rejected	8.55	1.01	1.31
	ERC Starting Grants	17.23	1.09	2.16
	Austria	8.81	1.24	1.48
2016—2018	Granted VRG	10.90	0.90	1.39
	Rejected	8.70	0.74	1.09
	ERC Starting Grants	17.49	0.85	1.97
	Austria	10.78	1.26	1.51
2011—2018	Granted VRG	13.24	1.02	1.79
	Rejected	8.61	0.88	1.21
	ERC Starting Grants	17.34	0.97	2.08
	Austria	9.66	1.25	1.49

The share of self-citations (less than one quarter) is relatively low (cf. Thijs & Glänzel, 2005). This confirms that the citation impact of VRG-projects has achieved is to the overwhelming share a result of foreign citations.

Usually three scores are sufficient, where the first one is identical with the mean value of the reference population. The resulting four classes are obtained by the intervals defined by adjoining scores (see, e.g., Glänzel et al., 2014). This method is a real alternative to percentiles but has two important advantages: 1.

CSS is not biased by ties in the underlying citation ranking and 2. CSS scores are self-adjusting and thus not defined on arbitrary pre-set values. The four classes stand for 'poorly cited' (1), 'fairly cited' (2), 'remarkably cited' (3) and 'outstandingly cited' (4) papers.

Papers in class 3 and 4 can be considered highly cited. CSS provides robust classes in terms of their insensitivity to publication year, citation windows and subject. Although CSS is not directly linked to percentiles, the distribution of papers over classes is about 70% (1), 21% (2), 6%–7% (3) and 2%–3% (4).

Deviations of the researchers' profile provide a multifaceted picture of their citation impact. A researcher's share in certain classes might be higher or lower than, or equal to the corresponding standard and his/her profile might thus follow the above-mentioned reference standard or be more or less polarised than the standard or more skewed towards poorly or highly cited papers, respectively. A researcher might have more highly cited papers than expected and at the same time less poorly cited papers than expected, but he/she might have more poorly cited papers then the reference standard.

Table 13 (on page 27) presents the CSS distribution for the VRG output for the two periods as well as the complete period 2011—2018. Table 21 in the Annex shows the distribution over CSS classes using the alternative method of retrieving VRG leaders' publications, including papers not directly associated to a VRG project.

The above-mentioned reference standard of 70 % (Class 1), 21 % (Class 2), 6 %–7 % (Class 3) and 2 %–3 % (Class 4) is more than a rule of thumb (see Albarrán & Ruiz-Castillo, 2011; Glänzel et al., 2014), it can be directly used for benchmarking. The distribution of VRG papers indexed in the WoS proved to have, according to the above rule, the share of poorly cited papers distinctly below the reference standard, while the share of papers in all other classes lies above the corresponding reference value. Usually, the papers in Classes 3 and 4 are considered highly cited and their share amount to about 9 % in the total reference population.

Table 12: Citation-impact indicators for international co-publications of VRG and control groups, 2011—2018

Period	Publication Set	MOCR	RCR	NMCR
2011—2015	Granted VRG	17.60	1.19	2.56
	Rejected	9.99	1.04	1.52
	ERC Starting Grants	17.86	1.13	2.35
	Austria	10.80	1.35	1.74
2016—2018	Granted VRG	11.46	0.91	1.46
	Rejected	9.51	0.70	1.14
	ERC Starting Grants	18.56	0.83	2.06
	Austria	12.75	1.36	1.74
2011—2018	Granted VRG	14.06	1.04	1.89
	Rejected	9.81	0.89	1.36
	ERC Starting Grants	18.16	0.98	2.21
	Austria	11.68	1.35	1.74

The corresponding share for VRG is around 20.2 %, which reinforced the findings and observation we make in the context of the relative citation indicators. But the decrease in share of 'High' performance class is related to the shift in profile of the output of the granted VRG projects.

Table 14 (on page 28) gives the distribution and evolution of the shares among the four classes for the three main areas or topics for the granted projects: Biology & Biosciences; Engineering and Applied Mathematics and Neuro & Behavioural sciences. Table 22 in the Annex shows these shares using the alternative method of retrieving VRG leaders' publications, including publications not directly associated to a VRG project.

Interdisciplinarity of VRG-projects

This report follows the bibliometric approach to interdisciplinarity according to which interdisciplinary research is reflected by the incorporation of information from different subjects (e.g., Rafols & Meyer, 2010; Leydesdorff & Rafols, 2011; Zhang et al., 2016). In particular, the cited references of scientific publications are considered to reflect these sources of information.

According to this approach, there are **three aspects** that must be considered when measuring the extent of interdisciplinarity.

— **Variety** is the number of non-empty subject categories to which cited references are assigned. Assuming that all things are equal, the greater the variety, the greater the diversity.

Table 13: Distribution of publications over CSS classes for VRG and control groups

Period	Publication Set	Low	Moderate	High	Outstanding
2011—2015	Granted VRG	37.7 %	31.9 %	24.6 %	5.8 %
	Rejected	61.5 %	25.7 %	8.8 %	4.1 %
	ERC Starting Grants	37.4 %	39.1 %	14.9 %	8.6 %
	Austria	60.1 %	26.2 %	9.1 %	4.6 %
2016—2018	Granted VRG	55.6 %	32.2 %	6.7 %	5.6 %
	Rejected	65.3 %	24.8 %	6.9 %	3.0 %
	ERC Starting Grants	45.9 %	28.6 %	18.8 %	6.8 %
	Austria	61.2 %	25.8 %	8.5 %	4.4 %
2011—2018	Granted VRG	47.8 %	32.1 %	14.5 %	5.7 %
	Rejected	63.1 %	25.3 %	8.0 %	3.6 %
	ERC Starting Grants	41.0 %	34.5 %	16.6 %	7.8 %
	Austria	60.6 %	26.0 %	8.9 %	4.5 %

— **Balance** is a function of the pattern of the assignment of elements across subject categories. Balance is also called evenness or concentration. Mathematically this can be expressed, e.g., by the Gini index. All else being equal, the more balanced the distribution, the larger the diversity.

— **Disparity** refers to the manner and the degree in which things may be distinguished, that is, how different from each other are the types of things that we observe. All else being equal, the higher the disparity, the greater the diversity.

Zhang has found a Hill-type indicator $^2D^S$ according to Leinster and Cobbold (2012) that expresses all three elements of interdisciplinarity and has a stronger discriminative than the usually applied Rao-Stirling measure. The indicator is based on subfield assignment since subject categories proved too narrow and subjects are partially too much interrelated for an interdisciplinarity analysis , while, in turn, the granularity of major research areas such as the 22 fields according to the Clarivate Analytics *Essential Science Indicators* (http://ipscience-help.thomsonreuters.com/inCites2Live/8300-TRS.html) proved to coarse for such exercises. In this study the 74 subfields according to the extended WoS-based Leuven-Budapest classification scheme (cf. Glänzel & Schubert, 2003) is used. $^2D^S$ takes real values larger than or equal to 1.0.

According to our experience (Zhang et al., 2016), values above 5.0 reflect strong interdisciplinarity and $^2D^2 > 10$ can already be considered extreme. Because of the short reference list of letters and the extensive list in reviews, the application of the $^2D^S$ indicator is restricted to articles.

Table 14: Distribution of publications over CSS classes in three main areas for VRG

Period	Publication Set	Low	Moderate	High	Outstanding
2011—2015	Granted VRG	37.7 %	31.9 %	24.6 %	5.8 %
	Biosciences & Biology	14.3 %	31.4 %	45.7 %	8.6 %
	Engineering & Math	72.0 %	28.0 %	0.0 %	0.0 %
	Neuro & Behavioral				
2016—2018	Granted VRG	55.6 %	32.2 %	6.7 %	5.6 %
	Biosciences & Biology	28.6 %	35.7 %	17.9 %	17.9 %
	Engineering & Math	75.0 %	22.5 %	2.5 %	0.0 %
	Neuro & Behavioral	58.3 %	41.7 %	0.0 %	0.0 %
2011—2018	Granted VRG	47.8 %	32.1 %	14.5 %	5.7 %
	Biosciences & Biology	20.6 %	33.3 %	33.3 %	12.7 %
	Engineering & Math	73.8 %	24.6 %	1.5 %	0.0 %
	Neuro & Behavioral	46.7 %	53.3 %	0.0 %	0.0 %

Table 15 provides the distribution of the publications over the three disparity classes. These classes are calculated analogously to the CSS in an iterative process with calculated averages over truncated distributions. Two averages serve as cut-off points for the boundaries of the three classes. Granted VRG projects have the strongest interdisciplinary profile. Table 23 in the Annex shows the distribution over disparity classes using the alternative method of retrieving VRG leaders' publications, including publications not directly associated to a VRG project.

Interesting is to see the relation between profile or classification of the research output of the VRG and the interdisciplinarity. Table 16 provides the share of publications for the three classes in each of the three main topics or areas. Table 24 in the Annex shows the share over areas and classes using the alternative method of retrieving VRG leaders' publications, including publications not directly associated to a VRG project.

4.7 Conclusions

The publication profile of the research output of the VRG-granted projects in the period 2011–2020 displays a strong continuity in the growth and development of the scientific activity. **The publication analysis shows that VRG-researchers receive a high citation impact and that their work reflects a very high scientific standard.**

The projects are characterized by intense international collaboration. The ratio of the relative citation indicators applied here, reaffirms the positive and highly successful publication strategy. However, these indicators show a decline in the second period which exhibits a shift from Biology and Biosciences towards Engineering and Applied Mathematics and towards Neuro- and Behavioural sciences. Given the small number of publications in each of the areas, it is not possible to conclude any causal relation between the shift in fields and the evolution of the citation indicators.

Table 15: Distribution of publications over Disparity classes for VRG and control groups

Publication set	Low	Moderate	High
Granted VRG	63.9 %	25.3 %	10.8 %
Rejected	77.1 %	22.0 %	0.8 %
ERC Starting Grants	75.7 %	20.3 %	4.0 %
Austria	71.6 %	24.5 %	4.0 %

Table 16: Distribution of publications over Disparity classes for VRG and three main areas

Publication set	Low	Moderate	High
Granted VRG	63.9 %	25.3 %	10.8 %
Biosciences & Biology	84.4 %	11.1 %	4.4 %
Engineering & Math	41.4 %	44.3 %	14.3 %
Neuro & Behavioral	75.0 %	15.0 %	10.0 %

V. Bibliometric screening of emerging fields

This section addresses the establishment of new fields in Vienna and whether the linkages between existing fields are strengthened through the VRG program.

First, the research fields and their respective linkages – delineated with bibliographic coupling of publications – are presented on a 3D surface map. Second, VRG leaders are compared to other Vienna-based scientists regarding the age of the knowledge base of the publications (i.e., the age of cited references) as well as the share of the number of publications.

5.1 Research fields of the VRG groups

The research fields of the VRG groups were retrieved from the Web of Science database (WoS) by Clarivate by searching for publications with an acknowledgement to the WWTF funding program ($N = 296$).

The delineation of research fields from this publication set was performed by bibliographic coupling using the Jaccard Index – a similarity measure calculated as the relative number of common cited references between all publication pairs.

Figure 15 shows the identified research fields of the VRG groups. Publication similarity is visualized in a two-dimensional space using a spring model, resulting in more similar publications being positioned more closely than dissimilar publications. The third dimension, represented by the peaks, indicates the research activity in the publication clusters: the higher the peak, the higher the locally agglomerated number of publications.

Figure 15: 3D-surface map of bibliographically coupled publications
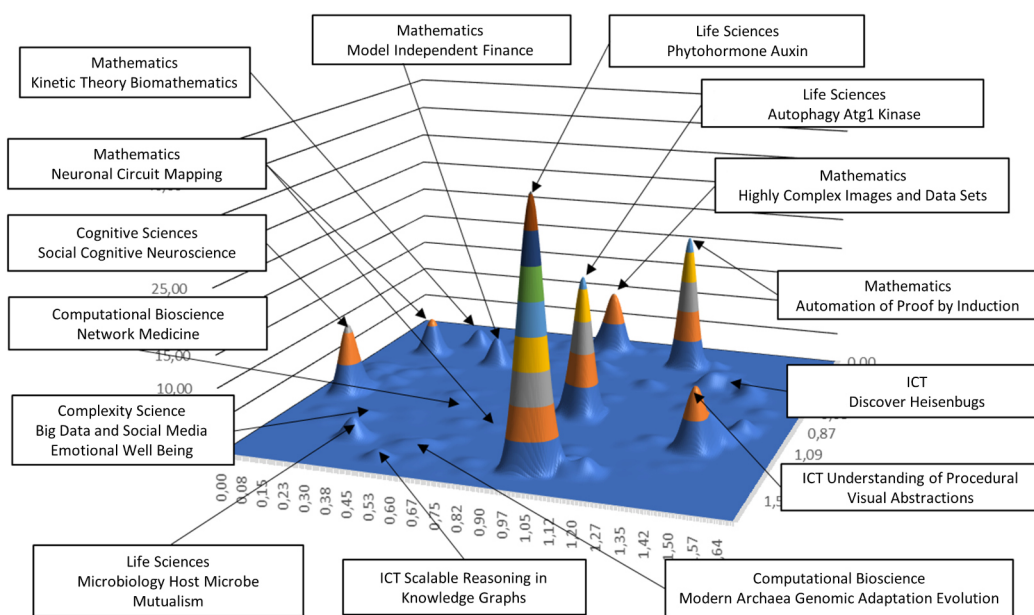
Notes: This figure displays the 3D surface map of bibliographically coupled publications; Data: 296 VRG publications of all years; The x- and y-axis represent local coordinates in the spring model, the z-axis represents the research activity defined by density of the number of similar publications weighted by their similarity (Jaccard-Index). Labels were added by the study team based on the inspection of the clusters.

The bibliographic coupling of the research output of VRG projects covers clearly delimited research themes, such as "VRG10–001 Life Sciences Autophagy Atg1 Kinase" or "VRG10–006 Life Sciences Phytohormone Auxin". With regards to research activity, funded projects with an earlier starting date show a higher number of publications.

Based on the publications of the VRG projects, the WWTF key areas are linked to existing disciplines in Vienna defined along the Web of Science scientific disciplines (see Table 17).

For example, a large number of publications in the WWTF research area Cognitive Sciences were identified in the disciplines Neurosciences & Neurology, Psychology and Endocrinology & Metabolism. Several project span across multiple disciplines from Complexity Sciences which contributes to Mathematical Methods in Social Sciences, Mathematics, Psychiatry and Psychology.

Table 17: Number of publications by WWTF Areas and Web of Science Disciplines 2011 to 2021 (June)

Discipline/WWTF Area	Cognitive Sciences	Complexity Sciences	Computational Biosciences	ICT	Life Sciences	Mathematics and…
Behavioral Sciences	7					
Biochemistry & Molecular Biology	2		2	6	33	1
Biotechnology & Applied Microbiology			2	4	2	
Cell Biology	1				31	
Computer Science				60		26
Developmental Biology					4	
Endocrinology & Metabolism	8					
Environmental Sciences & Ecology		1			4	
Genetics & Heredity					2	
Life Sciences & Biomedicine—Other Topics	3		2		9	1
Mathematical & Computational Biology			2	4		1
Mathematical Methods In Social Sciences		2				3
Mathematics		3		2		38
Microbiology			7		7	
Neurosciences & Neurology	20	1			1	1
Pharmacology & Pharmacy	2					
Plant Sciences					17	
Psychiatry	11	3				
Psychology	8	2				
Radiology, Nuclear Medicine & Medical Imaging	2				1	5

## 5.2 Contribution of VRG research to emerging/novel research in Vienna

To illustrate the contribution of VRG research to emerging or novel research in Vienna, Figure 16 shows the position of VRG research topics in the Viennese research landscape on the dimensions novelty and the share of VRG publications in the respective disciplines. Novelty has been approximated by the age of the underlying knowledge base, measured as the mean weighted publication year of cited references.

The contribution of VRG projects to Viennese research activity were classified according to field of science categories of WoS and positioned along the above-described dimensions. The share of VRG publications is based on all 296 VRG publications and Viennese publications in the period 2014 to 2021 (June). The novelty (mean age of cited references) has

been calculated for the Viennese publications in the last two years (2020 and 2021).

Research with an age of the knowledge base above the mean (M = 2011.23) and a share above the mean (M = 0.84 %) can be found in VRG contributions in Computer Science, Mathematical & Computational Biology, Cell Biology and Developmental Biology. The highest number of articles among the novel science categories could be found in Computer Science and Cell Biology.

Figure 16: Share of VRG publications and novelty/ (emergence) of Viennese publications
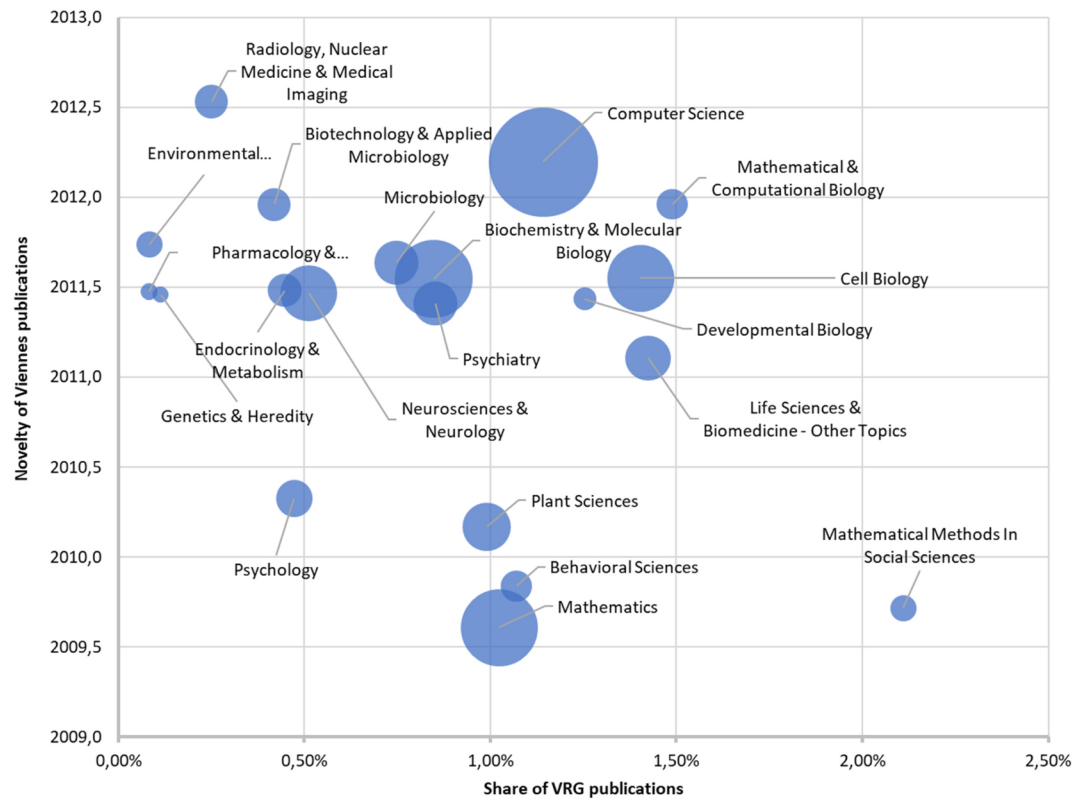
Notes: This figure presents the share of 296 VRG publications in 39.540 publications from Viennese authors in relevant disciplines (period 2014 to 2021) on the x-axis, and the novelty measured by the mean age of cited references by Viennese publications in the period 2020 to 2021) on the y-axis. Bubble size represents the number of VRG publications

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VII. Annex

7.1 Results from analyses including VRG leader's publications not directly associated to a VRG project

Table 18 Annual rate of retrieved publications in Journals and Proceedings (alternative)

Year	Journal literature	Conference Proceedings
2011	9	0
2012	11	0
2013	16	0
2014	21	5
2015	24	2
2016	25	5
2017	41	8
2018	41	3
2019	49	12
2020	64	8
Total	301	43

Table 19: Distribution of publications over ECOOM Subfields (alternative)

Sub-Field	Description	Publications	Share
E1	computer science/information technology	70	23.3 %
B1	biochemistry/biophysics/molecular biology	60	19.9 %
B2	cell biology	42	14.0 %
H1	applied mathematics	35	11.6 %
X0	multidisciplinary sciences	30	10.0 %
Z3	microbiology	26	8.6 %
N1	neurosciences & psychopharmacology	24	8.0 %
Z4	plant sciences	19	6.3 %
N2	psychology & behavioral sciences	19	6.3 %
M6	psychiatry & neurology	18	6.0 %
B0	multidisciplinary biology	15	5.0 %

Table 20: Count and Share of International co-publications in the period 2011−2020 (alternative)

Publication set	Low	Moderate	High
International VRG pubs	60	181	241
Granted VRG	74.1 %	82.3 %	80.1 %
Rejected	51.4 %	47.8 %	49.5 %
ERC Starting Grants	72.4 %	74.1 %	73.3 %
Austria	65.7 %	72.7 %	69.7 %

Table 21: Distribution of publications over CSS classes for VRG and control groups (alternative)

Period	Publication Set	Low	Moderate	High	Outstanding
2011−2015	Granted VRG	37.0 %	29.6 %	24.7 %	8.6 %
	Rejected	61.5 %	25.7 %	8.8 %	4.1 %
	ERC Starting Grants	37.4 %	39.1 %	14.9 %	8.6 %
	Austria	60.1 %	26.2 %	9.1 %	4.6 %
2016−2018	Granted VRG	53.3 %	32.7 %	5.6 %	8.4 %
	Rejected	65.3 %	24.8 %	6.9 %	3.0 %
	ERC Starting Grants	45.9 %	28.6 %	18.8 %	6.8 %
	Austria	61.2 %	25.8 %	8.5 %	4.4 %
2011−2018	Granted VRG	46.3 %	31.4 %	13.8 %	8.5 %
	Rejected	63.1 %	25.3 %	8.0 %	3.6 %
	ERC Starting Grants	41.0 %	34.5 %	16.6 %	7.8 %
	Austria	60.6 %	26.0 %	8.9 %	4.5 %

Table 22: Distribution of publications over CSS classes in three main areas for VRG (alternative)

Period	Publication Set	Low	Moderate	High	Outstanding
2011−2015	Granted VRG	37.0 %	29.6 %	24.7 %	8.6 %
	Biosciences & Biology	17.1 %	26.8 %	43.9 %	12.2 %
	Engineering & Math	69.0 %	31.0 %	0.0 %	0.0 %
	Neuro & Behavioral				
2016−2018	Granted VRG	53.3 %	32.7 %	5.6 %	8.4 %
	Biosciences & Biology	30.6 %	36.1 %	13.9 %	19.4 %
	Engineering & Math	75.6 %	22.0 %	2.4 %	0.0 %
	Neuro & Behavioral	58.8 %	35.3 %	0.0 %	5.9 %
2011−2018	Granted VRG	46.3 %	31.4 %	13.8 %	8.5 %
	Biosciences & Biology	23.4 %	31.2 %	29.9 %	15.6 %
	Engineering & Math	72.9 %	25.7 %	1.4 %	0.0 %
	Neuro & Behavioral	45.5 %	40.9 %	4.5 %	9.1 %

Table 23: Distribution of publications over Disparity classes for VRG and control groups (alternative)

Publication set	Low	Moderate	High
Granted VRG	67.4 %	23.0 %	9.6 %
Rejected	77.1 %	22.0 %	0.8 %
ERC Starting Grants	75.7 %	20.3 %	4.0 %
Austria	71.6 %	24.5 %	4.0 %

Table 24: Distribution of publications over Disparity classes for VRG and three main areas (alternative)

Publication set	Low	Moderate	High
Granted VRG	67.4 %	23.0 %	9.6 %
Biosciences & Biology	85.2 %	11.1 %	3.7 %
Engineering & Math	45.5 %	41.6 %	13.0 %
Neuro & Behavioral	83.9 %	9.7 %	6.5 %